MEDICAL WAR MANUAL No. 7

MILITARY SURGERY OF THE ZONE OF THE ADVANCE

DE TARNOWSKY

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Authorized by the Secretary of War and under the Supervision of the Surgeon-General and the Council of National Defense

Military Surgery

OF THE

Zone of the Advance

BY

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SURGEON TO COOK COUNTY AND RAVENSWOOD HOSPITALS, CHICAGO; MAJOR, M. C., U. S. R., AMERICAN EXPEDITIONARY FORCE, FRANCE, 1917–1918

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Inasmuch as stress of time has made it impossible to attempt a list of references and to give credit where credit is due:

To those who, consciously or unconsciously, have aided me; to the many writers on military surgery whose articles I have studied and whom I have quoted, often verbatim,

This volume is gratefully dedicated.

FOREWORD.

THIS concise *vade-mecum* on the treatment of war wounds is, in no sense of the word, a text-book on military surgery.

Its essential aim is to give a *résumé* of the primary treatment which, in the light of painfully acquired experience on the western front during the past three years, has proved most satisfactory in the opinion of those best qualified to judge.

Little or no attempt has been made to discuss pathology or diagnosis, fundamentals with which the army surgeon is deemed sufficiently well equipped.

It is written essentially for the Medical officer who, well grounded though he be in the principles and practice of his art in times of peace, finds himself now confronted with an environment and a class of traumatic lesions foreign to him.

Civil surgery is mainly directed toward the control of pathological conditions, through the agency of wounds deliberately made by the surgeon, usually under a favorable and selected environment.

In his newly assumed role of military surgeon the same doctor is no longer able to choose his own conditions; he has to make the best of those in which his lot is cast. As a famous French surgeon concisely states the matter: "*On fait ce que l'on peut, ou on le peut, quand on le peut, comme on le peut,*" *i. e.*, "One does what one can, where one can, when one can, how one can."

No longer allowed to consider the case of the individual as paramount, his treatment must invariably be subservient to the military necessities of the moment.

This brings up a question of fundamental importance with which we are immediately confronted. With us, speaking in general terms, neither the physician nor the sanitary personnel has had any previous knowledge of military matters.

At best he has had an uncertain amount of training in the National Guard or an all too short though intensive course in an instruction camp. In France every male citizen has been trained as a private soldier. The proper organization and management of the sanitary personnel of our new armies will be beset with almost insurmountable difficulties unless each medical officer grasps the basic idea that, while serving in the army, he must be first a soldier and then a surgeon. The extreme importance attached to the sanitary service in this war can best be epitomized by the statement of a famous French general who recently said, "The integrity of an army depends almost entirely on its medical officers."

The training received in civil practice would naturally prompt the surgeon to give immediate attention to penetrating lesions of the abdomen or other injuries classed under the general term of "emergency surgery." In the zone of the advance this would be a grave error, unless arrangements have been made for the care of such cases in specially equipped motor ambulance or field hospitals; such operations, requiring considerable time, equipment, and the services of at least three surgeons, if performed in any of the advanced formations, would necessitate neglecting a large number of minor injuries and result in a failure to promptly return to the firing line fighting men essential to victory.

Military necessity may therefore compel him to simply cleanse and dress the severely wounded and to send them as rapidly as possible to the evacuation hospital.

Again, he might desire more ambulances in his sector, but the road leading to his dressing station or field hospital might be entirely occupied by munition trains, and he must give the latter the right of way.

It cannot be strongly enough emphasized that the two essentials of war surgery must consist in (*a*) rendering the greatest possible number of fighting men fit for duty on the firing line within as short a time as possible, and (*b*) rapidly evacuating to the rear, by previously arranged routes, if possible under shelter, all men who are *hors de combat,* in order not to lower the morale of the troops on the same terrain. The very bad psychic influence produced upon reserve troops who are hurrying up into action, by the sight and sound of severely wounded men, cannot be overemphasized. Every effort should be made to spare them from such scenes.

The business of the regimental or field ambulance surgeon is to speed the wounded on their way to the rear and clear the casualties as fast as he can. Of the wounded in detail he can see little; he sees them only *en masse.*

It therefore becomes axiomatic that the slightly wounded should be given early and thorough treatment at the front, as they remain potential fighting units; hence the existence of the divisional station for slightly wounded. The severely wounded—who may or may not recover—cannot be given adequate treatment until they have reached the evacuation or even the base hospital.

The three factors, lack of time, inadequate equipment (including surroundings) and military necessity, must force the advance surgeon to accept this view-point if he is to do his full duty toward his commanding officer.

It is well to remember also that in warfare nothing is fixed or unchangeable. Medical arrangements may have to be devised anew for each action; they will vary with the plan of battle and usually must be modified as the battle proceeds.

A *sine qua non* of a good soldier is to forget—to submerge in a large degree—his individuality as promptly and as thoroughly as possible. We all become cogs in a vast machine; each cog must work harmoniously to its utmost capacity toward a common goal—victory!

Esprit de corps means prompt, unhesitating, often unthinking obedience to higher authority; may we all attain that very essential spirit!

As a final advice, I cannot add to this Foreword anything more useful than the "hints" personally handed to me by Colonel T. H. Goodwin, of the British army:

1. Avoid criticism of the action or orders of a senior officer. He is probably in possession of special information.
2. Be a father to your men.
3. Never make a perfunctory examination or give a hasty opinion. Spare no pains.
4. The keystone of efficiency in the army is loyalty. Loyalty to the army and to the medical profession; loyalty to one's unit and commanding officer; loyalty to one's juniors.

George de Tarnowsky,
Major, M. R. C., U. S. Army.

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MILITARY SURGERY

OF THE

ZONE OF THE ADVANCE

CHAPTER I.

GENERAL CONSIDERATIONS.

Soil Pollution.—For centuries the soil of France and Belgium has been sown with bacteria, mostly of fecal origin. The custom of utilizing human as well as animal excreta for soil fertilization is still a universal one in Europe. That the peasantry is immunized to this soil pollution is well known. They walk and work barefooted, frequently suffer from punctured wounds of hand or feet, but rarely develop tetanus.

Our troops, fresh from training or concentration camps where the most scientifically painstaking hygiene is enforced, may, without undue stretch of the imagination, be compared, as regards vulnerability, to aborigines suddenly brought into contact with new disease germs. We all know how high the mortality from tuberculosis, syphilis, measles, etc., is among such people. It is therefore only reasonable to expect a high degree of susceptibility to wound infections, especially by the tetanus and gas-gangrene groups of bacteria, among our men, and our minds should be alert to such contingencies.

Weather Conditions.—The surgical campaign on the western front will be fought in weather with a preponderance of wet days. This means that the men in the trenches have to spend days at a time with clothing, especially socks and shoes, soaked through by rain and ground-water. Aside from the prevalence of "trench-foot" disease which this brings about, continued exposure to "wet cold" lower bodily resistence and correspondingly increases the activity of the infecting organism.

Heliotherapy will also be rarely possible except for the severely wounded who may be sent to such base centers as those of the Riviera in southern France (Nice, Cannes, Menton). This fact does not condemn the open treatment of wounds, but lessens its efficacy, owing to the absence of actinic ray stimulation. As a substitute for heliotherapy, powerful electric lights are now being used, whose action upon sluggish, severely infected or painful wounds is similar to that of the actinic sun rays.

THE FACTOR OF EXHAUSTION.—Exhaustion must also be considered as of paramount importance in military surgery. Many of the wounds are inflicted during night or early morning surprise attacks, and the men, with resistance to infection lowered by hours of vigil and anxiety, are unable to muster sufficient antibodies to cope with clothing or soil bacterial flora. It also frequently happens that the wounded cannot be removed from the battlefield except under cover of darkness.

MISSILES USED.—Unquestionably this is a war of pointed bullet, shrapnel and high-explosive shell-fragment wounds.

Regarding the first named it is recognized: (*a*) that its shattering effect on bone is very great; (*b*) that it tends to turn on impact, thus making it more destructive of the soft parts of the chest and abdomen especially; (*c*) that its high initial velocity and flat trajectory cause "explosive effects" at longer range and, (*d*) that it is also somewhat more liable to break up into fragments.

Regarding high-explosive, shrapnel, hand-grenade and bomb wounds it may be said of the former that a direct hit by a large fragment is almost always immediately fatal. Injuries caused by fragments will vary all the way from a mere "peppering" of the skin to the carrying away *en masse* of large sections of the body. Every "fragment wound" is an infected wound.

The punctured in-and-out wound familiar to the civilian surgeon is encountered with comparative infrequency in the present war. He will, instead, be confronted with either an exit wound of the "explosive type" or, more commonly, the hideous lacerated wounds produced, often by bullet, invariably by high-explosive fragment. He must constantly bear in mind that these lacerated tissues are devitalized, forming an alkaline medium in which the gas-gangrene group of bacteria flourish most readily.

Time Element.—Last, but not least, is the time element. If conditions are ideal, if the attack is successful, the troops are advancing and there is no hindering "barrage fire," the wounded may be carried back to the regimental first-aid station within an hour or two after they have been wounded. They will probably reach a field or evacuation hospital within six to twelve hours and receive thorough treatment under adequate surroundings—providing the number of wounded does not overtax these units beyond their limit of efficiency.

But when, as occasionally has happened in this war, the exigencies of the battle make it impossible to remove the wounded from "no man's land" and the soldier is himself unable to crawl back to his own trenches under cover of darkness, he may have to lie on the ground for hours—or even days—before any assistance can be rendered. He may not even have the strength to apply his first-aid dressing; There he lies, on polluted soil, his clothes torn and battle-begrimed, befouled by his own excreta, surrounded by the bodies of dead comrade or foe, tormented by lice, fleas and flies, his resistance sapped by loss of blood, fatigue, pain, thirst, and hunger. What chance can there be for non-infection of his wound?

These are not exaggerations. Just such situations have occasionally developed here, there, everywhere on the western front since trench warfare began in the fall of 1914. They are emphasized in these general considerations in the hope that the ex-civilian surgeon may visualize the terrain in which he will have to work, the handicaps he will have to overcome, the risks he will have to assume as the leader of his men, the ingenuity and adaptability he will have to develop in order to meet new conditions as promptly as they arise, and the mental and technical readjustments he will be compelled to make in order to justify his presence in the immediate rear of the firing line!

CHAPTER II.

THE REGIMENTAL FIRST-AID STATION DURING ACTION.

LOCATION.—In trench warfare the relative position of the regimental aid station remains, as a rule, constant. It is usually situated in a fairly bomb-proof dug-out, in close proximity to the kitchen, latrines and communicating trench. Whenever an attack is impending the surgeon is apprised of the fact in order that he may prepare for casualties, ordering up additional supplies, dressings, splints, etc., from the nearest ambulance company or field hospital.

POSITION OF SURGEON.—He should preferably take up his position as near the commanding officer as possible in order to get rapid telephonic information concerning location and seriousness of casualties. As soon as the object has been attained, if the attack has been successful, the troops have moved forward into enemy trenches and the stretcher-bearers are able to collect the wounded in what was "no man's land" a few minutes before. Should the surgeon leave his aid station or not? This mooted question must depend for its answer on a variety of factors. If the stretcher-bearers are bringing in a constant stream of severely wounded men, many of whom require immediate surgical attention (hemorrhage, etc.), it is manifestly impossible for the surgeon to leave his post.

THE SURGEON MAY HAVE TO LEAD HIS MEN.—If, as the result of "barrage" fire, men are unable or unwilling to reach the wounded, it becomes the officer's duty to lead them, perhaps by a devious route and under cover of such shelter as may be obtainable, thus stimulating their flagging zeal by his presence. Never expect your men to go where they think you would be afraid to venture. The casualties are hurriedly examined; those able to walk are directed to the rear, taking shelter so far as possible. Remember that each case must be given a "diagnosis tag" before he is allowed to go backward. Should the surgeon omit this important detail the wounded man would in all likelihood be picked up by a provost guard and detained pending investigation of his case. The more severely wounded are placed in old trenches, in shell craters, behind any kind of natural protection, until they can be carried back to the aid station.

Quality of Work Done.—In the field the assistance rendered will necessarily be limited to applying first-aid dressings and such available or improvised splints as may be necessary for immobilization. Morphin and antitetanic serum are usually given in the first-aid stations, sometimes only on reaching the field ambulance or field hospital.

Advance with the Regiment.—Having disposed of the early casualties the surgeon's next thought should be to follow the advance, maintain his position near the commanding officer and locate the site for his new aid station.

Moral Value.—The fact that the sanitary personnel is advancing with the troops and keeping in constant touch with them is of immense moral value. Keep the officers of the ambulance company and field hospital constantly informed as to the number, and, in general terms, the nature of the casualties you are sending to the rear. With everybody along the line prepared in advance by telephone, or written messages carried by the slightly wounded, all unnecessary delay in giving the severely wounded proper attention is avoided. Keep cool and cheerful. Avoid foolhardy exposure, but do not shirk danger. The morale of the sanitary troops under your orders is an index of your influence over them.

Increasing Importance of the Regimental First-aid Stations.—The endeavor has been made, and to a certain extent carried out, more particularly in the French armies, to give better and more thorough primary treatment to the wounded before they begin their painful journey of evacuation to the rear. Whenever the nature of the terrain permits the regimental aid station is made spacious enough to accommodate a certain number of bunks, usually superimposed, on which the more severely wounded may lie in relative comfort. When it is remembered that a soldier, wounded early in the morning, sometimes cannot be moved until nighttime on account of "barrage" shell fire the great importance of absolute rest can be appreciated. Light, hot food, preferably liquid and appropriate to the nature of the wound, is also furnished. It is during this waiting period, provided the fighting is not continuous throughout the day, that more thorough cleansing, trimming and drainage of deep wounds can be accomplished. That this may not often be physically possible is granted, but the aim should constantly be to have the wounds in as aseptic a condition as possible as early as is consistent with military necessity. Surgeon Tuffier, of the French army, is entirely right when he says: "*Le poste de secours n'est plus un simple atetier d'emballage; c'est la formation ou l'on sauve la vie.*" "The regimental aid station is no longer a mere packing shop; it is the (sanitary) formation where life is saved."

In order to ensure an equally rapid removal of the wounded from the battlefield to the dressing station the probable terrain of the coming battle should be carefully examined and plotted by the surgeon. Explicit orders should be issued to all non-commissioned officers regarding the section each squad or group of litter-squads shall serve. Unless these details are gone over very carefully, and each squad knows his terrain beforehand, the wounded are apt to be gathered in too slowly and in the inverse of the proper order, *i. e.*, those nearest the dressing station will get picked up the first and those farthest away may be missed entirely. Litter-squads should never be allowed to start out at random for the battlefield without leaders.

CHAPTER III.

THE FRENCH ZONE OF THE ADVANCE.

General Considerations.—Fully realizing the importance of having an exact visualization of the conditions which will have to be met by our army surgeons, it has seemed best to describe, in minute detail, the result of a series of observations made at the front, through the courtesy of the military authorities. In order to report different types of sectors the writer made several inspections of the front lines, in order to be able to describe the handicaps of the one and the possibilities of the others. Type I was the result of a three days' visit during which he was the guest of General X, of the —th French army. As it was wise, in this sector, to be in the trenches before visibility is good, an early start had to be made each morning, the General's automobile having to stop some four miles from the front line trenches. From thence on one had to walk through the mud and water, both of which were plentiful.

TYPE I.

Topography of Country.—The country is very flat; the trees are all cut down, the villages entirely destroyed by fire and explosions, and there are very few hillocks or gulleys affording protection. Enemy stationary balloons (sausages) are constantly observing the whole countryside, eight of them being in full view as we walked along.

Location of First-aid Station.—In this particular sector the French had a first-aid station for every battalion of infantry or battery of light field artillery. In quieter sectors they only have two aid stations for a regiment. They are located from 150 to 500 yards from the first line trenches, in this particular zone 175 yards off. To reach the latter it was necessary to walk through an evacuation trench two miles long, which began on one side of an exposed road. This trench was six to seven feet deep and four feet wide, the front line trenches being somewhat narrower. At the bottom of the trench is a central gutter which tries to drain off some of the water, usually unsuccessfully. Small cross-bars of wood are laid on the bottom of the trench, keeping off the mud from one's shoes to a slight extent. In four different places the swampy nature of the soil made trench digging impossible. The stretcher-bearers have to climb up on the level and dash across the open section to the next trench. The direction of the trench changed every fifteen yards in order to avoid enfilading artillery fire. At every 500 yards a dug-out is constructed, usually two stories deep, in which the stretcher-bearers can take refuge when the bambardment becomes very intense.

Description of the First-aid Station.—Two stories deep, it consisted of two rooms, 60 x 18 x 7 feet, divided into three compartments by partitions. The first room was 16 feet the second one 30 feet underground, *i. e.*, 10 and 24 feet below the bottom of the trench. There were entrance and exit doors protected against gas attacks by heavy canvas curtains. The stairways were 3 feet square, placed at an angle of 45 degrees, which made the lowering and bringing up of the wounded a very difficult task. Wooden pillars, cross-beams and corrugated iron sheeting for the roof prevent the earth from falling in. Small wood-burning stoves give sufficient heat and a ventilating pipe was also provided, so that the air was reasonably pure. Lighting is obtained by means of dry cells and small bulbs. One of the rooms contains eight cots arranged in two tiers; the central room is the dressing room and the third one is for the personnel. The upper story is only used in periods of calm; as a rule the stretcher-bearers prefer to carry the wounded man down the two flights of stairs at once, in order to be safe from any possible heavy bombardment. The battalion kitchen is a similar dug-out, close to the aid station. The latrines are also underground, consisting of a trap with a tin or iron receptacle at the bottom. The dejecta are carried off daily and buried. Urinals consist of a hole dug in the side of the trench; a sprinkling of chloride of lime is thrown into the hole once daily.

Equipment and Personnel.—Owing to a dearth of army surgeons the battalion surgeon is now usually a senior medical student. He has eight stretcher-bearers under him, but can telephone to the central regimental aid station for more if needed. He is supplied with stimulants, ampoules of normal saline solution and antitetanic serum, but rarely uses either. He is compelled to use chloride of lime and bicarbonate of soda in case of gas victims. The former is sprinkled on the floor of the dressing room. The patients have their eyes, axillæ, perineum and scrotum washed in bicarbonate solution and 30 grains of the same drug are given internally before they are evacuated.

The equipment is very primitive. No water being available for cleansing purposes, the clothing around a wound is cut off with scissors or knife, the wound cleansed with pledgets of ether-soaked sponges and a dry dressing applied. For fractures, wire splints (*gouttières*) for upper and lower extremities were in stock, also straw splints, very light and easily adjusted. This straw matting is supplied in rolls, the surgeon cutting off what he needs for each case. It is thirty inches wide, very flexible and comfortable. Its three great advantages are light weight, flexibility and compactness. The use of the tourniquet is now rapidly losing favor in the French army. Most hemorrhages are checked by packing the sterile first-aid dressing into the wound and applying a tight bandage.

Shock is treated by lowering the head, wrapping in blankets and the administration of hot drinks.

TRANSPORTATION.—The dressing finished the stretcher-bearers carry the wounded soldier out of the dug-out and begin their two-mile walk through the evacuation trench. Four bearers are required, the work being so exhausting that they have to work in relays of two men, it being impossible for the four men to pass in the trench carrying a stretcher between them. At the central regimental aid station, which is in charge of a First Lieutenant M. C., the diagnosis tag is inspected and the wound reëxamined and redressed if there seems any doubt as to the correctness of the primary diagnosis or treatment. Unless the number of wounded contra-indicates it the first injection of antitetanic serum is given here and recorded.

At the central regimental aid station the soldier is taken charge of by the advance relay of divisional stretcher-bearers, who place the stretcher on a two-wheeled vehicle and convey it to the place where the ambulances are sheltered under the lee of a hillock or turn of the road. The wounded are driven to the automobile sanitary section, where the first sorting (*triage*) takes place under the supervision of a Captain M. C. All emergency cases are marked "urgent" and conveyed directly to the H. O. E., or hospital evacuation, where they receive immediate surgical attention. Urgent cases are those having tourniquets, cranial, laryngotracheal, thoracic or abdominal wounds as well as all gassed cases.

The slightly wounded in the ambulance, as well as all the wounded who have been able to reach the group of division stretcher-bearers, are sent from there to hospitals for the slightly wounded. As soon as they get well they return to their post without obtaining any furlough or reaching the base.

Severe wounds, such as compound fractures, etc., may be redressed and resplinted at the automobile sanitary station if the surgeon sees fit to do so; as a rule he reads the diagnosis tag or *fiche* and makes a cursory inspection of the patient's general condition without removing him from the ambulance —a precious time-saving device.

TIME ELEMENT.—Except in rare instances, such as a rapid advance beyond the enemy first- or second-line trenches, the wounded man can be picked up in his own trench and conveyed to the first-aid station within half an hour. The writer saw a wounded man with a lacerated scalp wound and compound fracture of the left elbow picked up less than a hundred yards from the aid station, carried in, cleansed, dressed and splinted and on his way to the central regimental aid station all within an hour.

From forty-five to sixty minutes are consumed in carrying the wounded man through the winding two-mile evacuation trench.

Transport by two-wheeled stretcher-bearer only took fifteen minutes. The road was exposed to artillery fire and the bearers ran the cart most of the way.

The transfer of the wounded men from the two-wheeled carts to the automobile ambulance and their transportation to the auto-sanitary section, nine miles in the rear, took an hour and a half.

After redressing and inspection the auto ambulance arrived at the evacuation hospital, eighteen miles from the front trenches, in an hour and a half. The average time for urgent cases, from the time they are picked up until they reach the evacuation hospital, is four hours. For severe cases, evacuated with the routine stops and inspections—six to eight hours were consumed. It must be stated, however, that this only holds good for periods of ordinary trench and artillery activity. When the troops are advancing in force or are repelling a heavy attack the wounded are not so fortunate.

SUMMARY.—This type of sector was manifestly unfitted for advance surgery. The entire country offered little or no shelter; all villages had been totally destroyed by the enemy before his retreat, and the French were compelled to build underground dug-outs where they lived like troglodytes. Most of the wells had been rendered unfit for use by the enemy before he retreated, necessitating the transport of all water for cooking, drinking and watering purposes. The regimental central aid station formed part of a complete underground two-story village, housing over two thousand men (artillery, infantry, engineer and signal corps and sanitary personnel). Absolutely no supplies could reach them by daytime and the single narrow-gauge railroad which supplied them by night was destroyed by artillery fire at least once daily.

The lack of screening (trees, hillocks, gulleys, etc.) forced the stretcher-bearers to use the long evacuation trench during daylight; at night-time they invariably walked across the fields.

The automobile sanitary station and evacuation hospitals were an unusually long distance from the front, on account of the deserted condition of the country and the paucity of railheads. The average distance from the trenches to the H. O. E. (evacuation hospitals) is from five to eight miles.

TYPE II.

Topogrpahy of Country.—Essentially the same as in Type I, except that this sector was devoid of normal-gauge railroads, these having been entirely destroyed, and therefore depended almost entirely on the single national high road for its replenishing. There was a single track narrow-gauge railroad (Decauville), which brought artillery supplies as far as the heavy field artillery emplacements, but its capacity was taxed to the limit, so that it could not be utilized for evacuation purposes.

The national high road, running due north, was in full view of stationary balloons (sausages), and an important city, still in enemy hands, dominated the whole sector for ten miles. Automobiles are stopped in a shallow gulley five miles from the front lines. At night-time the guard waves a red light to warn the drivers, as neither army barricades the roads, preferring to protect them by means of converging rapid-firing guns. On a foggy night, a few days before my visit, a new driver missed the red light and ran his car into the enemy lines, where he was captured.

Both the entrance and evacuation trenches were in full view of enemy observers. They had to be approached in spread-out formation, any grouping of men being sure to invite artillery fire. As soon as firing began, comparative safety could be obtained by jumping into the ditch which bordered either side of the road, and lying down flat. This has to be done because a shell, striking the heavy cobblestones with which the roads are built, will burst horizontally, the fragments flying in every direction from one to three feet from the surface of the ground. Out of a total of five nurses recently killed by shell fragments in an advance hospital formation, four were found under their beds, where they had crawled in a wrong endeavor to seek protection.

The rainfall in this sector is so heavy that the sides of the evacuation trenches, leading from the central regimental aid station to the rear, were constantly falling in, preventing proper drainage and rendering them practically useless. Nothing is more exhausting than climbing over heaps of mud or floundering through muddy water up to your knees or higher; two men, carrying between them the inert load of a wounded soldier, find the task a superhuman one. Consequently the evacuations are done at night-time *via* the high road, except during cloudy days, when the stretcher-bearers walk across the fields with their burden. Auto ambulances are only allowed to come to within five miles of the lines. Four bearers, relaying each other, can carry a wounded man at the rate of 1 kilometer per hour; the evacuation trench being two and a half miles long, three hours of arduous work were required before the auto ambulance was reached. The path across the fields was equally slow on account of swampy areas and exposed places which had to be avoided. The two-wheeled stretcher-carriers were only used on the high road where visibility was very low.

The battalion aid stations were extremely primitive dug-outs, largely utilized for gas attacks. Antigas solutions were in stock, with extra masks and a supply of oxygen. No surgery was attempted on account of the proximity of the regimental aid station, 750 yards to the rear. A senior medical student was in command, with four stretcher-bearers.

Regimental Aid Station.—The regimental aid station in this sector was thoroughly organized and equipped. It consisted of a large receiving and store-room above and a spacious stairway leading to a gallery into which small wards opened.

The receiving and supply room seemed open to the objection of not being fully bomb-proof, as it was only protected by a corrugated iron roof covered over by three feet of earth. The supplies were all stored against the inner wall, where protection was greatest. It was explained to me that the desire on the part of the personnel for sunlight and fresh air was not to be denied them. They would crawl up from the gallery below much as the stoker climbs up from the ship's hold. The wounded men were only kept long enough in the upper room to fill out their diagnosis tag with name, rank and organization. In periods of relative calm the personnel preferred to remain in the upper room, running the risk of a direct hit which would have demolished the whole place.

The supplies included dressings, bandages, straw splints (*gouttières Paillon*), Thomas splints, rubber tubing for Esmarch bandages, 100 extra gas masks for the soldiers and a supply of special gas masks (large and small Tissot type), besides small portable oxygen tanks for officers and stretcher-bearers. The latter had to be kept in the upper room in order to be instantly available in case of a gas attack. Ether, alcohol and other surgical supplies were kept in the operating room below.

The stairway was a shaft three feet square, placed at an angle of 45 degrees, having thirty-two steps, well beamed and boarded, leading directly into a gallery 6 feet wide, 7 feet high and 300 feet long, 27 feet below the surface of the earth, hence proof against a direct hit from the heaviest mortar or long-range naval gun. At right angles to the gallery were 25 separate rooms, 14 x 8 x 8 feet, containing either eight or ten bunks arranged in two tiers. At the end of each room was a ventilating shaft of wood which began at the ceiling and extended one foot above the surface of the earth. A tin cap on a spring hinge enabled the shaft to be closed during a gas attack. Attached to the inner side of the cap was a long string which passed down the air shaft into the room. At the first alarm the soldier nearest the shaft had orders to pull the string taut and tie it to a convenient nail. When the gas attack had ended and the antidotes had been sprayed and strewn around the string was loosened and the spring hinge released the cap. Light was obtained by acetylene lamps and candles. In other similar formations a small dynamo is installed, generating sufficient current to light the entire gallery and rooms.

A duplicate stairway existed at the opposite end of the gallery, providing an exit in case of a surprise attack.

The effects of gas attacks were amply circumvented by closure of the ventilating shafts and by thorough protection of both stairs. At the entrance of each was hung a stout sheet of canvas, immediately behind which was a double door which fitted snugly and closed accurately. Two yards down the stairs a second canvas sheet was placed, and another two yards farther down (or four yards from the entrance), a second door and third canvas sheet completed the antigas system. Outside of the receiving room is a siren, autohorn or large wooden rattle which is sounded as soon as gas shells begin to explode. Gas masks are applied by all of the personnel, and one of the stretcher-bearers on duty seizes a large sprayer (similar to the ones used by fruit growers), filled with a solution of potassium or sodium bicarbonate, and rapidly sprays all three of the canvas sheets. Having done so he stands between the second door and second sheet and continues to spray the second canvas as long as the gas attack lasts. The sheet must be kept moist but not dripping. At the same time chloride of lime powder is sprinkled on the floors, especially at the bottom of the two stairways. All stretcher-bearers wear the mask and thick leather gloves.

The operating and dressing room, 16 x 10 x 8 feet, was located at one end of the gallery, almost immediately at the foot of the entrance stairway. It was well ventilated and amply lighted by four acetylene lamps. Small wood or coal-burning stoves provided ample heat for the operating room and gallery, the smoke passing up the stairway through a pipe.

The operating table was a simple but adequate wooden one, and the field instrument case provided all the necessary instruments for first-aid surgery of the ordinary type. Sterilizing was done by boiling over a very efficient kerosene lamp (Primus lamp). The surgeon in charge, a captain, had trained one of his orderlies to give ether or ethyl-chloride anesthetics, and a second orderly acted as assistant. As in all sanitary formations in the zone of the advance the amount of operative work depended upon the activity of the sector. In periods of calm, thorough excising of lacerated tissues was done; fractures were set and immobilized with traction; hemorrhages were checked by direct ligation of the artery in the wound and shock was treated by giving hot drinks, lowering the patient's head, applying external heat and by normal saline phleboclysis, glass ampoules of normal saline, containing 250 c.c., being kept on hand for that purpose. Sterilization of the wound after excision *en masse* of all lacerated tissues (*débridement*), was obtained by means of ether in all deep lacerated wounds or seton (perforating) wounds by tincture of iodin in superficial wounds. The first injection of 500 units of antitetanic serum was also given here. No attempt was made to perform esquilectomy or to remove shell fragments unless they appeared within the wound and could be readily extracted. Tracheotomies for manifest edema or hematoma of the glottis were performed, but no laparotomies had been attempted, abdominal wounds receiving morphin and being evacuated as rapidly as possible. No intracranial or intrathoracic surgery was attempted. In other words, the regimental surgeon aimed to render a majority of the simpler wounds aseptic, but he, very properly, made no attempt to do any reparative work amid surroundings which were manifestly inadequate for such procedures.

During active fighting, when the entire 200 cots were often occupied by wounded men, nothing was done except to cleanse the wound with ether and apply a sterile dressing. Antitetanic serum was given; fractures were always immobilized and extension applied whenever necessary. Hemorrhage was checked by packing sterile gauze in the wound and applying a snug bandage.

Put tersely, the regimental surgeon must do, properly, as much as he can under the circumstances. After three and a half years of war the French sanitary service has learned that a service which lacks elasticity and quick adaptability is bound to fail. Given the proper personnel a certain definite latitude must be allowed each regimental surgeon in order that he may be able to render the best service to the greatest number of wounded in the shortest space of time.

Surgical Center.—In this sector the automobile surgical ambulances and evacuation hospital were situated in the same field, approximately eight miles from the lines. Two ambulances, or autochirs, as the French call them, with semipermanent barracks, each containing 550 beds, were located within twenty yards of the evacuation hospital, with a capacity of 1000 beds; a railroad spur a mile long and an embarcation *quai* 400 yards long ensuring rapid progress toward the base. Each ambulance or autochir was an independent unit, with its administrative officer, chief surgeon and staff.

Description of Autochir (Mobile Unit).—Originally a mobile unit, its entire *matériel* carried on five large motor trucks, it had acquired a semipermanent character by grouping and joining a large number of portable barracks together in a very definite grouping. It continued to utilize part of its mobile equipment, such as the sterilizer, portable *x*-ray room, electric dynamo, etc., the balance being stored ready for use, so that at a day's notice it could move forward with the army, leaving a well-organized unit behind to continue the treatment of the remaining wounded. The first essential of the autochir is instant mobility, as it may be called upon to move forward or join some other surgical center where its services are needed.

A central driveway brought the wounded men to the entrance (*Bureau des Entrées*). In periods of great activity the rule was to admit 400 consecutive wounded to one of the autochirs and then an equal number to its companion across the driveway. This plan enabled the staff of one unit to complete its quota of cases and obtain a few hours' well-needed rest before its next turn came around; it also tended to minimize congestion.

Upon entering, one came upon a long waiting room half to the right, half to the left of the main passage. All cases brought in on stretchers were classed as severely wounded (*grands blessés*) and placed in the left half of the room; all men who could sit up or walk were considered as slightly wounded (*petits blessés*) and placed in the right half of the room. This preliminary sorting (*triage*) was subject to revision during the operative procedures.

Progress of a Slightly Wounded Man after Entering the Autochir.—From the waiting room he passed to an undressing room, where his clothes were removed and he either took or was given a warm shower bath. During this process he retained his first-aid dressing. Thoroughly washed, dried and wrapped in a sterile sheet he received 500 units of antitetanic serum and entered one of the two minor surgery operating rooms, each containing four operating tables, where he received a thorough surgical examination. Backed up against these two rooms, but connected with them by temporary boarding, was the autotruck containing the *x*-ray room. Should the surgeon deem it necessary a radiograph is taken at this stage. Once radiographed the patient is returned to the operating table, where his wound is thoroughly prepared by scrubbing with soap and water, followed by ether. A general anesthetic is given, either ethyl chloride or ether being used; the wound is surgically excised and all necessary treatment of foreign bodies, bone fragments, etc., is carried out. As soon as the wound is dressed the soldier is carried by stretcher across the intervening twenty yards to the evacuation hospital, in which he is duly entered. In other words, this unit considers as slightly wounded (*petits blessés*) any patient who can be immediately evacuated after his operation. Should his wound be a very slight one he may even be put directly on the hospital train and sent to the base, after having his diagnosis tag and history sheet recorded in the evacuation hospital books. He merely is entered on the books without actually occupying one of the hospital beds.

With eight surgeons, a radiologist, anesthetizers and nurses in attendance the slightly wounded pass in a constant stream from the autochir to the evacuation hospital. It would be hard to conceive a more rapid or efficient system than the one just outlined.

Progress of a Severely Wounded Man in the Autochir (Mobile Unit).—From the waiting room on the left of the entrance he is carried to a small preparatory room where, if not already done at the regimental aid station, he receives 500 units of antitetanic serum. He is undressed, given a bath, wrapped in a sterile sheet and carried to a surgical waiting room, well heated by radiators, where he receives a thorough surgical examination. The most urgent cases are first selected, taken to the special *x*-ray room for *grands blessés* and from thence carried to one of the four operating rooms. Those suffering from severe shock, in whom internal hemorrhage can be ruled out, are first placed in a "shock room" in which are a number of electric light heated cots called *cellules chauffantes*. Normal saline solution is given intravenously, as well as hot drinks, unless contra-indicated.

The wounded not in severe shock are immediately *x*-rayed, anesthetized and operated upon. Two of the operating rooms are for cases in which sepsis is either present or expected; one is reserved for abdominal cases and the fourth one is for all other clean cases. There is also a smaller room for the removal of shell fragments (*éclats*) under the fluoroscope, conveniently placed between the two septic operating rooms.

As the majority of cases reach the autochir within eight hours from the time they are picked up the great desideratum of war surgery, primary closure, is realized in a large percentage of cases.

Each operating room has three tables, an operating unit, consisting of a surgeon and two assistants, besides the anesthetizer and nurses. Three patients are constantly in the room, the surgeon finishing the important part of one operation to find the next patient anesthetized, the wound area surgically prepared and protected by means of sterile towels, and the necessary instruments ready. Unless the gloves have been punctured or torn in the course of the preceding operation no additional hand-scrubbing is indulged in, the surgeon merely changing gown and gloves. The record in this particular autochir is 67 consecutive major operations performed by a single operative unit.

From the operating room the patients are removed to one of the wards unless they are deemed to be in a critical condition, in which case they enter a special recovery room, where they are kept under observation until they either die or have passed the danger line, when they are moved to a ward.

There are separate wards for officers, contagious cases and wounded prisoners.

Theoretically the severely wounded should be sent to the evacuation hospital as soon as they are transportable; practically they are evacuated as soon as 300 of the autochir beds are filled, it being the aim of the chief surgeon to have 250 beds constantly at his disposal for emergencies. In periods of relative calm, wounded cases presenting unusual surgical interest can be kept in the autochir until they are ready to be sent directly to the base.

Rotation of Service.—In order to stimulate enthusiasm and maintain *esprit de corps* at its highest pitch the operating units were rotated from slightly wounded to severely wounded and back again. The more delicate cases, such as intracranial, intrathoracic and intra-abdominal wounds, are reserved for those surgeons whose experience warrants their being trusted with this type of surgery. The bacteriological and pathological laboratories were well equipped and a microbic curve was kept of all open wounds. Ether dressings were almost invariably used; ether injections in joint infections, intrathoracic wounds and laparotomies constituted a routine procedure. Very few cases were treated by the Dakin-Carrel solution.

TYPE III.

Topography of Country.—This sector, the most famous in France, was the scene of the greatest defence in the present war. The country is quite hilly and was wooded, but artillery fire had been so intense that only a few tree stumps remained where thick forests had previously stood. Visibility of roads was thus increased, besides which the enemy knew the exact distance of every cross-road or turning from its own batteries and systematically shelled vulnerable points by indirect artillery and mitrailleuse fire. The destruction of villages was complete. Owing to the frightful number of men killed and buried in this sector, soil pollution was almost inconceivably bad, and wounds became infected much more rapidly than in quieter sectors.

The many narrow-gauge railroads were all utilized for the transport of munitions, and none could be used for the evacuation of wounded men. The evacuation trenches were from two to five miles long, with occasional open spaces along the bottoms of gulleys where stretcher-bearers and wounded were exposed to enemy visibility. In periods of relative calm the wounded were kept in the regimental aid station until nightfall, in order to enable the auto ambulances to drive up to within a few hundred yards of the former. During great activity, evacuations had to be undertaken under barrage fire. Soldiers who were wounded during the night or early morning could be evacuated to the nearest surgical unit within three hours. The writer personally saw a soldier with an intracranial subdural injury, caused by a shell fragment, lying in one of the beds of an autochir eight miles from the front lines. The wound had been received at six o'clock in the morning; thorough surgical first aid had been given at the regimental aid station; the ambulance picked him up and hurried him to the hospital, so that by ten o'clock of the same morning the soldier had been trephined, the shell fragment removed, the wound sutured and his brigadier-general had pinned the military medal over his bed. In this sector the battalion aid stations were simply utilized as bomb-proof places of safety from which the wounded could be carried to the regimental aid station.

The Regimental Aid Station.—Two of these stations were inspected. The first one was built in the side of a hill, in close proximity to the commanding officer's and reserve troops' quarters. Its construction was essentially the same as that described in Type II, except that no stairway was required, the two entrances simply penetrating into the hillside. Thirty-six bunks were arranged in two tiers. Light was obtained by means of a small dynamo which supplied the entire camp. Acetylene lamps were always on hand in case of accident. The importance of having a double or triple system of lighting was everywhere emphasized. The surgical supplies and appliances were sufficient to cope with any emergency.

In order to economize space there was no operating table. Four steel chains with large hooks hung down from the ceiling beams to which they were secured. When a wounded soldier was brought in the stretcher he was on was simply suspended by these four hooks and the surgeon could immediately proceed to the treatment of the wound. This completed, the patient was either removed to the ambulance *via* the trench or placed in one of the bunks until nightfall. This simple and easy arrangement minimized secondary traumatism, lessened shock and was time-saving. Instead of the hooks, which may not always be available, ordinary rope or wire loops are used in other stations.

The other regimental aid station in the same sector occupied the wine cellar of a Louis XIII chateau, which was otherwise almost totally destroyed. The cellar vaults were massive, but for additional security heavy supporting beams had been placed everywhere. Between twenty and thirty feet of crumbled walls lay over the cellar, protecting it against even heavy artillery shells.

Seventy bunks, in two tiers, provided ample facilities for wounded and personnel. Light was obtained by means of acetylene lamps and candles. First-aid surgery was all done on suspended stretchers in order to save space. Owing to the thickness of the walls no ventilation shafts had been cut through and the air was not very pure, the depth of the cellar preventing the two entrances from acting as efficient ventilators, even when both doors were opened. Behind the one remaining section of chateau wall was installed the regimental kitchen, exposed to direct hits or shell fragments. During a bombardment or gas attack the personnel had to take refuge in the cellar. In addition to the hot meals which are carried to the soldiers in the trenches the medical corps now sends hot tea, flavored with a slight amount of brandy, to the front lines twice daily, a most welcome potion, which the soldiers look forward to with eagerness. The prevailing idea of the French medical corps is to make the fighting men feel and know that their comfort is being looked after and that everything is being done to mitigate the hardships under which they have to live. The French are strong believers in the personal element, the little acts of kindness, even of tenderness, toward the individual soldier, which have helped to keep up both his fighting spirit and mental serenity. The *tisaneries*, as the hot-tea stations are called, did not come into existence as the result of army orders; they represent a voluntary contribution to the soldier on the part of the medical corps. Begun in a small way it was soon noticed that where the *tisaneries* existed and the regimental kitchens were installed near enough to the trenches, so that food reached the soldier hot, the *morale* and fighting edge were of the highest. Division surgeons are constantly urging and encouraging their regimental surgeons to devise improvements and make suggestions.

System of Evacuation.—During the daytime, after leaving the regimental aid station, the stretcher-bearers carried the wounded along a narrow and tortuous path, three miles long, fairly well masked from enemy eyes by camouflage. The trench was seldom used, as it was not possible to dig it deep enough on account of the rocky substratum. Moreover, it offered little or no protection from overhead indirect artillery or mitrailleuse fire which the enemy was almost constantly using in exposed places. A shell had burst along the path shortly before the writer traversed it and the rapid-fire gun bullets kept whizzing about, so that the stretcher-bearers' task was not a very safe one. Walking in single file, ten to twenty yards apart, was relatively safe, but any grouping of men was certain to invite a rain of bullets. Walking canes had to be kept close to the ground, because, being, as a rule, only used by officers, the sight of a cane was certain to bring a reminder of the fact that enemy fire controlled the path.

Ambulance evacuation was maintained by a splendid system of relay stations, each one having only one ambulance, because, in the past, whenever a group of ambulances set up a post it was subjected to shell fire and usually destroyed. Three stations were located along protected portions of the road, No. 1 being as near to the regimental aid station as the topography of the land would permit. As soon as Ambulance No. 1, with its load of wounded, passed Station No. 2 the latter's ambulance would move forward to Station No. 1; when Ambulance No. 1 reached Station No. 3, the latter's ambulance moved up to Station No. 2. By this means there was almost constantly an empty ambulance in each of the three relay stations. The division surgeon was satisfied that this relay system had effected an appreciable saving of ambulances and lessened the casualties of the ambulance personnel. Its essential advantage lay in the avoidance of grouping of stationary or moving ambulances.

HOSPITAL FOR SLIGHTLY DISABLED AND SICK MEN (ÉCLOPÉS).—All soldiers who, either through very slight war wounds or from sickness, are incapacitated for a few days and who, upon recovery, are not entitled to either ordinary or convalescence furloughs are classed by the French as *éclopés*, meaning slightly knocked out. They are kept close to the firing lines in order that they may be immediately returned to their company as soon as the surgeon discharges them. It corresponds, in general, to our hospital for slightly wounded. In this sector the men were housed in a large tent (Hangar Bessonneau), containing 130 beds, ten miles from the front. As a protection against shell fragments during a bombardment a central pit, 7 feet deep and 4 feet wide, had been built, running the entire length of the tent. It was covered over by boards on which the patients could walk. It was of course useless against a direct hit, but could be used against gas attacks.

Heating was obtained by means of two large iron stoves placed at either end of the tent in a hollow, twelve feet square and four feet deep, around which were seats for sixteen men who could thus keep warm and comfortable. The chimneys passed along the ground and out, becoming vertical five feet from the tent walls. This ingenious combination of heating and seating capacity is the original idea of Surgeon Campana who also had devised the central pit for protection against shell fragments.

EVACUATION HOSPITAL (COMBINED EVACUATION AND AUTOCHIR).—Owing to almost constant long-range artillery fire, this center was situated fifteen miles from the front lines, within five hundred yards of a railroad and in close proximity to the famous highway which is fondly referred to by the French as the Sacred Road (*Voie Sacrée*), as it enabled the army to transport munitions and men during the heroic defense of Verdun.

The autochirs in this surgical center had lost their identity, the mobile parts not being utilized. The units remain, forming, with the staff of the evacuation hospital, a group of sixteen operating units or *équipes*.

The entire group consisted of the staff and personnel of the two autochirs, having some six hundred beds at their disposal, and the staff and personnel of the evacuation hospital, with a capacity of one thousand beds.

Owing to the rather unfavorable topography of the land, the grouping of the buildings was not ideal. As in other formations, the wounded were separated into slight and severely wounded. The operating pavilion was subdivided into septic and aseptic rooms, but it was stated that this division was of little value in war surgery. The attempt to separate the "gassed" cases into those simply gassed and those both gassed and wounded was not satisfactory. While it seems best not to specify names or places, the writer received the distinct impression that, in the opinion of many French army surgeons, too much specialization had been attempted in some of the sectors.

In periods of great activity no primary suturing of wounds was attempted, as the wounded had to be rapidly evacuated to the base by train. Complete surgical removal of all foreign bodies and of all lacerated tissues (*débridement*, *épluchage*, *esquilectomie*) was always done before any further evacuation.

In periods of relative calm, primary suturing was done in practically all cases, but the wounded were kept in the hospital until the stitches were removed and the scar was surgically clean. Special stress was laid on the danger of evacuating soldiers whose wounds had been sutured, unless the wounds were entirely healed and the stitches removed.

Protection against fragments and even direct shell hits was most thorough.

1. Around each of the wooden barracks a double row of fine chicken wire, three feet high and one foot apart, had been stretched, leaving gaps for the doors. The interspace was filled with coarse gravel, affording ample protection against shell fragments. This system of protection was much more rapidly put up than were the sand bags, wicker baskets filled with earth or the piles of stone used in other formations. All of this work was done by the sanitary personnel of the group.

2. Cement vaults, thirty yards long, seven feet high, eight feet wide, with walls one foot thick and built zig-zag like a trench, were located between barracks, on the ground. Each vault could accommodate eighty slightly wounded men. They offered no protection against a direct hit but were used against gas attacks and aëroplane rapid-fire guns.

3. A series of underground galleries, thirty-five yards long, nine feet high and eight feet wide, with room for thirty stretchers, offered protection to the severely wounded. They were built by, first of all, excavating the ground; the gallery was then heavily beamed and planked and then covered over with ten feet of earth (obtained from the excavation) and finally protected by a layer of two-foot square blocks of concrete, twelve inches thick, laid closely together and joined by wiring. Each block had four small iron rings at its four corners, forming part of the block; the wiring together of these blocks was simple and rapid. Seen at a distance, they gave the galleries the appearance of huge tortoise shells.

TYPE IV.

Topography of Country.—Moderately hilly country through which a large number of narrow-gauge railroads run, facilitating rapid evacuation of wounded. The cars came up to the very entrance of one of the battalion aid stations; but could not be used when visibility was good. Drainage being good and the subsoil rocky, the trenches were dry and comfortable, so that the evacuation of the wounded by stretcher presented no unusual difficulties. On level ground the trenches offered good protection; the gullies were unfortunately under direct observation of snipers and rapid fire guns, and, in spite of camouflage, the crossing of these open spaces was always hazardous. Enemy trenches were, in places, only fifteen yards from the French trenches, the intervening space being entirely filled by wire entanglements.

Battalion Aid Stations.—All three battalion aid stations were excavated in a hillside, about two hundred yards from the front line trenches. Each consisted of a dressing room 10 x 8 x 8 feet and a gallery slightly longer in which were six bunks arranged in tiers. Surgical dressings, gas masks, sprinklers against gas attacks, and flexible splints of straw or of window shade material (store) were stored in sufficient quantities. No surgical cleansing of wounds was attempted, the wounded men being immediately evacuated to the regimental aid station as soon as the first-aid packet and immobilization had been applied. Evacuation was *via* the trenches to the narrow-gauge railroad or, as in the one instance already quoted, the stretcher was placed directly on one of the cars; the latter were always pushed by hand, as the engines made too much noise. When the railway track was not available, two evacuation trenches and a carriage road under fair natural protection, afforded good means of egress.

Life being very monotonous in a quiet sector, the sanitary personnel was constantly employed in improving the dug-outs, repairing the trenches and roads, gathering wood for the stoves, supervising the hygiene and disinfection of the sector, etc. Unless the battalion surgeon kept his personnel fully occupied, their morale declined very rapidly.

Regimental Aid Station.—This was located 1500 yards from the nearest battalion station, under shelter of a fairly steep hill, and in close proximity to the narrow-gauge railroad and road. The same hillside also housed the commanding officer and all of the reserve troops. The dug-outs were built in the side of the hill in three tiers or stories, giving the entire settlement the appearance of a Pueblo village.

The aid station consisted of entrance and exit galleries, 30 feet apart, each 20 feet long, 10 feet wide and 8 feet wide, running directly into the hill and connected at their base by a right-angle gallery 20 feet long and 14 feet wide, in which were placed thirty bunks in tiers. Electricity and acetylene lamps were used for lighting purposes. Sterilizing was done by boiling, an ample supply of good water being available at all times. The wounded were placed on a simple wooden dressing table; after treatment they were kept in one of the bunks until nightfall, if the bombardment was severe, or else evacuated *via* the railroad.

First-aid surgery consisted in cutting the clothes from the wound area, cleansing with ether and removing all gross shell fragments and particles of clothing or dirt. A dry dressing and immobilization with extension, if needed, completed the primary treatment.

Field Hospital.—The surgical center for severely wounded was situated sixteen miles behind the lines. It was not connected with an evacuation hospital and only contained three hundred and fifty beds. On the outskirts of an intact village full of troops, it was thought safer not to have any large surgical formation there, on account of aëroplane bombardments. The entire group of buildings was of the semi-permanent type, the wooden barracks being lined on the inside with corrugated cardboard which seemed to give the best protection against the cold. The *x*-ray and operating rooms were of the non-demountable type. The ward barracks were placed back to back, a small dressing room being built in between and connected to the two buildings by a small passageway. Only intracranial and intra-abdominal wounds and fractures treated by overhead suspension were dressed in the wards themselves.

Conclusions.—It must be strictly understood that the foregoing descriptions and the conclusions based on close observation of the French Service de Santé are not recommendations. After three and a half years of war, the French have evolved an adaptable, elastic system of advance sanitary formations which would seem hard to improve upon. The desire of the writer is rather to give our regimental surgeons (and battalion surgeons if we decide to adopt the same subdivision) the result of the combined experience of their French comrades before they themselves get into action. Without conflicting with our own regulations, our surgeons may find herein some practical ideas, adapted to a certain topography, which may help them to solve problems with which they are certain to be confronted.

Importance of a Thorough Knowledge of the Sector.—As soon as the battalion or regimental surgeon arrives in a new sector and has supervised the instalment of his *matériel*, he should rapidly gain an intimate personal knowledge of the first line trenches, dug-outs, listening posts, evacuation trenches and means of transportation to the rear. This knowledge should be gained on the day of arrival, if possible, because enemy surprise attacks are frequently coincident with the arrival of new troops in a sector. It should be acquired through day and night inspections in order that he may be able to describe the topography of the terrain to his personnel. The latter should also be given an early opportunity of familiarizing themselves with the system of trenches and evacuation routes, so that, when called upon to pick up the wounded, at least one man of each squad is familiar with the general contour and direction of the trenches. Unless one has actually walked through many systems of trenches, it is hard to realize how very easy it is to lose oneself, especially at night, and how valuable hours may thus be lost in transporting a wounded man from the field or battalion aid station to the regimental station.

The surgeon should also acquaint himself, through his commanding officer, with the location of enemy trenches, batteries, trench mortars and mitrailleuse redoubts, together with the "habits" of the enemy in that particular sector. By "habits," is meant the routine firing of the day or night during periods of normal activity. Certain open spaces, crossroads, gulleys, etc., are regularly under enemy fire at certain hours of the day or night, and the sanitary personnel must learn to avoid these exposed places during those periods.

Knowledge of the Probable Terrain to be Occupied in the Course of a Contemplated Advance.—On the preparation of an attack, the battalion and regimental surgeons are invariably apprised of the probable objectives to be attained. They must study the general topography of the country to be traversed, its enemy trenches, dug-outs and aid stations, in order to be able to utilize them during the engagement.

Before any offensive begins, the surgeon must have undertaken a reconnaissance of the terrain with his commanding officer, and have questioned the latter regarding: (*a*) the probable line and evolution of the attack if successful; (*b*) the probable line of retreat in case the offensive is halted. With this knowledge in mind, he can keep in close touch (*liaison*) with his commanding officer during the attack, and receive information regarding the occupation of enemy territory, the direction of his own and of enemy artillery fire and barrage fire, and thus be able to rapidly decide upon the safest line of evacuation through enemy trenches, "no man's land" and his own first lines to the regimental aid station which has automatically moved forward with the reserve troops.

The battalion surgeon must often, perhaps usually, extemporize the first-aid station within enemy lines. As soon as this has been done he must indicate to his personnel the proper evacuation routes for the wounded. Two or more tentative routes should be decided upon, as a counter attack or barrage fire may render certain routes impassable. Of equal importance is a thorough knowledge of the relay system of stretcher-bearers (*liaison*) enabling the wounded to be evacuated without undue delays.

During an attack, an accurate and continuous *liaison* between stretcher-bearers and battalion and regimental aid stations must be maintained. The relay system which seems to have given the French service the most satisfactory results is: (1) from the place where the soldier has fallen to the battalion aid station; (2) from the battalion aid station to the regimental aid station; (3) from the latter to the nearest point accessible to automobiles. This last relay may have to be subdivided into several sections if the distance is too great. A safe method of computation in trench evacuations is to allow four men per kilometer per hour for the evacuation of a severely wounded soldier. If only two men are allowed per stretcher, they should be relayed every five hundred yards.

Throughout the progress of an attack, the surgeon should be in constant touch, either directly or through despatch-bearers, with the battalion captain or ranking officer who, in turn, should keep him apprised of the progress of the battle, its successes or reverses and the probable point at which his troops may expect to halt.

As it is impossible to transport all of the *matériel* of a battalion aid station during an advance, the French now have, per company, an emergency bag containing individual first-aid packets, sterile gauze, bandages, light flexible splints in rolls (*gouttières paillon, gouttières store*), and a small medicine chest. The permanent *matériel* is brought up later on, when the advance has halted and the surgeon has selected his new aid station.

Experience has taught both the surgeon and the fighting troops to avoid occupying any large, well equipped or protected dug-outs or buildings recently evacuated, the enemy being very fond of leaving explosives with time fuses hidden in these localities.

Importance of Constantly Supervising the Equipment of the Sanitary Personnel.—The trite old saying that "familiarity breeds contempt" is nowhere truer than in the front-line trenches. The surgeons should constantly see to it that their personnel does not leave the aid station without having steel helmets, gas masks, leather or rubber gloves against gas burns and individual first-aid packages. They will otherwise forget one or the other, in spite of warnings or punishments. When an advance is contemplated, or a severe attack is being repulsed, and reserve stretcher-bearers are sent to the aid stations, the surgeon should immediately inspect the new personnel and especially see to it that the men understand the use of the gas masks, portable oxygen tanks, etc., and know how to put them on rapidly.

Repeated talks and demonstrations on the checking of ordinary hemorrhages, the dangers of the Esmarch bandage, the handling of fractures, etc., will keep the efficiency of the personnel at its highest pitch.

At no time should the surgeon lose sight of the fact that he must try and keep his personnel intact. He should always be their leader, counsellor and adviser in all matters pertaining to their well-being and to the efficiency of the service. The French army has learned through experience that the seasoned personnel of the medical corps will never sacrifice life or limb uselessly; the new personnel, on the contrary, through unwise zeal, curiosity or carelessness, is apt to suffer casualties which are of no military value. In trench warfare especially, there are innumerable opportunities for useless wastage of personnel. Lack of familiarity with the terrain, an unguarded raising of the head, etc., will often suffice to reduce the personnel of the Medical Corps.

First-aid Surgery during an Attack (*Offensive or Defensive*).—As the evacuation of wounded must be rapid and continuous, they should not be detained longer than is absolutely necessary at the battalion aid stations where the treatment will merely consist in a rapid ether disinfection and application of a dry sterile dressing, immobilization and a preliminary filling out of the diagnosis tag.

Many front line surgeons are of the opinion that the final sorting (triage) of wounded into slightly wounded and severely wounded (the latter still further subdivided into transportable and non-transportable) should take place at the regimental aid station. The slightly wounded can walk to the nearest hospital for slightly wounded or utilize such means of transportation as may be available (returning motor trucks, wagons). The "intransportable" cases are those needing immediate surgical intervention and are immediately taken by ambulance to the advance surgical hospital for operation. The severely wounded classed as "transportable" are evacuated to the autochirs and evacuation hospitals.

In order to shorten the duration of evacuation, the tendency of the French sanitary service is to decrease the number of examinations and to do the sorting or triage in the ambulance itself, instead of removing the wounded to a triage hospital, examining him and then replacing him again in the same ambulance before he can continue his journey.

In few words, the ideal sought by the French sanitary service is: (1) first-aid dressing on the field; (2) preliminary surgical cleansing, dressing and immobilization with or without extension at the battalion aid station or regimental station if the former is overtaxed; (3) continuous, uninterrupted evacuation to the nearest surgical center where urgent and non-urgent cases can receive permanent, complete surgical treatment.

The amount and kind of surgical treatment possible in the front line sanitary formations, and the distance between the regimental aid station and the surgical centers must be variable, as they are always governed by the activity of the sector, its topography, and the available skilled staff and personnel.

CHAPTER IV.

THE BRITISH ZONE OF THE ADVANCE.

General Considerations.—It may be stated as an absolute truism that any comparison between the French and English methods of treatment or evacuation of the wounded in their respective zones of advance is impossible, because of radical differences in topography of land and general conception of trench warfare.

The English have maintained a comparatively short front, difficult to hold and correspondingly more difficult to advance in. They have pinned their faith in density of front, with continuous activity along the entire front, alternating with intense attacks in selected sectors. The enemy, constantly and diligently harassed, retaliates in kind; the pressure is constantly maintained, night and day. Thus unending "strafing" has naturally multiplied the problems of evacuation, increased the distance between the front lines and the regimental aid posts and lengthened the elapsed time between the reception of a wound and its thorough surgical treatment. The evacuation hospitals, or C. C. S.'s (casualty clearing stations), are under more or less constant bombardment, either by large-caliber naval guns or aëroplane bombs (Archies); they have frequently had to be moved about from place to place, and it has been impossible to keep the casualties in the zone of the line of communications until their wounds are healed.

The inevitable result has been that the British base hospitals have had to perform a good percentage of primary operations and a still larger percentage of secondary or completing operations.

Primary closure of wounds, after thorough excision of all devitalized tissues, which is now almost an axiom in the French army, is still in the experimental stage with the British (January, 1918). This apparently radical difference in the zone of the advance should not be laid at the door of conservatism; rather is it due to the time element, the extremely precarious position of the C. C. S.'s and consequent necessity of rapid evacuation of the wounded men to the base.

An advance research hospital has lately been established in one of the C. C. S.'s for the purpose of testing out the possibilities of primary or primo-secondary closure of wounds. The results are very encouraging and will, no doubt, lead to a gradual adoption of the French method. Every effort is made to get the casualties to the C. C. S. while the wound infection is still localized; stretcher-bearers and ambulance drivers are straining every effort toward expediting evacuations, working under surroundings of almost undescribable difficulties.

Topography of the Land.—The salient visited forms part of the plain of Flanders, the few gentle slopes affording no protection from enemy visibility. The rainfall is always very heavy, and the constant presence of surface water makes trench digging impossible. The principal city is a mass of ruins and the few scattered villages in the two sectors visited have entirely ceased to exist.

For miles in every direction, there is hardly a square yard which is not represented by a shell hole, full to the brim of muddy water. The mud, a mixture of clay and sand, is treacherous to the extreme; men have actually disappeared as though swallowed up in quicksand. Roads are either under constant shell fire or have been entirely destroyed as one approaches the front lines, consequently all movements of troops as well as evacuation of wounded take place along the "duck-board" paths laid on posts driven in the mud. Bodies of horses and men lie, unburied in shell holes, polluting water and soil and filling the atmosphere with a stench which seems at times almost unbearable. Trenches being impossible to construct or maintain, on account of the mud and water, the men in the front lines are forced to crouch in shell holes from which the water is baled or pumped out. The only relative protection against shell fragments is afforded by the "pill boxes" which the enemy had constructed when he held that part of the sector. These pill boxes are ferro-concrete mitrailleuse forts, approximately twenty feet square and eight feet high in the interior chamber. The British use them for regimental aid posts or relay stations for stretcher-bearers.

A "duck-board" path is usually three feet wide and from one to three feet above the mud and water. Attempts have been made to build them double or even treble width, in order to evacuate the wounded on two-wheeled stretcher carts, but the experiment has, so far, not been very successful owing to greater exposure to shell fire. In order to avoid enfilading fire they are always built zig-zag, changing direction about every twenty yards. A special evacuation line, four miles long, was built, but owing to the density of troop movements, this path has to be utilized by fighting units as well as non-combatants, so that the congestion is often very great.

A few narrow-gauge railroads extend to within two thousand yards of the front lines, but they are so frequently destroyed by shell fire that the Medical Corps has not seen fit to utilize them for purposes of front-line evacuations.

Viewed from a military, sanitary and surgical point of view, it is impossible to conceive of a more stupenduous task than the one confronting our Allies in this sector. It is unbelievable until one has actually visited it from front lines to zone of communications; it is equally impossible to describe its horrors after one has seen it. One cannot help feeling unbounded admiration for the bulldog tenacity, courage and spirit of self-sacrifice which alone have enabled the British army to "hang on" to this salient for almost four years and to advance their lines in the face of such gigantic, topographic and climatic difficulties.

THE REGIMENTAL AID POST.—Situated about 1000 yards from the interconnected shell holes which form the front line, it occupied one of the aforementioned "pill boxes." The writer is proud to be able to state that the First Lieutenant M. C. in this post was one of the many American medical officers in the temporary service of the British army. He had under his command a sergeant H. C., two orderlies and eight squads of stretcher-bearers. Owing to the meager dimensions of the shelter, which also had to house the entire personnel, no attempt could be made to treat any wounds surgically. Thomas splints, dressings, and bandages were in stock, with sodium bicarbonate for "gassed" cases. No antitetanic serum was given there, but morphin could be and was administered to suitable cases. The aid station was essentially a protection against shell fragments, and a point of departure for the stretcher-bearers. The personnel slept in the most sheltered part of the "pill box" and the cooking was done in a small "lean-to" added onto the side least exposed to shell fire. During a barrage fire which the writer witnessed the rear of one of these kitchens was completely destroyed by a direct hit, while another shell fell immediately in front of the pill-box entrance, fortunately without causing any casualties.

The chief antiseptic used was a 2 per cent. solution of picric acid, wet dressings being applied to all severe wounds. There was no dressing table and no emergency operations such as tracheotomies or clamping of bloodvessels could be performed. Tourniquets had to be used, but were released and readjusted at the aid station and relay posts, if written instructions to that effect were put on the diagnosis tag. Hot drinks were supplied to both wounded and combatants, and shock cases were heated by means of a Beatrice stove enclosed in a makeshift receptacle to which a piece of stove piping was soldered. An iron cradle is placed over the stretcher, blankets thrown over it and tucked around the patient, and the piping carried the hot air to the extempoized chamber, corresponding to the *cellule chauffante* of the French. The simplest hot-air apparatus consisted of a Beatrice stove placed inside of a four-gallon gasoline can with a hinge door on one side and the stove piping riveted or soldered on top. Experiments have proved that within ten to fifteen minutes 140° of heat can be obtained. The same apparatus is also used for drying blankets, rubber boots, etc. Hot-water bags are also used around severely wounded men during their evacuation, empty ones being brought back with the stretcher.

Relay Posts.—Approximately 1000 yards apart, they constitute shelters for three or more squads of stretcher-bearers in charge of a sergeant H. C., with reserve supplies of stretchers, blankets, hot-water bags and dressings. Two or more relay posts are maintained between the regimental aid station and the advanced dressing station 5000 yards behind the front lines.

Water is brought up in four-gallon gasoline cans from the nearest filtered and chlorinated water-supply station. Hot food reaches the relay posts and front lines in gasoline cans placed in gunny sacks and surrounded by a three-inch layer of hay. The food remains hot for six hours. When surrounded by a one-inch layer of cotton-wool, the food in the cans will retain its heat for ten hours.

Advanced Dressing Station.—Approximately 5000 yards behind the firing line, it represented a divisional field ambulance occupying a semipermanent post. The ruins of a chateau had been fairly adequately protected against shell fire by means of corrugated iron roofing and four layers of sand bags. A double sliding door gave good protection against gas attacks. Light was supplied by acetylene lamps and candles. A captain M. C. was in command and a sergeant

H. C. and eight orderlies constituted the personnel. The dressing room, 8 x 12 x 22 feet, contained a dressing table, sterilizing outfit and an ample supply of ordinary surgical instruments, splints, dressings, etc., besides 600 blankets, 100 suits of pyjamas and 60 hot-water bags. Emergency operations could only be performed during periods of relative calm. Antitetanic serum was occasionally given here, but not as a routine procedure. Gassed cases, either caused by phosgene or combined chlorin and phosgene, were treated by inhalations of steam with one ounce of tincture benzoin comp. to a pint of water. The slightly gassed cases walked around the improvised nozzle, taking turns at inhaling the steam. The severely gassed cases, "lying cases," had the same steam passed around from stretcher to stretcher.

From the advanced dressing station a narrow-gauge railway could bring the wounded to the corps main dressing station, if not subjected to barrage fire. Evacuation was by means of two specially fitted up trucks with a carrying capacity of sixteen stretcher and eight sitting cases. The trucks were drawn by a small gasoline engine, the round trip taking an hour. Motor ambulances, although subjected to shell fire, also reached the advanced dressing station, especially at night-time.

Bomb-proof shelters were in the course of construction, but the presence of surface water rendered the task an extremely difficult one. Shelters were as a rule built of corrugated iron sheeting covered over with three or four layers of sand bags. None were proof against a direct hit. Sleeping bunks for staff and personnel were invariably surrounded by a wall of sand bags three feet high in order to obtain protection against shell fragments. In another sector of the same salient a dug-out, 400 yards long, 6 feet wide and 7 feet high, had been constructed 24 feet under ground. Water trickled down both entrance and exit stairways and from the ceiling and sides of the gallery, necessitating the constant use, night and day, of two hand pumps in order to prevent flooding. The stretcher bearers were obliged to live amid these unsanitary surroundings, sleeping on water-soaked stretchers placed on the floor of the gallery. This experiment was not considered a success by the medical corps, but some shelter had to be provided for the men, as there were no available pill-boxes or ruins of houses to act as a nucleus of protection.

Collecting Post for Slightly Wounded and Sick.—Situated 1000 yards behind the advanced dressing station and approximately 6000 yards behind the firing line, it consisted of several corrugated iron huts reinforced by sand bags, in which the sick and slightly wounded could gather for evacuation *via* a narrow-gauge railway. Their wounds were rapidly cleansed, tincture of iodine or picric acid being the antiseptic used. The M. O. in charge divides the cases into those who will be well in a week and those who will require two weeks or a little longer, a certain elasticity being allowed in the latter cases. No diagnosis is made of the men reporting as sick; they are sent to the divisional rest station for observation. Twice daily, the narrow-gauge railway gathers the men in the collecting post and carries them to the divisional or corps resting stations. Should the railway become unavailable, the horse ambulances in reserve are utilized for this particular evacuation.

Corps Main Dressing Station.—Eight thousand yards behind the firing lines, and occupying the spacious cellars of a public building, in the principal city of the salient, it represented the first semipermanent field ambulance where emergency operations could be performed amid proper surroundings. The evacuation of wounded from two sectors converged at this point.

The cellar was bomb-proof, well lighted by electricity and acetylene lamps, possessed space for some fifty stretchers and had a round dressing room large enough for six operating tables and necessary equipment. The wounded, arriving by motor ambulance from the advance dressing station, are examined in the motor itself by a surgeon; the severe cases needing immediate operation, such as intra-abdominal, intra-thoracic or intracranial wounds, are not removed from the ambulance but continue their journey directly to the C. C. S., thus shortening the interval by at least two hours. The patients requiring emergency operations (hemorrhages, threatened edema of the glottis, etc.), are immediately carried down in the operating room and treated; shock cases, if they have not yet received treatment, or have relapsed, are also given a "hot-air" course and 30 grains of sodium bicarb., by mouth, together with hot drinks, highly sweetened, before continuing with their journey. Fractures are examined and splints readjusted if necessary. To recapitulate: severe cases remain in the motor ambulances and go directly to the C. C. S.; all other cases are carried to the corps main dressing station for treatment or to await evacuation by hospital train. At a stated hour every day the hospital train takes these cases to various C. C. S.'s along the line.

Antitetanic serum (500 to 1000 units) is given to all cases in the C. M. D. S., and morphin, gr. $\frac{1}{4}$, in restless cases.

Even in periods of relative calm, no surgical excision of lacerated tissues is attempted; no foreign bodies or pieces of detached bone are removed unless they appear in the wound and are readily removable. There is no *x*-ray equipment present, or contemplated, in the dressing station.

The vast bomb-proof, well-ventilated and well-lighted cellars formed an ideal place for advanced surgery and the writer received the distinct impression that such a possibility was being considered. There were ample means in the surrounding ruins to house a much larger surgical staff and personnel in bomb-proof rooms, and several evacuation routes, roads, narrow- and normal-gauge railroads, afforded ample means for receiving and evacuating the wounded.

Division and Corps Rest Stations.—These correspond to the French *Hôpitaux des Éclopés* and to our own hospitals for the slightly wounded. The practice is to keep all sick and wounded who will presumably be well in a week at the D. R. S. If, in the opinion of the surgeon, a given case will require longer than a week, he is sent to the C. R. S. where he is further studied and accurately diagnosed. In order to keep up the morale of these cases, all sorts of amusements (concerts, movies, games, etc.), are provided.

Once daily a special shuttle train carries the evacuation cases (not cured within the specified time) from the D. R. S. to the C. R. S., or from either of these stations to the C. C. S., if prolonged treatment is deemed necessary. The staff and personnel of these rest stations is obtained from the reserve divisions behind the two converging sectors. As a general practice, all cases requiring over two weeks' hospitalization are sent down to the C. C. S. for treatment.

Trench-foot Prophylaxis Stations.—During the rainy season, and in the absence of massed attacks or "shows," as the British call their advances, trench-foot produces the greatest single percentage of casualties. The whole question has been most minutely studied; no time or expense has been stinted in order to produce results. The present system of prophylaxis and active treatment has given the most satisfaction, but the ideal has not yet been attained. Wherever possible, the men in the shell holes constituting the front line are relieved every forty-eight hours. In a certain unusually exposed sector this has not been found economical, the commanding officer being able to prove that the casualties incident to the relief of troops through barrage fire were greater than those caused by trench-foot. The men in this sector are consequently required to remain at their posts for five-day periods.

Repeated questioning of trench-foot victims brought out the fact that prophylaxis in shell holes could not be observed in many cases. One soldier tersely expressed himself as follows: "If I get my feet out of the mud and water, I slip in and drown; after twelve hours my feet are so swollen that I cannot remove my shoes; how can I have my feet rubbed or change my socks?" Several officers corroborated his statement. Each man in the front line is equipped with a square of tarpaulin or rubber sheeting, on which he sits or crouches; in order to warm his tea, he is supplied with a "Tommy's cooker," a small lamp containing solidified paraffin as fuel, over which he heats his cup or pan, fifty of these stoves being supplied to each battalion. Hot food reaches him at night-time in improvised thermos cans. Before going to the trenches, and immediately upon returning therefrom, each soldier is obliged to take the prophylaxis against trench-foot (see Trench-foot Regulations). The use of rubber boots has proved disappointing on account of the impossibility of drying the interior of the boots. The perspiration soon soaks the socks through and through, and the men complain bitterly of cold feet. Puttees are prohibited in the shell holes because they favor venous stasis; the men wrap "gunny sacks" around their legs, with a piece of loosely applied string to keep them in place.

Trench-foot Regulations of the British Army.—*Prevention.*—In order to minimize the occurrence of trench-foot and frost-bite during winter, instruction in the measures of prevention detailed below will be commenced before cold weather commences.

Commanding officers will be reminded that the loss of effective strength due to the prevalence of this trouble is an indication of faulty discipline and faulty interior economy, and they will, therefore, be held responsible that the instructions laid down are carried out under the strictest supervision by company officers.

Regular foot-rubbing drills will be carried out throughout the army during inclement weather, both in and out of the trenches. Such drills improve the circulation, and should be started long before the men have to go in the trenches.

The following preventive treatment will be carried out, either by divisions (at the main dressing stations), or regimentally in a hut or building set apart for the purpose. The treatment will include the use of:

(*a*) A soap made of:

Soft potash soap	. . . . .	1000 parts
Powdered camphor	. . . .	25 "
Powdered sodium borate	. . .	100 "

and—

(*b*) A powder composed of:

Powdered talc	. . . .	1000 parts
Camphor	. . . .	25 "

A teaspoonful of powder and $\frac{1}{4}$ oz. of soap will be required for each man.

The quantities of the ingredients required per division per week are experimentally:

Potash soap	. . . .	300 pounds
Camphor	. . . .	22 "
Sodium borate	. . . .	35 "
Talc powder	. . . .	500 "

The feet will be washed in hot water with ordinary soap, then in hot water with the soap (*a*). They will next be carefully dried, and the nails will be attended to by the chiropodist. Particular care must be taken to clean out the grooves at the sides of the nails. Finally the feet will be dusted with the powder (*b*), a little of which will also be dusted into the socks. (In each trench-foot prophylaxis there is a central low table with a half-inch of talcum powder spread over the top, over which the men walk barefooted in order to rub the powder thoroughly over the feet. The socks are also turned inside out and thoroughly dusted with the same powder. This method has been found to be most rapid and thorough.) The men are then ready to go in the trenches.

While in the trenches his boots and socks will be taken off at least twice a day. The men will be tolled off in pairs, and each man will be held responsible for the feet of his comrade. He will first dry and then massage the latter's feet from the toes upward. He will then dust some of the powder over the feet, between the toes, and into the socks. This treatment renders the feet antiseptic, gives rise to a very pleasant aromatic smell of camphor, and is very popular with all ranks.

Cure.—The measures detailed above will, if carried out thoroughly, reduce the numbers of cases of trench-foot to a minimum, but they will not abolish them altogether. The application of the preventive treatment will result in a much milder class of cases, and these cases will be cured by the following treatment which will include the use of:

(*a*) The soap prescribed in (*a*) above.
(*b*) Camphorated oil.
(*c*) Camphor and ether solution, namely:

Camphor	30 parts
Ether	1000 "

(*d*) A spray of:

Peroxide of hydrogen	10 volumes
One per cent. solution of sodium borate	10 "

(*e*) Boracic camphorated solution, namely:

Powdered camphor	17 grains
Borax	$\frac{1}{2}$ ounce
Boiled water	1 quart

Wash the feet with soap (*a*) and warm water. Cut and clean the nails, taking particular care with the grooves at the sides of the nails. Wrap the feet in absorbent cotton-wool soaked in solution (*e*). Cover this with gauze soaked in the same solution, being careful to include the toes. Apply jaconnet and loose bandage. Renew the dressings every day until the swelling and edema disappear. This frequently takes place in three or four days. The jaconnet can then be discontinued. Then anoint the feet every day with camphorated oil until the feet are quite cured. Small blisters or bullæ need not be opened. Large ones, however, are freely excised aseptically and treated with solution (*c*).

In the graver forms with extensive sloughing, gangrene and suppuration, each dressing is preceded by spraying with the spray (*d*). It is necessary to remove sloughs as soon as possible, in order to get at the infective agents which multiply under the black patches, but care should be taken not to open up fresh channels of infection by too much surgical interference. Sores should not be made to bleed; only those portions should be removed which can be detached easily with forceps. Diseased portions of bone should be allowed to come away without help from bone forceps.

A dose of antitetanic serum should be invariably given in all cases. Where ulceration exists, the dose is repeated once weekly.

The effect of this treatment is most remarkable in promoting a healthy action in sloughing ulcers, rapid healing and cessation of pain. In fairly severe cases, the swelling quickly subsides and the men are fit for duty in two or three weeks.

The early application of the treatment is most important, and it is a mistake for men not to report sick early.

A continuance of exposure to wet and cold may cause loss of foot or limb.

Keep cases in the C. C. S., if possible, for five or six days, as this is the dangerous period. Evacuated cases should be lying, not sitting. This is most important; placing the feet in a dependent position favors sloughing and retards recovery.

Trench-foot is favored by standing in wet boots and is aggravated by the use of tight boots, tight puttees and the wearing of anything causing constriction of the lower limbs. Action on the following lines, in addition to the preventive treatment given above, will therefore be carefully and systematically carried out:

(*a*) Trenches will be kept as dry as possible.

(*b*) Men in water-logged trenches will be relieved every twenty-four hours, if possible.

(*c*) Rubber boots to be worn in water-logged trenches, or boots two sizes too large and very loosely laced.

(*d*) No puttees should be worn in the trenches.

(*e*) Extra pair of socks for every man in the trenches. (The men are now given three pairs of socks before they go up to the front lines; they should also be provided with an extra pair of boots.)

(*f*) Encourage men in trenches to move about. Do not allow the men to hold their feet near a fire or to dip them in hot water.

(*g*) Warm food, hot drinks, shelter and warmth are to be provided for the men in the trenches.

(*h*) On leaving the trenches after a tour of duty, the men should remove wet boots and socks, thoroughly dry-rub the feet and put on dry socks and dry boots.

TREATMENT OF SCABIES IN THE BRITISH ARMY.—Under conditions of active service, that treatment is best which is most suitable for the majority, most easily carried out, and least expensive (sulphur ointment costs about 1 cent per ounce in England). Any system, to be effective, must fulfil three conditions: Burrows must be opened to permit access of the parasiticide to the insect and ova; the parasiticide should be of such a nature as to destroy the parasite without producing dermatitis; finally, to prevent reinfection, contact clothing and blankets must be disinfected. These three desiderata can be obtained by the following technic:

1. Hot bath with soap and thorough scrubbing with a soft brush.

2. Sulphur ointment (half-strength) twice daily for three days.

3. Steam or sulphur vapor for the clothing and blankets.

The ointment must be thoroughly rubbed over the whole body, below the neck.

Cross-infection must be prevented by supplying each man with a separate portion of ointment.

Impetigo, due to streptococcal infection, is a frequent and obstinate complication.

Corps Delousing Station.—It is well-nigh impossible to live in the zone of the advance without becoming "lousy." The station visited consisted of a stone building with wooden barracks for the men. While the latter are having a hot shower with soap and soft brush, their clothes and leathers are being deloused. Air-tight chambers with sliding doors, each capable of containing three hundred pieces of clothing, hung on racks, are heated up to 214° for ten minutes, followed by dry heat for ten minutes, in order to dry the clothing. The leathers are treated in a separate chamber. The steam is first turned on until the thermometer registers 200°; it is then turned off until the temperature drops down to 190°, when the sliding door is opened and the leathers, strung on racks, are put in. The door is closed and hot dry air is turned in for half an hour. This method has been found not to injure leather. Both clothes and leathers are thoroughly dry after they have been given a shaking in the air, and they are immediately returned to the men in the bathing huts who have been given numbered metal disks which correspond to those tied onto their clothing and leathers. The system is rapid, thorough and has given perfect satisfaction. Before they take their bath, the men are regularly inspected by a junior M. O. for skin diseases, etc.

British Hospital Train.—In the sectors visited the hospital train was used for the purpose of evacuating all severely wounded cases from the C. M. D. S. to the C. C. S., except those urgent cases which were carried directly by motor ambulance without any stops. The train, a standard model, had two M. O.'s and a personnel of three nurses, twelve orderlies H. C. and six cooks. Hot food was provided on board and the dressing room was equipped for emergencies such as secondary hemorrhages, etc.

THE BRITISH EVACUATION HOSPITALS OR C. C. S.'s.—Owing to the exposed nature of the terrain and the constant harassing warfare carried out in the British sectors, the C. C. S.'s have been subjected to repeated bombardment by long-distance guns or avion bombs. Several of them have been destroyed; others severely damaged. The result has been to place them much farther behind the lines than the corresponding French formations. This fact must be borne in mind while attempting to draw any comparisons. Again, largely owing to their precarious positions, the majority of them are still housed in tents or marquees, instead of wooden barracks. The experience of the British army has been that a tent, which has been in place for four months, cannot be taken down and moved without tearing to pieces. It is estimated that only about 10 per cent. of a tent can be salvaged upon moving camp. They are looked upon as expensive in the long run, cold, easy to catch on fire and very liable to blow down during a hurricane. Semicircular corrugated iron barracks, containing forty-four beds are now rapidly replacing the tents. Wooden or corrugated barracks are used for operating rooms.

Each C. C. S. is based on a capacity of three hundred beds, but the majority have expanded to one thousand beds. It is freely admitted that during a "show," primary suturing is never attempted on account of insufficiency of operating teams and lack of beds. The wounds are surgically excised and the wounded sent down to the base by hospital train twenty-four to forty-eight hours later, if transportable. The patients who have to remain longer become very nervous and apprehensive on account of the constant noise of British and enemy aëroplanes and the occasional bombing at night.

The research C. C. S. has been conducting a series of experiments in order to determine the value of primary closure of wounds and the relative value of various solutions. The presence of hemolytic streptococci in culture is regarded as a contra-indication to primary suture, yet the tendency is to rely more and more on the general clinical aspect of the wound and patient, and less on the laboratory report. While not yet ready to render a final report on the various solutions employed, the results so far tend to prove that the *sine qua non* of success lies, not in the antiseptic or stimulant used but in the radical excision of devitalized tissues.

Joint injuries are being closed primarily, after removal of foreign bodies, including projectiles, and lavage with normal saline. Methylated spirit is used for cleansing and irrigating wounds because it is cheaper than ether. Drainage in joint cases is restricted to those cases presenting extensive comminution of bone, particularly of the head of the tibia.

B. I. P. (bismuth, iodoform, liquid paraffin) of Rutherford Morrison is used once in extensive wounds. If the paste is repeatedly applied, the granulations become weak and show a tendency to break down. The present plan of treatment is to apply B. I. P. once and then use methylated spirit for subsequent dressings. Brilliant green had not yet been tested out.

CHAPTER V.

PROJECTILES.

General Considerations.—The striking fact, in considering the etiology of wounds in the present war, is that 80 per cent. of all injuries are caused by the explosion of shrapnel shells, high-explosive shells, hand or rifle grenades, bombs and mines. Approximately 18 per cent. of all wounds are caused by rifle or machine-gun bullets, and less than 1 per cent. occur as the result of bayonet charges in which the butt of the rifle is as frequently used as the cold steel.

During the Russo-Japanese war, artillery came to be considered as largely of moral value, only 10 to 15 per cent. of all wounds being caused by them. These facts confirm the dictum that "the present war is an artillery war."

Types of Projectiles:

1. *From Hand Weapons:*
   - Rifles.
   - Revolvers.
   - Machine guns.
2. *From Artillery:*
   - High-explosive shells.
   - Shrapnel.
3. *From Grenades*—(*a*) *hand*, (*b*) *rifle:*
   - Bombs, Mines.

1. *Hand Weapons.*—The German bullet has the greatest initial velocity (940 yards the first second after leaving the rifle); the U. S. Army bullet has an initial velocity of 900 yards, the French 767, the Austrian 684, the Russian 703, and the English 813 yards.

The heavier the bullet the longer it will retain its initial velocity. The French bullet, weighing 197 grains, is more dangerous at greater distances than is the German, which only weighs 154 grains.

When speaking of the effects of bullets it is well to remember the range; the greater the striking force, the more extensive are the lesions:

Very short distances, up to 109 yards.
Short distances up to 547 yards.
Middle distances, 547 to 875 yards.
Long distances, 547 to 1093 yards.

Zones of Action of Bullets:

1. Explosive zone, to 547 yards.
2. Perforating zone, 547 to 2188 yards.
3. Contusion zone, beyond 2188 yards.

Ricochets and Deformed Bullets.—When a bullet enters the tissues it may either enter in the same shape as when it left the rifle, or, owing to a ricochet (*i. e.*, its having first struck some hard surface and then continued in its trajectory), it may become deformed before striking.

In other instances, due to faulty construction and other causes, the component parts of the bullet may separate, the jacket remaining in the wound while the core passes through; or the jacket may pass through and the lead core break up into fragments or even fine lead dust. The German bullet, having its base uncovered by the copper shell is frequently wilfully reversed by the soldiers, so that it enters the body base first.

About 33 per cent. of bullet wounds are caused by ricochet or deformed bullets. Wounds caused by ricochet and deformed bullets are less deep but always lacerated and hence more serious as a rule than those made by a direct hit.

Revolver bullets are only effective within ranges of 75 to 100 yards.

2. *Artillery Projectiles.*—(*a*) *High-explosive Shells.*—These are cylinders of iron and steel with a conical head. The

projectile has thick walls and the hollow core is filled with an explosive charge (tri-nitro-toluene, etc.), which is exploded by means of a time fuse or percussion cap. The casing is ruptured and fragmented, and each individual fragment becomes in itself a projectile capable of inflicting serious and lacerated wounds, owing to the shape of the individual pieces.

The German high-explosive shells vary in weight from a few pounds to a ton, and they consist of a thick iron case containing in a central cavity a violent explosive charge of tri-nitro-toluene, of which as much as 200 pounds may be present. Such shells usually burst on percussion by a detonator which acts by impact. The fragments vary all the way from 150 pounds to a few grains.

A soldier may be completely destroyed, may have an entire limb torn off or crushed to pulp, may receive one or several deeply lacerated wounds, or may be superficially "peppered" by minute fragments.

The mere explosion of a shell generates great power of destruction, the expansion of the gases alone being sufficient to kill.

(*b*) *Shrapnel.*—These shells consist of a cylinder of steel which contains a varying number of round lead bullets approximately 0.5 inch in diameter. The bursting charge is in the base, and is exploded by means of a time fuse in the head. Shrapnel has approximately an initial velocity of 1700 F. S. At the time of bursting, the lead balls are driven out in the form of a cone at an additional velocity of 300 F. S. The case itself does not undergo much fragmentation, but each individual bullet, as well as the time fuse and the casing, becomes a separate projectile.

In the present war of trenches, shrapnel has been found to produce little or no effect on earth or sand-bag protections, and has been largely superseded by the high-explosive shell. Used against massed troops fighting in the open, shrapnel is very effective.

(*c*) *Grenades, Bombs, Mines.*—Grenades consist essentially of corrugated iron or other metal, containing a relatively large charge of high explosive. The corrugations aid in fragmentation of the case; the thickness of the latter varying considerably. The thick shells usually only contain the explosive; the thin shells being filled with explosive plus irregular jagged pieces of metal, metal shavings, iron boot-nails, etc.

When a grenade bursts, the case is broken up into numerous fragments of every size, varying from a pin's head to an irregular or quadrilateral piece weighing as much as an ounce.

All forms of grenades and bombs also scatter stones, earth or sand from the parapets, and these become projectiles, and are specially liable to injure the face, neck and shoulders of men standing in the trenches.

Hand grenades are of various shapes, such as "bottle," "hair-brush," and "ball." The latter is now the standard. Rifle grenades differ only from the hand form in that they have a long rod extending from the head of the grenade and fitting the barrel of the rifle. At the lower end is a small loose cap of copper, which revolves on the rod and fits the rifling of the barrel, acting as a gas check. These grenades are projected by means of a small charge of powder in the rifle. They have this advantage over the hand grenade, that the soldier does not have to expose any part of his body in order to fire them, as is the case with the hand grenade.

Bombs.—These are larger grenades propelled from trench mortars. The "aërial torpedo" is a bomb with wings and a tail attached to it in order to steady its flight.

Mines.—These (in land warfare) consist of charges of high explosives buried in the ground and exploded by means of an electric spark. The earth, sand, rocks, wood, metal, etc., thrown up by the explosion form the projectiles. Severe burns are also inflicted in many cases.

CHAPTER VI.

BACTERIOLOGY OF WAR WOUNDS.

THE bacteriology of wounds in war is essentially that of the terrain on which the fighting is waged. With practically every wound an infected one it is perhaps not amiss to state that every injury receives, in addition, a dose of the resident germs of the battlefield. The degree and amount of infection will vary with the wound, large lacerated wounds presenting a greater surface and a more favorable medium for the subsequent growth of pathogenic germs. The extent to which clothes and skin have been soiled by the earth, the amount of earth which may have been carried into the wound and the subsequent additional soiling which the wound may receive before it receives its first dressing also have an important bearing on the subject.

Bacteria of the gas-gangrene type require a certain amount of devitalized tissue on which to flourish before making their presence felt.

From a stand-point of war surgery, wounds are complicated by infections from either of the following groups of bacteria:

1. AËROBIC BACTERIA. (Requiring or Indifferent to Oxygen.)—

(*a*) Streptococcus (white gangrene).
(*b*) Staphylococci (simple cellulitis).
(*c*) B. pyocyaneus.
(*d*) Colon group.

2. ANAËROBIC BACTERIA. (Cannot Grow in Presence of Free Oxygen.)—

(*a*) Tetanus.

(*b*) B. of malignant edema (vibrion septique).

(*c*) Gas-gangrene series (B. aërogenes capsulatus, also called B. perfringens).

GAS-GANGRENE SERIES.—*Important Points to Remember.*—

1. Flourish freely on dead or devitalized tissue (especially muscle).

2. Require a neutral or alkaline medium and become rapidly inert if this medium is changed to acid.

3. Deep-hidden pockets deprived of oxygen are their favorable habitat.

4. Tend to pass through a sporulation stage, their spores being exceedingly resistent to most antiseptics and to sterilization by heat. Instruments, dressings, etc., should be placed in the autoclave or boiled for one hour after coming in contact with this type of infection.

5. Their toxins are elaborated locally and only enter the general circulation shortly before the death of the patient.

6. If recognized early, toxin production can be stopped by efficient local treatment.

7. The presence of a mixed infection favors the development of anaërobes.

The Interallied Surgical Conference (1917) adopted the following conclusions regarding the bacteriology of war wounds:

1. Every important surgical formation should include an experienced bacteriologist, with proper assistants and necessary equipment.

2. The proper treatment of war wounds necessitates a close collaboration between the surgeon and bacteriologist. The latter should come in personal contact with the wounded men, and should study and discuss with the former regarding the necessary examinations to be made and the line of action which ought to be followed.

3. The routine examinations should be bacteriological, cytological and humoral.

4. The nature of these examinations should not be maintained within narrow limits, but, in general, the principal problems to be investigated are the following:

(*a*) The immediate bacteriology of wounds.

(*b*) The bacteriology of wounds before and after surgical treatment and before and after a long journey of evacuation.

(*c*) The bacteriology of wounds which are persistently suppurating or associated with complications.

(*d*) The bacteriological control (microbic curve), followed by sterilization of the wound, in view of its suturing.

(*e*) The biological and bacteriological control of wounds in order to estimate the degree of efficiency of different methods of treatment.

(*f*) Blood examinations (hemoculture, red and white count, coagulability, defensive properties; possible indications for blood transfusion).

(*g*) Special infections of certain regions (joints, serosæ, connective tissues, muscles, brain tissue, cerebrospinal fluid, etc.); this work should include bacteriological, cytological and humoral investigations.

(*h*) General indications for and application of vaccine therapy.

5. In addition to these practical laboratories, used for the daily routine problems of surgery, it is advisable to have either special laboratories of scientific research for the study of general questions pertaining to war surgery or to adapt the preëxisting ones more fully to this particular field.

CHAPTER VII.

TRAUMATIC SHOCK.

General Considerations.—Traumatic shock is a disturbance of functional equilibrium, characterized clinically by reactions of depression which may be severe enough to prove fatal. Its two essential manifestations are subnormal temperature and arterial hypotension.

It is often associated with severe hemorrhages or precocious toxemias, which make an exact appreciation of the relative importance of each etiological factor extremely difficult and sometimes impossible.

Its exact etiology is obscure and its pathogenesis is still being diligently studied. Five principal theories have been propounded in order to explain the clinical phenomena and institute a rational therapeusis:

1. Physical and physiological theory of Crile.

2. Chemical theory of Henderson, according to which arterial hypotension is due to a deficiency of carbonic acid in the blood.

3. Organic theory: insufficiency of adrenalin in the blood.

4. Antecedent theory: variations of shock due to some antecedent pathological disturbance.

5. Vasomotor paralysis theory.

6. Theory of Porter that fat embolism is the causative agency.

Clinically, the factors producing the symptom-complex of shock may be divided into exciting and contributing or accentuating causes.

(*a*) *Exciting Causes.*—

True nervous shock.

Hemorrhage.

Trauma.

Precocious septicemia.

(*b*) *Contributing and Accentuating Factors.*—

Pain.

Cold, hunger, thirst, fatigue.

Injury to important viscera.

Multiplicity of injuries.

Psychic influences (anxiety, fear, etc.).

Additional traumatism caused by prolonged transportation by:

(1) Man carriage.
(2) Stretcher.
(3) Two-wheeled cart.
(4) Ambulance.

(*c*) *Symptomatology.*—

(1) Cold sweat, cold extremities, clammy skin.
(2) Subnormal temperature.
(3) Low-tension pulse of variable rapidity. A persistent diastolic arterial hypotension of less than 60 mm., independent of hemorrhage or toxemia, is an index of the gravity of the shock and the principal indication for its treatment. The effect of the treatment can only be correctly estimated by repeated applications of the sphygmomanometer.
(4) Partial or complete muscle flaccidity.
(5) Dilated pupils.
(6) Lessened or total loss of sensibility.
(7) Shallow, irregular respiration.

(*d*) *Treatment.*—(*a*) *In the Regimental Aid Post or Field Ambulance.*—

1. Empirically the injection of 10 c.c. of camphorated oil,

repeated every two hours, has given fairly satisfactory results. This may often be the only therapeutic measure at the disposal of the regimental surgeon.

2. The hot-air bath or *cellule chauffante.* If the post or ambulance has its own electric installation the patient is placed on the table, or the stretcher is put on racks or suspended by means of hooks or ropes. An iron or wooden cradle, to which four or six electric bulbs are attached, is placed over the center of the patient's body and three or four blankets are thrown over the cradle and carefully tucked around the wounded man. A temperature of 104° to 106° is thus quickly obtained and should be maintained until a clinical reaction is manifest. If a sphygmomanometer forms part of the equipment it should be used to accurately control the effect of the treatment. In the absence of electricity, dry heat may be obtained by means of a Beatrice lamp, alcohol lamp or solidified paraffin lamp, enclosed in an empty gasoline can or wooden box to which a piece of stove pipe or wooden funnel is attached, the nozzle of which is placed between the cradle and patient.

3. The patient's head should be lowered unless there is a wound of the cranial contents or of the thorax.

4. Acidosis is treated by giving 30 grains of sodium bicarbonate by mouth if the patient can swallow liquids. The English believe that carbohydrates are very stimulating in shock cases and therefore give very highly sweetened tea, etc. Cannon has recently recommended intravenous administration of 4 per cent. sodium bicarbonate solution.

5. When the patient has sufficiently reacted to make evacuation safe, hot-water bags are placed around him and an extra blanket or two should be wrapped around him before he is taken up by the stretcher-bearers.

6. Minimizing of traumatism is very important; all fractures and extensive lacerations should be immobilized before the wounded man is evacuated from the post or ambulance.

7. The ambulance should be heated. The simplest method is by lengthening the exhaust pipes of the motor and having them pass through the interior of the ambulance, just beneath the two lower stretchers, in which the shock cases should be placed. The exhaust tubes should end by passing laterally out of the car above the rear wheels. Electric bulbs have also been connected to the magneto, thus continuing the electric hot-air bath during the entire journey.

8. The wound or wounds should be treated as thoroughly as the terrain, equipment and time element will permit. A patient whose wound has been made tolerable will be less liable to have a relapse of shock syndrome during his evacuation. In the primary treatment of the wound should be included the checking of any visible hemorrhage.

9. If as he comes out of shock the patient begins to complain of severe pain and is restless $\frac{1}{4}$ grain of morphin should be given hypodermically.

(*b*) *In the Evacuation Hospital.*—The position of the patient, the warming up of his body and the restoring of his blood-pressure constitute the three essential factors in the treatment.

1. The patient should be placed in the horizontal or slight Trendelenburg position. In wounds of the brain or chest this position is contra-indicated. Bandaging of the extremities, if properly done, is useful; proximal constriction, as from improper bandaging, is worse than useless. The proper method is to first elevate the limb in order to restore its blood to the central circulation and then, with the limb still elevated to apply a roller bandage from the toes toward the trunk so that the blood is kept out of the limb.

2. By means of the electric bath the temperature of the surface of the body should be maintained at a uniform degree, preferably about 104°. The warming up of the patient is a most important part of the treatment.

3. Absolute rest is imperative. Any useless movement

and anything causing pain or excitement should be spared the patient.

4. Enteroclysis (Murphy drop method), using an isotonic solution with 1 per cent. alcohol added, is to be recommended.

5. Attempts must be made to restore arterial pressure by means of intravenous saline injections. The British have used 10 per cent. glucose and 7 per cent. gum arabic solutions for these injections. From 1 to 2 pints are injected at a time. Dépage, of the Belgian army, gives a first injection of one liter of Locke's solution: NaCl, 0.9; KCL, 0.042; $CaCl_2$, 0.024; $NaHCO_3$, 0.02; glucose, 0.01; water, 100 gm.

If this is not successful a second injection is given, consisting of: NaCl, 0.8; $CaCl_2$, 0.1; water, 100 gm.

Not more than a half-liter of this second solution should be used. Should blood-pressure not remain up after the second injection a third one is given, consisting of 0.5 c.c. of a 1 to 1000 solution of adrenalin chloride in 50 c.c. of Locke's solution.

In general, fractional injections of 250 c.c. or less are more useful in true shock without severe loss of blood. The action of injections on arterial tension is more lasting when given at the end of the operation. Subsequent injections should be governed by the blood-pressure curve, which should be taken every half-hour. A new injection should be given every time the pressure drops.

6. Whether shock should be considered an indication or contra-indication to operation, depends on the severity of the shock and the type of operation contemplated.

If hemorrhage can be ruled out and the patient is cold and pulseless, shock should be treated first. This also holds true when the operation is a long or complex one, such as a laparotomy. An extensive laceration of a limb, necessitating amputation, constitutes an indication for immediate operation.

7. Novocain for local and nitrous-oxide-oxygen for general

anesthesia are the methods of choice. Ether is also very safe. Intraspinal anesthesia has given variable results.

8. Operations in the presence of shock demand a rapid simple technic, with perfect hemostasis.

CONCLUSIONS.—In spite of the enormous clinical and experimental work which has been performed during this war the treatment of shock is still a baffling one. The present lines of therapeusis used are, in general, but practical adaptations of methods long in use by civilian surgeons. The treatment is still almost empirical; certainly not more than symptomatic.

CHAPTER VIII.

HEMORRHAGE

Primary Hemorrhage.—Injuries involving the main trunks in the neck, thorax or abdomen and those of the main vessels of the liver, spleen or kidneys are usually fatal before surgical help can be given.

Hemorrhage from any of the larger peripheral arteries may be profuse enough to endanger life and in exceptional cases may necessitate the temporary use of a tourniquet.

Treatment of Hemorrhage.—(*a*) *On the Battlefield.*—
1. Pack gauze in wound and bandage limb. This is a procedure fraught with considerable danger. If done at all, the fact should be noted on the diagnosis tag, giving the date and hour at which it was done.

2. Immobilize wounded part.

3. Should a tourniquet be used under conditions of great urgency, it should be loosened for a few minutes at least every hour, and not reapplied unless the hemorrhage returns. Under no conditions should a wounded man be left with a tourniquet on unless he can be attended to regularly.

(*b*) *At the Regimental Aid Station.*—1. *Local Treatment.*—Whenever possible, find the bleeding-point and ligate the vessel *in situ* above and below its wounded part. If the primary search is unsuccessful and subsequent attempts necessitate serious enlargement of the wound, it is often more desirable to deliberately seek and ligate the artery beyond the wound margin, under conditions of strict surgical asepsis.

Prolonged forcipressure, *i. e.*, clamping on artery forceps either on the vessel or, frequently, on a mass of lacerated tissue from which the blood is issuing, will sometimes succeed.

Plugging with gauze, but *only as a very temporary measure.*

2. *General Treatment.*—Maintain body heat (blankets, hot-water bottles, etc.).

Restore blood-pressure by—

(*a*) Lowering patient's head.

(*b*) Proctoclysis (tap water or one-half strength saline).

(*c*) Intravenous saline, 500 to 1000 c.c.; may be repeated within a few hours if blood-pressure has not reached a safe limit. Ten per cent. glucose may be added.

Transfusion.—The citrate method is simplest. The dosage will vary from 500 to 1000 c.c., depending on blood-pressure. Time and equipment will be lacking for the preliminary anaphylactic and Wassermann tests but few accidents are reported and the results have been good.

LIGATION OF ARTERIES.—*Temporal Artery.*—Crosses over the zygomatic arch just in front of the pinna of the ear. To expose it, make a vertical incision immediately in front of the antitragus. The artery lies in dense cellular tissue with the vein posterior. An arteriovenous aneurysm may be produced at this point by a wound.

Facial Artery.—Crosses the jaw immediately in front of the anterior border of the masseter muscle. Make incision along the lower edge of the jaw, separate fibers of platysma and divide the layer of fascia which attaches the artery to the bone. The facial vein lies *on* the masseter muscle, nearer the angle of the jaw. Always apply a double ligature as the arterial anastomosis is very free.

Branches of External Carotid.—Hemorrhage from the main trunks is usually fatal before any operative measures can be adopted. Hemorrhage from any of the larger branches of the external carotid may necessitate ligature of the external or common carotid artery. In an emergency it is quicker and easier to tie the common carotid than to expose the external carotid.

Method of Exposure of Carotid Sheath.—Incision along the anterior border of the sternomastoid muscle, the center of incision being opposite the cricoid cartilage. Divide the platysma upward until the edge of the omohyoid is exposed. The carotid sheath is immediately beneath it, the vein to the outer side and the vagus nerve behind. Open the sheath on its inner side and pass the aneurysm needle from the outer to the inner side.

Frequently, however, once the main artery has been found, an incision carried upward will quickly expose the bleeding-point and thus avoid ligature of the main trunk.

Remember that ligature of the common carotid is frequently followed by a transitory hemiplegia.

Subclavian Artery.—Wounds at the root of the neck may lead to secondary hemorrhage from the subclavian itself or more frequently from the vertebral, or from branches of the inferior thyroid artery.

Expose the third part of the subclavian by an incision carried along the upper border of the clavicle for at least three inches, commencing at the outer margin of the sternomastoid muscle. Incise the deep fascia until the posterior belly of the omohyoid is visible. The artery lies below it.

Pass the aneurysm needle from above downward, hugging the artery, in order to avoid the middle cord of the brachial plexus.

Axillary Artery.—May have to be tied in the first or third part of its course.

(*a*) First Part.—Raise arm to put the pectoralis major on the stretch. Make an incision along the lower border of the clavicle three inches long and terminating at the junction of the pectoralis major and inner border of the deltoid muscle. Identify and avoid injuring the cephalic vein at this point.

Divide the platysma and pectoralis major muscles close to the lower border of the clavicle. Retraction of the cut muscle fibers will bring the costocoracoid membrane into view. Divide it, pull down the upper edge of the pectoralis minor and the axillary vessels will be exposed. The vein lies to the thoracic side of the artery, with the brachial plexus on the outer side of the artery.

(*b*) Third Part.—Raise arm and rotate it outwardly. Make an incision along the inner border of the coraco-brachialis muscle and divide the fascia. The artery lies to the outer side of the vein.

Brachial Artery.—Incise along inner border of biceps, but avoid opening the muscle sheath. Remember not to injure the median or ulnar nerves.

Radial Artery.—Incise down to and open the outermost intermuscular space in the front of the forearm.

Ulnar Artery.—Incise along the radial (outer) side of the tendon of the flexor carpi ulnaris. Pass the aneurysm needle from the ulnar toward the radial side in order to avoid the nerve.

Superior Gluteal Artery.—Turn patient on his face. Make a vertical five-inch-long incision in the buttock midway between the superior spine of the ilium and the great trochanter. Separate the fibers of the gluteus maximus, and divide the gluteus medius in order to expose the artery.

External Iliac Artery.—Make an incision three inches long and one-half inch above and parallel to Poupart's ligament. Split the inguinal canal open. Pick up the transversalis fascia at the inner angle of the wound and divide it. Push the peritoneum out of the way and expose artery. The vein lies to its inner side, therefore the aneurysm needle should be passed from the inner toward the outer side of the vessel.

The Femoral Artery.—(*a*) In Scarpa's Triangle.—The "line of the artery" is from the center of Poupart's ligament to the back of the inner condyle of the femur.

Make an incision one inch below Poupart's ligament, draw the sartorius muscle to the outer side and expose the sheath of the femoral vessel. The vein lies to the inner side of the artery. Pass the aneurysm needle from the mesial to the external side.

(*b*) In Hunter's Canal.—Incise along the "line of the artery," the lower end of the incision being three inches above the inner condyle of the femur. Divide the fascia and expose the sartorius, whose fibers run downward and medially. Retract this muscle medially and expose the roof of the canal. Incise fascia, expose the artery and pass the aneurysm needle from within outward.

Popliteal Artery.—(*a*) Upper Part.—Make an incision from the posterior part of the inner condyle of femur upward along the hamstring tendons.

Retract the tendons (including that of the sartorius) toward the popliteal space.

Pass the aneurysm needle mesially in order to avoid the vein.

(*b*) Popliteal Space.—Turn patient on his face. Start at inner condyle of femur and incise skin obliquely from within outward for four inches.

Avoid or double ligate the external saphenous vein.

Divide the deep fascia and draw the internal popliteal nerve to the outer side.

The vein and artery are intimately attached and must be separated with great care. Pass the aneurysm needle from without inward.

Anterior Tibial Artery.—Lies under the tibialis anticus muscle and close to the outer border of the tibia.

The skin incision should be made in the lower third of the leg, along the outer border of the tibia.

Divide the deep fascia between the tibialis anticus and the extensor proprius hallucis.

The anterior tibial nerve lies external to the artery.

Posterior Tibial Artery.—Make an incision five inches long, beginning one-half inch behind the inner border of the tibia.

Retract the internal saphenous vein inwardly and the inner edge of the gastrocnemius outwardly.

Cut the tibial attachment of the soleus and retract its cut fibers outwardly. Divide the deep fascia of the leg and expose the artery.

Pass the aneurysm needle from without mesially in order to avoid the posterior tibial nerve.

Peroneal Artery.—Make an incision along the back of the fibula in the middle of the leg.

Cut the fibular attachment of the soleus.

Cut through the deep fascia and expose the vessel.

SECONDARY HEMORRHAGE.—This serious, often fatal, complication has been of frequent occurrence.

Etiology.—The basic cause is sepsis producing necrosis of the vessel wall, even in the absence of previous traumatism of same. It is especially apt to occur in deeply lacerated wounds which have not been freely opened and which contain masses of devitalized tissues, foreign bodies and bone fragments.

As contributory causes, tight packing of gauze or injudicious placing of tubal drainage must be mentioned.

Certain vessels are believed to be anatomically predisposed to hemorrhage, either primary or secondary, depending upon the degree of fixation of the vessel and the firmness of the bed upon which it lies, *i. e.:*

(*a*) Circumflex branches of axillary artery.

(*b*) Subscapular or posterior scapular artery, in proximity to the scapula.

(*c*) Gluteal artery.

(*d*) Circumflex branch of profunda femoris.

(*e*) Femoral artery in the lower third of Hunter's canal.

(*f*) Articular branches of popliteal artery.

(*g*) Anterior tibial artery as it lies on the interosseous membrane.

(*h*) Posterior tibial artery.

TECHNIC OF THE CITRATE METHOD OF BLOOD TRANSFUSION.—*Apparatus Required* (*All Thoroughly Sterilized*).—

(*a*) Flask of the salvarsan type.

(*b*) Rubber tubing.
(*c*) Two cannulæ (gauze No. 11).
(*d*) Tourniquet.
(*e*) Graduated glass jar (500 to 1000 c.c.).
(*f*) Glass rod.
(*g*) 25 to 50 c.c. of a sterile 2 per cent. sodium citrate solution.

Technic.—(*a*) Place donor on operating table, apply the tourniquet lightly around the arm; prepare the operative field surgically.

(*b*) Puncture either the median basilic or median cephalic vein with a cannula and receive the blood in the glass jar containing 25 to 50 c.c. of the citrate solution. If 500 c.c. of blood is to be given it is preferable to mix 25 c.c. of the citrate solution with 250 c.c. of blood, then add 25 c.c. more of citrate and allow 250 c.c. more of blood to flow in.

(*c*) While the blood is running into the glass jar it is thoroughly stirred by means of the glass rod.

(*d*) Prepare recipient's arm in the same manner, either puncturing the vein or exposing it by a small incision. Introduce the cannula and remove the tourniquet.

(*e*) Pour a few cubic centimeters of sterile saline solution into the salvarsan flask and fill the rubber tubing in order to expel all air. Connect the tubing with the cannula, pour the blood into the flask and allow it to flow in.

In order to prevent sudden overloading of the circulation (especially when 1000 c.c. are to be given) it is advisable to stop the flow of blood from time to time by compressing the rubber tubing with the fingers.

(*f*) As the last few cubic centimeters of blood leave the flask, remove the cannula in order to avoid the danger of air embolism.

(*g*) It is rarely necessary to ligate the vein. A sterile compress of gauze and a roller bandage complete the procedure.

It is immaterial what sized cannula is used for the injection of the blood, but in taking the donor's blood a large No. 11 cannula must be used, otherwise the blood will clot before it can be thoroughly combined with the citrate solution.

The preliminary tests (Wassermann, agglutination, hemolysis) will have to be dispensed with, but very few accidents have been reported. It is advisable, however, to study the donor's record for previous diagnosis of syphilis.

Direct Transfusion by the Percy Method.—*Apparatus Required.—Modified Brown Tube.*—The tube consists of a glass cylinder, 4 cm. in diameter, with a cannula leading from one end, the other end being drawn out into a tube, 1 cm. in diameter, to which a Y-connection is made. To one arm of the Y a rubber tube is attached for suction to aid in filling the tube and to the other arm a rubber bulb is connected to aid in injecting the blood. The cannula part of the tube is so constructed that it can be inserted directly first into the vein of the donor and then of the recipient.

An open dissection of the vein of both donor and recipient is made for two reasons: (1) if the operation were done subcutaneously it would be necessary to use a needle with a rubber connection to the cannula, which connection would make a roughened area which would favor clotting, whereas with the smooth, paraffin-coated cannula there is no such tendency; (2) after the tube is filled with blood the cannula can be inserted into the vein of the recipient without delay, an essential feature after blood has been withdrawn.

The tube should be cleansed by washing with water, alcohol, and then with ether, and, after it is perfectly dry, 2 ounces of melted grocer's paraffin is poured into the tube through the upper end. It is then wrapped in a towel and placed in a steam autoclave for fifteen minutes under fifteen pounds of pressure, after which, with sterile rubber gloves over the hands, the tube is rolled around while cooling, so that every part of the inside is covered with melted paraffin and any excess allowed to run out of the large end. Care should be taken not to allow the cannula to become plugged with paraffin. If it does the tip is warmed over a flame and the paraffin allowed to run back into the tube.

Sterilizing the rubber tubing, glass Y and mouth-piece is done by placing them in a towel and autoclaving in the same way and at the same time as the transfusion tube or boiling them for twenty minutes.

The atomizer bulb is thoroughly washed with alcohol to sterilize it. When ready to use the connections are all made and 2 ounces of sterile liquid paraffin aspirated into the tube through the cannula by means of suction at the mouth-piece.

Technic.—The arms of both the donor and the recipient are prepared as for surgical operation. Proper constriction of the donor's arm is essential if one wishes to draw off a large quantity of venous blood rapidly.

An ordinary blood-pressure apparatus placed about the arm and pumped up to 60 to 80 mm. of mercury makes an excellent constrictor.

It is imperative to use a separate set of instruments on different tables for donor and patient in order not to transmit infections.

(*a*) Under local anesthesia make an incision over the cephalic vein of both the donor and recipient.

(*b*) Place a proximal ligature around the donor's vein and a distal ligature around the recipient's vein.

(*c*) Place Carrel clamps on that portion of the vein away from the ligature, and make a longitudinal incision 3 mm. long midway between clamps and ligatures.

(*d*) Hold the vein incisions open by means of small clamps.

(*e*) Place the cannula, pointing distally into the vein of the donor, and release the Carrel clamp.

(*f*) By means of suction at the mouth-piece, venous blood is drawn into the tube up to the required amount. The blood is well protected from the sides of the glass by the paraffin coat and from the air by the liquid paraffin which floats over and completely covers the blood. As soon as the tube is filled (about three and one-half minutes for 600 c.c.), the aspirating tube is clamped, the cannula removed from the vein and the small clamp reapplied to the donor's vein.

(*g*) Place the cannula in the recipient's vein and release the Carrel clamp. Velocity of flow of blood is controlled by careful pumping of the rubber bulb. Not more than five minutes should be spent in obtaining the blood, nor more than five minutes in injecting it.

(*h*) From 500 to 1000 c.c. may be transferred in cases of severe hemorrhage.

(*i*) Ligate veins of donor and recipient and apply dry sterile dressings to the wounds. While the Percy method is a very excellent one the technic and apparatus necessary make it of doubtful value in the zone of the advance.

CHAPTER IX.

WOUNDS OF THE SOFT TISSUES.

CLASSIFICATION.—(*a*) Perforating or seton wounds (in and out wounds).

(*b*) Non-perforating or penetrating wounds (wound of entrance only).

(*c*) Lacerated and contused wounds.

(*d*) Gutter wounds.

(*e*) Incised wounds (sword, bayonet (sideswipe)).

PERFORATING WOUNDS.—Perforating wounds are caused by rifle or shrapnel bullets and shell, grenade or bomb fragments, etc.

A perforating bullet wound, if the bullet has struck point on, will present a small round wound of entrance, the edges of which are inverted and slightly congested, whereas the wound of exit, which may be of practically the same size, will show edges slightly everted.

If, however, a slight deflection of the bullet has occurred or the bullet has been reversed, the wound of entrance will be larger, more ragged and more inverted, and there will be a correspondingly greater contusion of the surrounding tissues. The wound of exit is large, ragged and lacerated, exposing to view torn muscles, tendons and fascia. The loss of superficial tissues is usually great.

"Pirogoff's pouch" is a small cavity between the skin and aponeurotic fascia filled with blood-clot. It is found near the wound of exit and is caused by the bullet pushing away the skin and superficial fascia from the more resistant deep tissues.

Perforating wounds from shrapnel bullets show much the same characteristics as do those from rifle bullets. The wounds are generally larger and the surrounding tissues are more profoundly traumatized.

Shell and grenade fragments may also cause perforating wounds, but they are superficial and usually burrow under the skin and come out again within a short distance. The wound of entrance is ragged and may not correspond to the size or shape of the projectile causing it. The wound of exit is very lacerated; torn muscles, fascia and tendons often protrude from it. The surrounding tissues are profoundly traumatized.

Non-perforating or Penetrating Wounds.—Non-perforating or penetrating wounds caused by bullets fired at long range or by bullets whose velocity has been greatly reduced by contact with some obstruction. They enter the soft tissues base foremost, deformed or disintegrated. Smaller shell, grenade and bomb fragments will produce identical wounds.

The nature of the wound depends upon the type of projectile causing it as well as on the velocity at the time of the impact.

Shrapnel wounds, having a low velocity usually cause penetrating wounds, the bullet being retained.

Shell fragments, being of every variety of size, shape and weight, cause large excavated, lacerated wounds, with great loss of skin and deeper tissues.

If the fragments be very small the skin may be simply "peppered," but many of the pieces of shell will penetrate through skin and fascia into the muscles. Removal of these fragments is often a formidable task.

Grenade wounds will vary from superficial skin punctures to deep cul-de-sacs extending into the muscles. They also frequently produce large, gaping wounds with considerable destruction of tissue.

At the bottom of the cul-de-sac the projectile will usually be found, together with pieces of clothing, dirt, sand, etc.

In many cases, though the wound of entrance be small, there will be found extensive destruction of deeper tissues, with severe contusion and interstitial hemorrhages.

LACERATED AND CONTUSED WOUNDS.—Produced by bullets which have deviated from their true axis and by fragments of high-explosive shells, grenades or bombs.

The wound margins are torn and lacerated, as are also the fasciæ and muscles.

They are essentially tearing or contusing wounds, causing considerable loss of tissue.

GUTTER WOUNDS.—(*a*) Superficial, involving skin alone.
(*b*) Deep, involving fasciæ and muscles.

They are caused either by bullets striking the tissues superficially and plowing through the tissues or by ricochet shell, grenade or bomb fragments.

The wound will vary from a simple abrasion to a gaping wound several inches in length and width and extending through skin, fasciæ and muscles.

INCISED WOUNDS.—1. Those involving the neck are either immediately fatal or they may involve one carotid sheath, with or without injury to the trachea.

2. Incised wound involving soft tissues alone, if given prompt primary surgical treatment, will rarely become infected and only occasionally require extensive suturing.

3. Primary suturing of an incised muscle, after proper surgical treatment of the associated skin wound, is always indicated, except in the presence of other complicating wounds.

CHAPTER X.

GENERAL TREATMENT OF WOUNDS.

FIRST-AID DRESSING.—First-aid packet (in metal cases $4 \times 2\frac{1}{4} \times 1$ inch): Bandages, gauze, sublimated, 4×84 inches. Compresses, gauze, sublimated, $3\frac{1}{2} \times 3\frac{1}{2}$ inches (one sewed to each bandage). Two of each plus two safety-pins and directions for application will be found in each packet.

An additional "shell-wound" packet is also supplied, consisting of a bandage, gauze, sublimated, 3×48 inches, attached to a compress of sublimated gauze 6×9 inches, and a bandage, gauze, sublimated, 5 yards by 3 inches, with two safety-pins, the whole sealed up in a tough paper package with directions printed thereon.

These packets are carried by each officer and enlisted man of the army. In addition, each enlisted man of the Sanitary Corps carries a supply of gauze, bandages, iodin swabs, etc., in his web belt.

Applied, as it necessarily must be, without any previous adequate diagnosis of the nature and extent of the wound the first-aid dressing should always be removed at the regimental aid station.

TREATMENT AT THE REGIMENTAL AID STATION.—Trench warfare—in reality siege warfare on a gigantic scale—has permitted the hitherto highly mobile regimental aid station to become a semipermanent formation. Depending on the terrain and the nature of the operation, the aid station is housed in the following locations:

(*a*) Cellars of houses destroyed by shell fire (very common).

(*b*) Natural caves, grottoes or previously made cellars, etc. (as in the *Champagne* district).

(*c*) Dug-outs made splinter-proof and as near shell-proof as the nature of the terrain will permit.

The regimental aid station represents the first important stage in the surgical treatment of war wounds. On its thoroughness and completeness will depend the favorable or unfavorable evolution of the case. Every means should be employed in order to promptly transport the wounded from the battlefield to the regimental aid station.

A war wound should always be considered as more serious than it appears at first sight. Every wound produced by artillery projectile, every hand grenade or bomb wound, and the majority of bullet wounds must be considered as infected wounds with often concealed areas of devitalized tissues, plus foreign body. There have been few exceptions to this rule.

It will be manifestly impossible, during an action of any magnitude, to render surgically clean every wound brought to the aid station.

In the light of experience, the following types of wounds should claim first attention:

1. Wounds of the neck with threatened or actual edema of the glottis.
2. Severe hemorrhage.
3. Slight superficial wounds.
4. Deeply lacerated and contused wounds.
5. Compound fractures.

Threatened or actual edema of the glottis may demand tracheotomy.

Severe hemorrhage. (See chapter on Hemorrhage.)

(*a*) Seek vessel in the wound and ligate it above and below.

(*b*) Prolonged forcipressure.

(*c*) Gauze packing (final resort) (tourniquet to be avoided).

Slight superficial wounds:

(*a*) Cleanse with ether.

(*b*) Apply tincture of iodin.

(*c*) Apply sterile dressing.

(*d*) Evacuate to the station for slightly wounded.

Deeply lacerated and contused wounds:

(*a*) The systematic and complete removal of all foreign bodies (pieces of clothing, leaves, dirt, gravel, fragments of missiles, etc.) is of paramount importance and cannot be too strongly emphasized or too often repeated. This means getting at the bottom of the wound and rendering the entire wound surgically clean.

(*b*) The radical removal of all lacerated devitalized tissues (skin, fascia, muscle, etc.) under conditions of strict surgical cleanliness is based on sound surgical judgment and is recognized to have given the most satisfactory results. A war wound should be converted into a cone-shaped opening, the base of the cone being at the skin level.

(*c*) As infection tends to remain localized for several hours (six to eight), primary suture of lacerated wounds (in the absence of bone involvement) is a safe procedure if the removal *en masse* of all devitalized tissues has been previously carried out and too long an interval has not elapsed between the receipt of the wound and the treatment in the aid station. (See General Treatment of Wounds.)

Compound Fractures. (See chapter on Fractures.) Same treatment as in 4, plus the removal of all loose fragments of bone, and of attached fragments if this be necessary in order to gain access to the deeper parts of the wound. Always immobilize a fracture.

General Method of Treating Wounds.—*General Considerations.*—It is safer to leave a wound alone than to half-cleanse it. A wounded man arriving at the regimental aid station, after the rapid inspection which assures against interference with breathing (edema of the glottis), should primarily be examined for the following conditions:

(*a*) Unchecked hemorrhage.

(*b*) If hemorrhage is checked by the tourniquet, how long has it been on; how much harm is it doing; how much longer can it safely remain *in situ?*

(*c*) Profound shock.

(*d*) Severe pain; morphin should be given whenever pain and restlessness are marked.

(*e*) Manifest discomfort of patient. Shift position; readjust splints: loosen bandages if necessary.

Place the patient on the operating table and carry out all subsequent procedures with the same ease, judgment and thoroughness which one would give to a major operation in civil practice. A general anesthetic is usually necessary.

Protect patient from loss of heat (blankets, hot-water bottles if available, avoidance of unnecessary exposure of the body, etc.).

With shears or knife cut all clothes away from the wound, leaving ample space for the subsequent cleansing. Clothes should never be removed from a patient while he is in the regimental aid station. Regardless of the site of the wound it will usually be found possible to adjust clothing in such manner as to obtain a clear operative field.

Place wads of cotton or rolled towels around the dependent portions of the field of operation; place a sterile towel under the wound and around the cut edges of the clothing. The cotton or rolled towels will prevent or minimize wetting of patient's clothing, an important point to remember when considering the long and fatiguing journey which the wounded man will have to take as soon as he has had his wound treated.

Remove first-aid dressing and plug the wound with oil-soaked gauze if any oil is available, or with gauze soaked in some antiseptic solution. This should be a routine procedure, in order to avoid further contamination of the wound during the process of scrubbing.

Shaving and scrubbing of field of operation: The preparation of the field of operation should be entrusted entirely to the enlisted man or non-commissioned officer of the personnel and he should receive careful instruction regarding this most important duty. He should be impressed with the idea that large amounts of water or solutions poured over the wound will needlessly saturate the patient's clothing. He can use a minimum of sterile water and keep wiping or mopping the surplus off with pledgets of gauze or cotton as he goes along. The scrubbing should never be too vigorous, and the use of a brush may be omitted altogether in most places, using gauze sponges instead.

Having completed the mechanical cleansing of the operative field remove the gauze plug and swab operative field and edges of wound with ether.

Remove foreign bodies (clothing, dirt, etc.), and all devitalized tissue. A clean-cut excision, $\frac{1}{4}$ to $\frac{1}{3}$ inch from the edge of the wound, can be carried out *en masse*, thus removing with it all, or almost all, of the foreign bodies.

It is often of advantage to insert the finger into the wound as a guide to where the tissues must be divided. After removal of all débris, etc., wash the new wound surface out with normal saline solution.

Closure of the Wounds: (if only six to eight hours old).

Having determined that the wound has been rendered surgically clean the method of closure will necessarily vary with the size and evenness of the wound.

The essential aim is to get through coaptation of its walls, leaving no spaces or pockets for the accumulation of blood.

Deep interrupted sutures, passing if possible underneath the bottom of the wound, will usually accomplish the purpose; proximity of bloodvessels or nerves may render tier-suturing necessary.

A dry gauze dressing and bandage complete the operation.

Drainage.—When Indicated: "When in doubt, drain" is a reversal of our present attitude in civil practice, but the frequence and virulence of infection in the present war make it necessary to observe the old dictum. Certain it is that any wound which has not been completely rendered surgically clean by *en masse* removal of all foreign bodies, including bone fragments and missiles, must be drained, drained thoroughly and through the most dependent portion when this is possible.

As it is seldom possible to have a roentgenographic apparatus in a regimental aid station the surgeon will often be in doubt as to the presence of missiles in the wound, in which case he must err on the safe side and drain.

The principle of drainage which has given the best results depends on the intermittent flow of a fluid between the tissues. The drainage tubes employed merely convey this fluid to all parts of the wound and are the "means to an end." The tubes should be surrounded by gauze, which is also lightly packed throughout the wound and then saturated with the solution.

Splints should never prevent free access to the wound, and the dressing must be changeable without removal of the splint. Immobilization of the wounded part is always necessary even in the absence of a fracture.

Technic which Must Be Acquired for Surgery of the Zone of the Advance.—In battalion or regimental aid stations, as well as in field ambulances or field hospitals, it will sometimes be physically impossible for the surgeon to scrub his hands and change gloves for each wound. Water may not be available and the supply of gloves must necessarily be very limited. With a little experience, which he would do well to acquire before actually getting into action, the surgeon can learn to excise most wounds and dress all cases without having his hands come in contact with septic tissues or objects. With a pair of dressing forceps or one artery and one dressing forceps he can complete any kind of dressing, including the introduction of drainage and irrigation, and still be ready for a series of cases without subsequent scrubbing of hands or changing of gloves. An orderly or stretcher-bearer quickly learns how to apply bandages and ordinary splints. If the surgeon does not master this time-saving and all-important technic his sanitary formation will become encumbered with wounded and the entire system of evacuation may break down temporarily. Even during periods of calm, dressings should be done by the "fingers off" method.

Primary treatment must vary with the number of casualties. The advance surgeon should always bear in mind the paramount fact that his principal duty, from a purely military point of view, is not so much to treat wounds as to rid the field of battle of soldiers who have temporarily or permanently become useless as fighting units. When an advance in force is going on, or the troops are resisting a powerful attack, and the casualties are pouring back to the sanitary formations in a steady, apparently unending stream, he cannot stop to complete operations which are not immediately life-saving. Wounds can be excised *en masse*, but should not be closed; fractures should not be permanently set; esquilectomies or atypical partial joint excisions should be avoided, etc. In other words, the treatment should stop at the mere prevention of sepsis by excision of the wound; the base hospitals will have to complete the work. The French, in order to describe this type of deferred primary suture or treatment of wounds, very tersely refer to it as "primosecondary" treatment in contradistinction to "secondary treatment" or suture, which always means drainage.

Laparotomies will not tolerate delay; craniotomies for subdural hemorrhage must be done at once; tracheotomies and certain thoracotomies demand instant intervention, and severe hemorrhages will necessitate ligation, but the reparative details must all be postponed.

Every advance surgeon must therefore acquire two methods of procedure and adapt them to circumstances. When an attack in force is slowly, methodically planned the medical corps can usually anticipate the extra demands by increasing the number of advance sanitary formations; if such is the case, each operating group of surgeons may only be allotted a definite number of casualties and the treatment can be made as complete as in calm periods. This is not always possible. Troops may be called upon to attack in force or to defend themselves suddenly, and summary treatment and rapid evacuation will alone prevent congestion of the advance sanitary formations.

Conclusions.—1. The radical excision of all lacerated tissues, but particularly of muscle tissue, has lessened the danger of gas gangrene to a marked degree.

2. *En masse* excision of tissues is not justifiable when, by so doing, important nerves or bloodvessels would be sacrificed. A double excision of lacerated tissues, on either side of the nerve or vessel, with tunnelling underneath these structures, will give ample drainage and prevent sepsis.

3. Excision must be ample in the presence of lacerated muscle tissue, conservative in the neighborhood of joints where only tendons and fasciæ are present (knee, ankle, elbow, wrist). In the latter cases the French surgeons substitute *épluchement* to excision *en masse* (*épluchement*, literally "plucking of feathers," means conservative plucking of tissues and foreign bodies).

4. Primary suture should only be considered: (*a*) When the wound is less than eight hours old.

(*b*) When the excised area can be closed by tier suturing without leaving any pockets.

(*c*) In the absence of an associated fracture. (Some French surgeons, in advance formations, have been changing compound fractures into simple ones through primary excision and closure of the wound, after reducing or even wiring the fracture, but the method has not met with general approval.)

(*d*) When there are no shell fragments remaining in the wound. (This is only true of wounds exclusively involving soft tissues.)

(*e*) In periods of calm when the surgeons have time to complete all of their operative procedures.

(*f*) When the tension of the sutures, after closure, is not great enough to jeopardize the circulation.

5. Primosecondary (retarded primary) suturing should be the rule:

(*a*) When the wound is more than eight hours old.

(*b*) When absolute coaptation and perfect hemostasis are not readily obtainable.

(*c*) When temporary drainage is indicated.

(*d*) When the wounded have to be immediately evacuated to a rear formation after excision of the wound.

(*e*) During a severe offensive-defensive action, when the time element represents an absolute contra-indication to primary closure.

6. Secondary suturing is indicated:

(*a*) In all infected wounds, as soon as the microbic curve and clinical appearance of the tissues are satisfactory (see Dakin-Carrel treatment).

(*b*) Whenever the presence of a mass of scar tissue limits joint movements.

(*c*) In order to obtain better cosmetic results.

(*d*) In painful scars.

CHAPTER XI.

TETANUS.

General Considerations.—Tetanus is a preventable infection. If wounds have received thorough surgical treatment in the zone of the advance and the prophylactic dose of antitoxin has been administered at the same time, tetanus will not develop. The late cases, occurring in base or convalescent hospitals, are probably the result of secondary infection from the surgeon's hands, instruments, dressings, etc., the spores of tetanus being extremely resistant to ordinary methods of sterilization.

Etiology.—(*a*) *Exciting Cause.*—The tetanus bacillus is a slender motile bacillus, one-end of which is swollen and occupied by a spore.

It is always anaërobic; its spores are the most resistant known.

It is a normal inhabitant of the intestines of many of the herbivora and its spores are scattered throughout the heavily manured soil of the western front. (See Chapter II.)

Its toxins are slowly absorbed by the end-plates in the muscles and pass up the motor nerves to the cord.

The incubation period is from one to twenty days, during which time the toxins are travelling along the nerve sheaths to the nerve centers.

The growth is purely local within the wound.

(*b*) *Contributory Causes.*—1. A deep wound or pocket of skin whose recesses are cut off from the outer air.

2. The growth within the wound of a mixture of aërobic and anaërobic organisms.

3. Contamination of the projectile or fragment with earth containing either the bacillus or its spores.

4. Contamination of surgical instruments, dressings, etc., with tetanus spores.

PATHOLOGY.—There are no characteristic lesions either at the site of the wound or in the central nervous system.

SYMPTOMS.—The rapidity of onset is in direct ratio to the distance of the wound from the central nervous system. Locally, slight twitching of muscles in the vicinity of a wound is always suggestive. There are no changes in the appearance of the wound which are of diagnostic value. Punctured wounds, wounds with a comparatively small destruction of skin and considerable laceration of deeper tissues, and containing foreign bodies and dirt, are most likely to harbor the tetanus bacillus.

General Symptoms are: Constitutional signs of sepsis. Chills, cold sweats, rapid pulse, variable temperature. The afebrile cases usually get well.

Tonic Spasms: Stiffness of the jaw, neck and tongue, difficulty of swallowing, opisthotonos, etc. Spasms always associated with intense pain, and readily provoked by noises, draughts of air, moving the patient, etc.

PROGNOSIS.—Unfavorable, because by the time symptoms appear the combination of the toxin with the cells of the central nervous system has already taken place.

The shorter the interval between the receipt of the wound and the appearance of the symptoms, the smaller the chance of recovery.

The average mortality during the present war has been 60 per cent.

TREATMENT: (*a*) *Prophylactic.— General Measures.*— Prompt and complete surgical treatment of the wound. (See chapter on Wounds.) Tetanus always occurs as a mixed infection; whenever there is a growth within the wound of aërobic and anaërobic organisms, the former, by using up the oxygen in the wound, favor the growth of the tetanus bacillus.

Specific Measures.—Every wounded soldier must receive 500 units of antitoxin, subcutaneously. The day and hour of the injection must be recorded on the "Diagnosis Tag." The rule in the British army is to give a second injection of 500 units within ten days except in the most superficial wounds.

(*b*) *Active Treatment* (Threatened or Developed Cases).—*Treatment of the Wound.*—Surgical treatment of the wound will prevent the further elaboration of ectotoxins and should be promptly attended to.

Specific Treatment.—Massive, combined intravenous and intraspinal injections should be begun at the earliest manifestation of the disease and repeated as frequently as the progress or arrest of the individual case warrants.

Three thousand units intraspinally, with 500 to 20,000 units intravenously, should be given simultaneously and repeated within twenty-four hours. Larger doses have been given (30,000 to 60,000 units).

Subsequent treatments depend upon the clinical progress of the case. Five thousand to 10,000 units intravenously are given daily or every second day until clinical symptoms of nerve irritation have disappeared.

Anaphylaxis is just as apt to occur, and the symptoms thereof are equally severe whether a large or small dose of serum is injected. There is no necessity for alarm.

Magnesium Sulphate Treatment (Meltzer).—The results obtained by this method warrant its being used in conjunction with the specific treatment. It can be administered subcutaneously, intravenously, intramuscularly, or intraspinally.

(*a*) *Subcutaneously.*—Not more than 2 c.c. and not less than 1.2 c.c. of the solution (25 per cent.) per kilogram of body weight should be injected subcutaneously at least four times in twenty-four hours. As there may be considerable pain, a light inhalation of ether may be given. No massage should be given to hasten the absorption.

(*b*) *Intravenously.*—The concentration should not be more than 3 per cent. and not more than 5 c.c. per minute should be allowed to flow into the vein. The injection of 10 c.c. of a 6 per cent. solution intravenously in active cases of tetanus will check the spasms for an hour. The injections may be repeated while waiting for the tetanus antitoxin to take effect.

(*c*) *Intramuscularly.*—Combined with inhalations of ether. This method is based upon certain findings that a moderate inhalation of ether increases considerably the efficiency of the magnesium sulphate. The patient should be fairly well etherized, and 2 c.c. of a 25 per cent. solution of magnesium sulphate injected into the muscles of the thigh. At the end of the injection the thigh should be gently massaged and the anesthesia continued lightly for about twenty minutes.

(*d*) *Intraspinally.*—This is done in the same way as for lumbar puncture, and 1 c.c. of a 25 per cent. solution for every 10 kilograms of body weight should be given.

General Treatment.—Rest and quiet in a darkened isolation room. Chloral hydrate, chloretone, potassium bromide, morphin, etc., may be useful. Ether or chloroform will have to be used in the very severe spasms.

SUMMARY.—1. As all types of infection tend to remain localized for several hours, the early careful and thorough removal of all devitalized tissues, all foreign bodies (including bone fragments and missiles) and the obliteration of all pockets and "cul-de-sacs" from a wound will remove the danger of tetanus.

2. The early prophylactic dose of antitoxin should never be omitted, even in the most trivial of wounds. The mere presence of a blister (as in trench-foot) becomes an indication for prophylactic injection.

3. In a developed case of tetanus, the combined massive doses of antitoxin given intravenously and intraspinally, and repeated at frequent intervals, offer the best guarantee of cure.

The magnesium sulphate method may be helpful.

The carbolic acid method has not given results warranting its further use.

CHAPTER XII.

GAS-BACILLUS GANGRENE.

General Considerations.—The B. aërogenes capsulatus welchii (perfringens) and the vibrion septique are the common types of organisms associated with these cases. The literature dealing with these bacteria is extensive. No less than fifteen names have been given to as many strains which are either identical with or very closely related to the B. welchii.

As the symptoms and treatment appear to be identical, regardless of the name applied to the smeared or cultured organism, a differentiation between them is merely of academic interest.

Gas gangrene is a severe infection caused by extensive tissue invasion by anaërobic bacteria (Vignes).

The essential characteristic of this type of infection, which completely differentiates it from infections caused by aërobic germs is the rapid destruction of living tissue without the latter showing any tendency to inflammatory reaction. This destruction, caused by microbic secretions, represents in fact a digestion of tissues (Lardennois and Baumel).

Taylor defines gaseous gangrene as "the death of an extensive mass of muscle due to the mechanical action of gas produced from a local focus by saprophytic bacteria."

Captains McNee and Shaw Dunn, R. A. M. C., say: "In our experience gas gangrene is essentially a muscle disease, and we have never seen it commence where injury of muscle could be excluded. Where the main artery is destroyed, massive or 'group' gangrene generally occurs, whole groups of muscles being simultaneously involved from end to end by the growth of organisms throughout the muscles from which the blood supply has been cut off. The spread of gas gangrene into living and healthy muscle, with an intact blood supply, is probably explained by two facts: (1) Gas gangrene tends to spread in the longitudinal axis of muscles, so that single muscles are involved from end to end, while neighboring ones are untouched; (2) individual muscle fibers stretch without interruption from one tendinous attachment to another."

d'Este Emery's views may be summarized as follows: "The toxin kills the leukocytes, which are the natural protection of the body. To have a sufficient supply of these it is necessary that the circulation be intact. Therefore tissues devitalized by trauma, by constriction of the limb or by actual damage will favor the disease. The disease does not stop when healthy tissue is reached because the toxin, when present in large amounts, inhibits emigration and kills the leukocytes. If there is no free escape the toxin accumulates to such an extent that it soaks through into the healthy tissue and kills the defensive leukocyte, thus favoring the spread of the gangrene."

Flemming states that wounds are primarily infected by anaërobes and secondarily by pyococci.

Etiology.—Anaërobes reach the wound through particles of dirt and clothing; pyococci probably come from the neighboring skin. Flemming found B. perfringens in 81 per cent. of soldiers' clothing; the germs are especially numerous in woolen cloth. Damp air and perspiration favor their multiplication.

Anaërobes usually inhabit the intestines of herbivora and are distributed in manured soil, dust and also in river water.

The organisms are large, anthrax-like, Gram-positive, non-motile anaërobic bacteria, with slightly rounded ends, usually occurring singly or in pairs, rarely in short chains. They take ordinary stains.

In the human body they invariably multiply in devitalized muscle tissues or in blood clots enclosed in a wound. Their activity is greatly assisted by the presence of streptococci, staphylococci or other pyogenic bacteria, because the latter absorb the oxygen in the tissues whose presence would inhibit the growth of the anaërobes. They also cause a rapid coagulation of blood, thus shutting off the oxygen which would limit their growth.

The biology of B. perfringens, with its powerful fermentive action on sugars and resulting evolution of gas, fits in very well with the extraordinary rapidity of spread of acute gas gangrene.

Lardennois and Baumel state that anaërobes decompose albuminoids, carbohydrates and fats, reducing them to simpler products, some of which have a foul odor, with liberation of hydrogen, carbonic acid gas, etc.

Contributory Factors.—1. Presence of a mixed infection.

2. Presence of large masses of devitalized or dead muscle tissue.

3. Retention of extravasated blood and of wound secretions.

4. Extensive fracture and comminution of the long bones, particularly of the femur, forming inaccessible pockets.

5. Interference with the circulation (tourniquet, arterial wounds, crushing injuries of muscles).

6. Blood-soaked dressings or clothes which are left in contact with the wound for a long time, depriving it of oxygen and interfering with the circulation at the same time.

PATHOLOGY.—In the superficial type the findings are essentially those of a cellulitis plus the presence of gas in the subcutaneous tissues.

In the massive deep types the pathological picture is that of rapid necrosis with liquefaction of muscle tissue. "The gas bubbles are invariably between bundles of fibers, never in them; the arrangement of leukocytes and bacteria around the margin of a bubble is always the same—they have been pushed aside during life, as have also the muscle fibers, which, however, nowhere show signs of having been subjected to pressure, signs of which are also absent in the exudate and the capillaries between the neighboring fibers." (Bashford.)

The blood elements have undergone coagulation necrosis; arteries and veins are thrombosed, with necrotic walls. In addition to these local changes, destructive changes are found in the brain, suprarenals and liver.

General Symptomatology.—1. *Pain.*—Almost constant; usually begins as a sense of constriction, the wounded soldier complaining that the dressing over his wound is too tight.

2. *Odor.*—Variously described as ammoniacal, musty or nauseating.

3. Increased tension of the limb or muscle.

4. Percussion over the limb or muscle gives a subdued tympanitic note several hours before crepitation can be elicited.

5. By placing the stethoscope over the limb and squeezing the muscle or group of muscles a crepitant sound may be elicited which is not recognizable to the touch.

6. The invaded muscles contract slowly and the range of contraction is less than in the normal.

7. Brilliant green stains devitalized muscles less rapidly and less characteristically than in the normal.

The clinical types often merge rapidly from superficial to deep or from local to massive. (1) gas cellulitis; (2) localized gangrene; (3) massive gangrene (entire limb).

Type I (Local Diffuse).—(*a*) *Local Cellulitis.*—Reddening of skin (bronzing, brick red). Characteristic foul odor to wound discharges, with bubbles of gas in the discharge. No gas in the deeper tissues. Mild toxemia.

(*b*) *Diffuse Cellulitis.*—The skin becomes mottled with blue, purplish or gray blotches; frequently "bronzing" of the skin takes place. The limb is swollen and edematous; there is a crackling sensation on touching the skin; distal circulation is unaffected. Profound toxemia, with rapid pulse of small volume, variable temperature, cold extremities, and, commonly, hiccough and emesis.

TYPE II (LOCALIZED GANGRENE).—Usually associated with a compound fracture (especially of the femur). The skin is mottled purple. Localized crackling of the skin and deeper tissues is readily elicited. The limb is not uniformly swollen. A foul, dirty fluid, containing bubbles of gas, but no typical pus, exudes from the wound. Toxemia of variable degree is present. Distal circulation may show signs of obstruction.

TYPE III (MASSIVE GANGRENE).—The onset may be extremely rapid, often occurring in a patient apparently well on the road to recovery. It usually develops within forty-eight to seventy-two hours after receipt of the injury. The most severe type is seen in those wounds where there has been a severe disturbance of circulation (torn artery, tourniquet). The process may be a progressive one or massive gangrene may develop without warning, invading an entire cross-section of the limb simultaneously.

Characteristic Symptoms:

1. Sudden, sharp, lancinating pain in the limb, below the wound.
2. Marked edema of limb, with blotchy purplish discoloration of skin.
3. Obliteration of distal pulse.
4. Profound toxemia with high temperature and rapid, low-tension pulse.
5. Characteristic fecal-like odor around the wound.
6. From the wound opening issues a scanty discharge, composed of broken-down blood-clot; it is of brownish color and contains bubbles of gas (carbon dioxide).

Examination of the wound will reveal the following picture:

1. The subcutaneous tissues are filled with lymph-like fluid containing bubbles of gas.

2. The intermuscular septa and muscle sheaths are similarly filled with lymph-like fluid and gas; there is often separation between sheath and muscle tissue, extending beyond the wound for a considerable distance.

3. Accumulations of fluid and gas are found around the shaft of the bone or bones involved.

4. The muscle tissues are terra-cotta colored and avascular, and portions of muscle have disintegrated into foul-smelling necrotic masses. There is extensive gas infiltration of the muscle fibers.

5. In consequence of the muscle changes, bands of fascia stand out prominently.

6. Gas tends to spread along the perivascular tissues and the planes of intermuscular connective tissues.

Prognosis.—(*a*) As regards the integrity of the limb involved:

1. Prompt recognition and treatment of Type I will usually save the limb.

2. In the localized gangrene type the prognosis is fair, providing distal circulation can be restored, and the wound rendered surgically clean and mechanically drained.

3. In the massive type of gangrene the limb cannot be saved.

(*b*) As regards life of the patient:

A sudden fall of temperature to subnormal, with rapid, shallow respirations, low blood-pressure and cold extremities, indicates that the toxins are freely circulating in the blood. The mortality in these cases is 100 per cent. Early recognition of the massive type of gangrene with prompt amputation will save 50 per cent. of these cases.

Diagnosis.—1. Presence of a septic wound, poorly exposed and not mechanically drained.

2. Gas in tissues (emphysema).

3. Presence of bacillus in smear preparations of wound secretions.

4. A suddenly developing pain in the limb, below the wound, is of great diagnostic value if it occurs at a time when

there is little or no production of gas in the tissues and there are no signs to warn of the impending catastrophe (Pfanner).

5. Value of x-ray examinations in suspected cases: The presence of gas is manifested by an increased radiotransparency of the soft tissues. Careful study of the plate enables some roentgenologists to determine the presence of gas within the muscle sheaths, etc.

"Fine striations demarking the individual muscles so that they resemble a sketch made in black and white, are stated to occur with vibrion septique infections (Tech)."

Radiographically speaking, there are two main types of gas formation:

1. Where there is a comparatively small number of discrete bubbles.
2. Where there is extensive gas infiltration.

Fallacies to be Avoided:

1. The actual wound may involve such a loss of tissue as to cause increased radiotransparency of the part.
2. No reliance must be placed on negative plates.
3. Abscesses often simulate gas bubbles.
4. Bubbles of air may be trapped or sucked up within the tissues.
5. If the wound has been syringed with hydrogen dioxide, oxygen bubbles will be present in the tissues.
6. Extensive ecchymoses will increase radiotransparency of the soft tissues. While the x-ray diagnosis of this infection is interesting, it must be looked upon as merely an adjunct to the clinical picture.

TREATMENT.—1. *Prophylactic Treatment*—

(*a*) See General Treatment of Wounds.

(*b*) Prophylactic doses of antitoxin may be advocated in the near future (Bull).

2. *Active Treatment.*—(*A*) *Local*—

(1) Superficial Cellulitis: Multiple incisions through the skin and subcutaneous tissues. Intermittent irrigations or

wet dressings soaked in Dakin-Carrel solutiou. In deeper infections the intermuscular septa and individual muscle sheaths should be split open and widely drained. Many of the French surgeons inject small amounts of ether above the emphysematous area.

(2) Limited Gangrene: (*a*) Make multiple, deep incisions in the emphysematous area.

(*b*) Remove all devitalized tissues; it may be necessary to excise an entire muscle or group of muscles.

(*c*) Provide ample mechanical drainage and irrigate intermittently.

(*d*) If the hand or foot becomes pulseless, try deep incisions through the forearm or calf; if this does not promptly restore the circulation, amputate.

(*e*) After rendering the wound as surgically clean as possible, and providing drainage, mark the limit of the discolored skin area; if it spreads centrally, amputate the limb.

(3) Massive Gangrene:

(*a*) Early amputations offer the only hope of saving life.

(*b*) A circular no-flap amputation is best.

(*c*) Amputate through edematous area, but where the circulation is still fairly normal. Shock is lessened if local infiltration and nerve blocking is resorted to. The treatment of the stump is described in the chapter on Compound Fractures.

(*B*) *General Treatment.*—General supportive measures should be carried out. Liquids per mouth, rectum, intravenously or subcutaneously will maintain blood-pressure to some extent. Easily digested or peptonized foods should be exhibited at regular, frequent intervals. Stimulants should be avoided; morphin should only be used in case of severe pain and restlessness. The exact value of any line of general treatment is hard to determine.

(*C*) *Specific Treatment.*—Still in the experimental stage. Encouraging reports are now coming from the Rockefeller

Institute which may have an important bearing on the future treatment of these cases.

SUMMARY.—1. There are no other bacteria against which we are so powerless as anaërobes, when they have an opportunity to localize in broad masses of devitalized muscle.

2. Anaërobes act locally, producing rapid necrosis by coagulation of blood.

3. The systemic disturbances are due to the septicemia produced by the simultaneous presence of pyogenic bacteria in the wound and in the systemic circulation. Anaërobes only break into the systemic circulation just before the death of the patient (Koch).

4. Preventive treatment, *i. e.*, treatment of the wound in the zone of the advance, is the only limb and life-saving measure at our disposal.

5. The question of a specific antitoxin is still *sub judice.*

CHAPTER XIII.

CRANIAL INJURIES.

General Considerations.—The separation of cranial injuries into those demanding immediate life-saving intervention and those which can be safely evacuated to base hospitals for treatment is well-nigh impossible.

Difference in the terrain, activity or quiescence in local trench warfare, differences in personnel and equipment, etc., all contribute to the difficulties of the problem.

English and French military surgeons unanimously agree that all wounds should receive prompt and thorough surgical treatment either at the Regimental Aid Station or in one of the formations of the zone of the advance. (Field Ambulance, Field Hospital.)

Whether or not this primary treatment should include removal of foreign bodies, fragments of bone or missiles at the front is a mooted question, the answer varying with the time element, the security obtainable from shell fire, the equipment available and the known skill of the personnel.

It has therefore seemed best to include, at the end of this chapter, a verbatim statement of the English and French systems of treatment.

Classification of Cranial Injuries—

1. Simple scalp wounds.
2. Erosions of periosteum and outer table.
3. Fractures produced by rifle bullets fired at ordinary ranges.
    (*a*) Gutter fractures.
    (*b*) Penetrating fractures (bullet in bone, bullet in brain).
    (*c*) Perforating fractures.

4. Fractures produced by shell fragments (high-explosive, grenade, bomb) or by slowly moving missiles, such as shrapnel bullets or rifle bullets at long range. Short-range rifle bullets produce the same type of fractures:

(*a*) Fissure fractures.

(*b*) Depressed fractures without penetration of the skull by the missile.

(*c*) Comminuted fractures.

CLASSIFICATION OF BRAIN INJURIES—

1. Caused by massive hemorrhages:

(*a*) Middle meningeal artery or its branches.

(*b*) Longitudinal sinus.

(*c*) Other important bloodvessels.

2. Caused by compression:

(*a*) Hemorrhage (extradural, intradural).

(*b*) Depressed or comminuted bone fragments.

3. Caused by direct trauma of brain tissue.

(*a*) Missiles.

(*b*) Bone fragments.

4. Severe concussions of brain without fracture or hemorrhage. Since the introduction of the steel helmet, cases are reported where severe damage to brain tissue has occurred without appreciable bony lesion or hemorrhage.

5. Massive or localized edema of brain.

GENERAL SYMPTOMATOLOGY OF CRANIAL INJURIES—

1. *Local Signs and Symptoms:*

(*a*) Scalp wound.

(*b*) Pain.

(*c*) Fissures or depressions of outer table.

(*d*) Mobility and crepitus.

(*e*) Escape of blood, cerebrospinal fluid or brain tissue.

(*f*) Ecchymoses.

(1) Subconjunctival in fracture of the anterior fossa.

(2) Perimastoid in fractures of the posterior fossa (twelve to twenty-four hours after injury).

2. *General Symptoms—*

(*a*) Unconsciousness:

(1) Immediate.

(2) Following a lucid interval as in middle meningeal hemorrhage.

Unconsciousness varies within wide limits, being more severe and prolonged when there are minute punctiform hemorrhages throughout the substance of the brain (contusion) or when gross compression or gross lesions of the brain are present (lacerations, hemorrhage from middle meningeal artery, displaced inner table, etc.). Focal symptoms following a period of unconsciousness, and preceding a second loss of consciousness, are pathognomonic of hemorrhage.

(*b*) Vomiting.

(*c*) Headache—vertigo.

(*d*) General flaccidity and loss of deep reflexes.

(*e*) Variations in pulse and blood-pressure.

(*f*) Variations in respiration.

(*g*) Variations in temperature.

(*h*) Persistent headache, even in the absence of skull fracture, is indicative of increased intracranial pressure.

(*i*) Persistent vertigo is most often associated with injuries of the cerebellum.

(*j*) General flaccidity is present in all cranial injuries of the more severe type.

(*k*) Variations in the pulse and blood-pressure. A slow, bounding pulse associated with rising blood-pressure, is pathognomonic of cerebral compression.

(*l*) Respirations may be sighing, languid, explosive, irregular, shallow, deep or Cheyne-Stokes in quality.

(*m*) Variations in temperature:

(1) Transitory subnormal temperature in simple concussion of the brain.

(2) Severe contusions, compressions or lacerations of brain tissue show a rise in temperature.

(3) Pontine lesions show an extreme elevation of temperature (106° to 109° F.).

3. *Localizing Symptoms.*—Unconsciousness often obscures many or all of these symptoms.

(*a*) Eye of injured side may be turned in any direction, regardless of the position of the opposite eye.

(*b*) Conjugate deviation; *i. e.*, turning of the head and both eyes *toward* the side of the lesion.

(*c*) Nystagmus, external or internal strabismus, etc.

(*d*) Loss of reaction in one or both pupils is a grave symptom.

(*e*) Dilatation of the pupil with loss or diminution in reaction on the same side as the lesion.

(*f*) Local paralyses and disturbances in muscular tone:

(1) Irritative lesions (slight pressure):
Twitchings.
Spasms.

(2) Profound pressure symptoms:
Monoplegias.
Crossed paralyses.

(3) Sensory changes occur in areas corresponding to the motor paralyses, the anesthesia usually preceding the paretic condition.

(*g*) Disparity in deep reflexes:

(1) Irritative lesions.
Deep reflexes exaggerated in the contralateral half of face, arm or leg.

(2) Paralytic lesions.
Deep reflexes lessened or absent in contralateral half.

(*h*) Disturbances in temperature on the paralyzed side and disturbances in the higher psychic formation and aphasias are of little immediate diagnostic value.

Treatment.—In all but the manifestly moribund cases, surgical cleansing of the wound or wounds is of prime necessity.

(See Treatment of Wounds.) The regimental surgeon should be able rapidly to classify cranial injuries into:

(*a*) Those who will recover without surgical intervention (if sepsis does not intervene).

(*b*) Those needing surgical intervention.

(*c*) Those presenting such gross injury to vital brain structures as to render surgical aid futile.

Type A.—1. Fractures involving the frontal region (anterior fossa). Extensive comminution of bone and destruction of brain tissue are followed by complete recovery provided the wound is rendered and kept surgically clean.

2. Small fissures without depression of inner table.

3. Gutter fractures with only limited depression of the inner table.

Borderline cases will be encountered in this group. There may be severe contusion of brain tissue, edema of the brain or the formation of an extradural or intradural hematoma producing a train of focal symptoms which will necessitate surgical intervention.

Type B.—1. Gutter fractures with marked depression of the inner table.

2. Penetrating wounds with bone fragments or missiles in the brain.

3. Perforating wounds with focal symptoms of extra- or intradural hemorrhage.

4. Severe hemorrhage requiring ligation.

Type C.—1. Massive comminutions involving the temporosphenoidal or occipital regions.

2. Cases in which there is a manifest general edema of the entire brain (profound coma, low blood-pressure, rapid pulse, subnormal temperature, absence of focal symptoms).

3. Cranial injuries associated with severe lesions of other organs.

General Treatment of Cranial Injuries.—1. Whenever available the skiagraph should be used in order to determine the type of fracture and the presence or absence of missiles.

2. Thorough preparation of the surrounding area, carefully protecting the wound from further contamination. (See Treatment of Wounds.)

3. Removal of all devitalized and lacerated soft tissues.

4. Removal of all small or sharp-pointed fragments of bone and preservation of large fragments.

5. If the dura is intact and no focal symptoms have developed, leave it alone and close the wound after replacing all large bone fragments.

6. If the dura is torn and the skiagram reveals the presence of spicules of bone or of one or more missiles, gentle exploration of the lacerated brain tract with the gloved finger and removal of the foreign bodies cannot further traumatize the tissues, provided the missile is not impacted.

7. The giant magnet is often useful in the removal of metal fragments (except copper). Unless the exact angle of penetration of the missile is recognized and the magnet is so manipulated as to draw the missile out along this same angle, considerable additional trauma to brain tissue may ensue. The weight and bulk of the magnet also make it difficult to keep in the zone of the advance.

8. Severe hemorrhage or persistent oozing from one of the main branches of the middle meningeal hemorrhage will require double ligating with fine catgut. Persistent oozing from the pia or arachnoid is readily controlled by applying small pieces of muscle tissue.

9. Dural defects should be closed by pieces of fascia or dental rubber. The French Service de Santé is now supplying in sealed glass tubes, pieces of sterile bovine pericardium, which is giving excellent results.

10. Intradural drainage should not be resorted to.

11. Whenever possible the wound should be sutured, leaving a small drain extending to the meninges.

12. The dressings should only be changed when they are saturated or the secretions have dried up, making the dressing uncomfortable.

Present English and French Systems of Treatment.—While apparently very different, the technic of the English surgeons can be largely accounted for by two facts: (1) comparatively little surgery is done in the zone of the advance; (2) many of their reports deal exclusively with results obtained in base hospitals in England.

The French idea, on the other hand, is to bring the ambulance hospital to the wounded soldier, and to perform a complete surgical operation with the least possible delay.

(*a*) English School (Makins, Hull, Sargeant, Holmes, etc.):

1. Removal of foreign bodies:

(*a*) The question of the removal of metallic fragments is difficult to decide, inasmuch as their ultimate fate and their possible effects upon the surrounding brain are at present uncertain.

(*b*) Primary removal of deep-seated missiles carries with it the additional risk of sepsis. Many patients with foreign bodies deeply lodged in the brain recover.

2. Intracranial pressure:

(*a*) Apart from the rare instances of extensive intracranial hemorrhage, traumatic edema, while playing an important part in symptomatology, does not reach a sufficient degree of intensity to endanger life.

(*b*) The instances of severe intracranial hemorrhage not rapidly fatal are very few, and even among these there is a certain number which surgical intervention is not likely to save.

(*c*) Experience has shown that an intracranial hemorrhage which is not sufficiently severe to demand operative relief, and which can be recovered from, gives very unmistakable signs of its progress.

(*d*) Exploratory operations, on the chance of discovering a hemorrhage, are rarely if ever called for.

(*e*) In case of intracranial pressure from secondary edema, which is causing severe headache and herniation of the brain, this can always be controlled by lumbar puncture. Occasionally contralateral decompression has afforded good results in these cases.

(*f*) French School (symposium presented and resolutions passed by the Société de Chirurgie, Paris):

1. All head injuries should be carried from the place where they fell to the place where they can be operated upon as rapidly as compatible with the military necessities of the moment.

2. All head injuries should be explored immediately upon arrival at the designated hospital, regardless: of the hour of arrival of the date and hour of the wound, of the statements on the diagnosis tag, of the clean appearance of the dressing room or of the patient's state of fatigue.

3. It is far better surgery to explore ten head injuries without finding a single fracture than not to explore and miss a single diagnosis of fracture or hemorrhage.

4. Head injuries should, whenever possible, be transported directly from the battlefield to the evacuation hospital because:

(*a*) Once operated upon they should not be subjected to further transportation until they are convalescent.

(*b*) Because field ambulances and field hospitals are within range of artillery fire and the noise and concussion are very detrimental to such cases.

5. If primarily evacuated to a field ambulance or field hospital the wound should be prepared surgically (shaving, scrubbing, trimming and dressing) before further evacuation to the rear.

6. Radiography is of inestimable value, but a temporary break-down of the apparatus should not deter the surgeon from immediate exploration, if clinical symptoms of compression manifest themselves.

7. French surgeons strongly advocate tincture of iodin and ether in the surgical preparation of the case.

8. Head injuries should reach the operative table from two to six hours after being injured.

Reasons for operating:

(1) To check hemorrhage.
 (*a*) Superficial.
 (*b*) Deep.
 (*c*) Extradural.
 (*d*) Intradural.

(2) To remove septic tissues:
 (*a*) Excision of scalp wound.
 (*b*) Removal of clothing, dirt, leaves, sand, etc.
 (*c*) Removal of spiculæ of bone.

(3) To remove depressed fragments of bone:
 (*a*) Single removal of fragments.
 (*b*) Removal of fragments which have pierced the dura.

(4) To evacuate a hematoma:
 (*a*) Extradural.
 (*b*) Intradural.

(5) To remove foreign bodies:
 (*a*) Fragments of bombs.
 (*b*) Fragments of hand grenades.
 (*c*) Shrapnel and high-explosive fragments.
 (*d*) Shrapnel bullet.
 (*e*) Rifle bullet or pieces of same.

(6) To render the brain tissues and meninges aseptic.

(7) To drain the wound.

2. Scalp incisions will usually consist in enlarging the wound.

3. Indications for trephining:

(1) No obvious signs of depressed fracture, but:
 (*a*) Entrance and exit wounds are far distant from one another.
 (*b*) Patient unconscious at time he received his injury.

(*c*) Persistent headaches or giddiness.

(*d*) Fracture of outer table without depression of same.

(2) Depressed fractures without injury to the dura.

(3) Fractures with injury to the dura.

Fractures with injury to the dura and presence of a foreign body.

4. Methods of trephining:

(1) Simple lifting of fractured bone.

(2) Gouge, bone-biting, de Vilbis.

(3) Chisel and hammer.

(4) Trephine.

The opening should be ample enough to thoroughly explore the cranial cavity, examine all tissues and remove fragments and foreign bodies. At the same time, undue mutilation of the bony vault should be avoided.

5. Should bony fragments be replaced? Small, sharp, irregular fragments should never be replaced, as they tend to shift about and traumatize the dura. Large depressed, fairly even fragments, should have their sharp edges trimmed off and may then be sterilized by boiling (or immersion in ether) before being replaced. The advantages of replacing such pieces of bone are:

(*a*) Prevention of hernia cerebri.

(*b*) Scaffolding over which bony or fibrous cells proliferate.

6. Should the intact dura be incised?

(*a*) Never if normal colored and pulsating normally.

(*b*) Invariably, if the surface of the dura is decidedly cloudy or blackened, tense and non-pulsating, or it presents a circumscribed loss of elasticity (unequal tension). One will invariably find a hematoma or a contused brain area, or both, in such cases. Some surgeons prefer preliminary aspiration. If the blood can be withdrawn, leave the dura intact; if a blood clot is present, open the dura and evacuate the hematoma.

7. Should a torn dural opening be enlarged? Yes, invariably. Enlarge the cranial opening if necessary, in order to expose the dura. Remove all lacerated dura. After completing the operation cover the dural defect by means of:

(*a*) Fascia lata (best).

(*b*) Dental rubber.

Remember that a piece of fascia as large as the palm of the hand will contract down to one-half or even one-third of its normal size. It should either be tucked in under the bone or lightly anchored to the dura with very fine interrupted catgut sutures. Dental rubber makes an excellent, non-irritating protective membrane; it has also been used to cover peritoneal defects and contused arterial or venous walls. (Matas.)

8. What are the best methods for controlling intracranial hemorrhage?

(*a*) Pieces of muscle (autogenous) applied directly to the bleeding surface without making undue pressure.

(*b*) Coagulen Kocher-Fonio 5 per cent. solution in sterile water, boiled not to exceed five minutes and freshly prepared.

9. Having enlarged the dural wound, what further steps are necessary?

(*a*) Removal of blood-clots.

(*b*) Trimming of lacerated brain tissue.

(*c*) Removal of bone spiculæ, pieces of cloth, dirt, etc.

(*d*) Search for and removal of metallic foreign bodies which have previously been localized by the *x*-rays.

Immediate removal of foreign bodies is justified because:

(*a*) Tract through brain tissue is already present.

(*b*) No further injury to brain tissue need be made.

(*c*) If wound is large, sepsis is already present.

(*d*) Abscess has not formed.

Secondary (late) removal of a foreign body presents the following disadvantages:

(*a*) Exploring through scar tissue.
(*b*) Additional laceration of brain tissue.
(*c*) Often have to operate in an infected area (abscess, etc.), with danger of dissemination of the infection.
(*d*) The presence of a metallic body within the cranial cavity is a constant menace to the patient.

It should be distinctly understood that exploration of brain tissue for primary removal of missiles is only justifiable when the laceration is extensive enough to permit the introduction of the index finger without further traumatizing of tissues. The tract must be large enough to make it absolutely certain that important nerve centers will not be injured by the exploration.

Exploration should be carried out with the greatest care and gentleness, and the surgeon should desist in his search if his finger is no longer able to follow the tract and encounters the resistance of normal brain tissue.

The difference in sensation imparted to the experienced finger, between lacerated and normal brain tissue, though distinct, is slight in degree, and the inexperienced operator may easily be misled into false channels.

If the exploring finger has succeeded in locating the missile a small gall-stone scoop can be safely passed alongside it and the foreign body engaged in the scoop without additional trauma. It is often preferable to withdraw the finger, place its tip in the hollow of the scoop and reintroduce them both simultaneously.

Technic of Removal of Missiles in the Presence of Extensive Brain Lacerations.—(*a*) Use all proper means of localizing the foreign body by means of *x*-rays. Of special importance is an exact estimation of the depth of the missile from the surface and the determination of impaction of the metal in bone tissue. Should the latter condition be determined, exploration is contra-indicated. (See Chapter XXVIII.)

(*b*) Having determined that the size of the tract justifies exploration, gently introduce the gloved little finger of the left hand; locate the object with the tip of the finger and determine its motility.

(*c*) If the missile is freely movable, pass the scoop alongside the finger or introduce the scoop and the finger simultaneously.

(*d*) Engage the missile in the scoop, press it against the finger-tip and withdraw both at the same time.

(*e*) If the missile is not freely movable, but does not appear to be impacted in bone tissue, a straight or curved artery forceps can be used, keeping the little finger in the wound as a guide and gently working the piece of metal out. (As an aid in recognizing the tract of the missile or bone fragment the preliminary injection of a few drops of methylene-blue solution has been recommended. On theoretical grounds there would seem to be no contra-indication to the use of an aqueous solution of the dye.) If it is found desirable to bring the foreign body into view the lacerated brain tissue can be gently pushed aside by means of two or three groove directors. This will often facilitate the removal of sharp, irregular missiles or fragments of bone without further traumatism to brain tissue.

10. Should intracerebral drainage be used? No. It is dangerous and irritating. Extradural wicks may sometimes be used. Drainage from skin to trephine opening is commonly used and maintained until all danger of sepsis is past. Drains should only be changed on definite clinical indications. Extradural wicks should be renewed every second or third day. If the gauze is applied very lightly over the wound, it will not act as a plug, checking the exit of secretions. In depressed fractures, where the replacing of the fragment does not leave any space for extradural drainage, and the latter seems to be indicated, a circular opening can be punched through the most dependent portion of the fragment, and the wick passed through it.

11. When may postoperative head injuries be safely

evacuated to the base hospitals? (*a*) Cases presenting no dural or subdural lesions can safely travel within a few days after the operation, provided symptoms of meningo-encephalitis have not developed.

(*b*) Cases with lesions of the dura and brain, where no foreign body was present (or, if present, was removed) should remain where they were operated upon for one month. The bumping and jolting, the erratic train schedules of the zone of the advance or of that of the line of communications, the impossibility of regulating the proper dressings, make earlier transportation dangerous.

(*c*) Cases with severe brain lesions and a foreign body which has been found impossible or inadvisable to extract should be kept under observation for sixty days or more.

12. Early complications in head injuries: (*a*) Brain abscess.

Usually due to the presence of a foreign body which has been overlooked, often of microscopic size (steel dust, etc.). Prognosis unfavorable unless the foreign body is early removed. Use of giant magnet often invaluable.

(*b*) Epilepsy or epileptoid seizures. Look for abscess or foreign body.

(*c*) Hernia cerebri.

Type: (*a*) Soft, diffuse, wine-colored and associated with high temperature. Indicative of a progressive meningo-encephalitis. Treatment by drainage very unsatisfactory; prognosis bad.

(*b*) Hard, limited, rose-colored, not associated with increased temperature. Indicative of a retrogressive lesion. Prognosis good; late cranioplasty often indicated.

13. Late complications in head injuries usually caused by: (*a*) Latent activation of an encysted abscess.

(*b*) Exuberant bony callus causing pressure symptoms.

(*c*) Meningeal adhesions or scar tissue within brain substance, producing circulatory disturbances.

The manifestations are innumerable and the treatment pertains entirely to the base hospitals. The French army surgeons recommend that a trephined soldier should never be sent back to the firing line.

14. Cranioplasty. Indicated in all large cranial defects whenever a tendency to herniation of type (*b*) manifests itself. As it is best to delay this operation in order to be certain that no nidus of infection lurks behind or that a spicule of bone has not been missed, this operation will only exceptionally be performed in the advanced hospitals.

Anesthesia: Local as a rule.

Technic (Morestin):

(1) Use the sixth to eighth costal cartilages.

(*a*) Lamina of cartilage.

(*b*) Entire cartilage.

(*c*) Pieces of cartilage.

(2) Remove and place cartilage in warm saline solution.

(3) Reopen scalp wound and freshen edges of cranial defect.

(4) Carefully avoid the dura.

(5) Completely fill in the defect with pieces of cartilage, trimmed to fit accurately. Large pieces of costal cartilage, having perichondrium attached to one surface, should be placed with perichondrium in contact with dura. Cartilage always tends to curl upon itself, the concavity invariably representing the perichondrial side.

(6) It is not necessary to suture fragments together or to the cranial vault.

(7) Close skin flap without drainage. Portions of scapula, pieces of tibia, etc., have been used with equal success.

The French army surgeon Estor reports 41 cases of cranioplasty, with 41 successes, using gold plates to cover the defects.

Advantages claimed for the gold plate:

(*a*) Only one incision required.

(*b*) Appeals to soldier's imagination.

Disadvantages:

(*a*) Foreign, non-absorbable body.

(*b*) Cost ($4 to $6 per plate.)

15. Cranial prosthesis by means of sterilized cranial plaques. (Sicard and Dambrin, *Soc. Méd. des Hôpitaux de Paris*, February 8, 1917). Nineteen cases with perfect results. They believe that regardless of the method used, bone or cartilage is eventually absorbed and replaced by fibrous tissue.

Technic:

(1) Accurately measure the cranial defect.

(2) Remove corresponding area of outer table from skull of a recently expired patient.

(3) Fenestrate the plaque, especially its borders.

(4) Place plaque in ether for twenty-four hours, then in a solution of equal parts of ether, alcohol and formol for twelve hours and finally sterilize in the moist autoclave at 120° C. for one-half hour.

(5) After careful freshening of the margin of the cranial defect, place the plaque in position and anchor it by passing catgut sutures through three or four of the fenestræ and suturing to periosteum. Wherever possible periosteum should be slid over the plaque and sutured over same.

(6) Close the wound without drainage.

CHAPTER XIV.

WOUNDS OF THE FACE AND NECK.

General Considerations.—Trench warfare has made wounds of the face of very common occurrence. Exact percentages are not obtainable, because many of these wounds are associated with and classified under the headings of compound fractures or head injuries.

The use of the steel helmet has largely mitigated the wounds from smaller shell fragments and shrapnel bullets.

It has been shown, for instance, that 80 per cent. of all penetrating wounds of the eye were caused by steel or copper dust; the use of the helmet has greatly reduced this type of wound.

Aside from the general treatment given to all wounds, there are very few emergency, life-saving operations, which will have to be performed in the zone of the advance.

The immense vascularity of the soft tissues of the face tends effectively to localize infection. It is therefore preferable to evacuate all such cases to the base hospitals for plastic and prosthetic repair.

Classification of Wounds of the Face.—While recognizing the fact that most wounds of the face involve several regions simultaneously, it is of advantage to discuss each region separately in order to emphasize salient points:

1. Wounds of the orbital cavity and eye.
2. Wounds of the nose and nasal cavity (ethmoid, sphenoid and frontal sinuses).
3. Wounds of the mouth and buccal cavity.
4. Wounds of the ear (*a*) external, (*b*) middle, (*c*) internal, (*d*) mastoid.

5. Wounds of the malar and superior maxillary bones (antrum wounds).
6. Wounds of the inferior maxilla.
7. Wounds of the soft tissues.

TREATMENT.—*Wounds of the Orbital Cavity and Eye.*—(*a*) *Wounds of the Bony Parts.*—(See Treatment of Fractures of the Skull and Compound Fractures.) Treatment in the regimental aid station will be limited to removal of bone fragments and trimming off of all devitalized tissues. Persistent hemorrhage will usually respond to light gauze packing. These wounds may involve the outer or inner walls of the orbit, the optic foramen, the anterior fossa of the skull, the frontal, sphenoidal or ethmoidal sinuses, or one or more of the bones of the face. Treatment of any of these complicated conditions manifestly belongs to the base hospital.

(*b*) *Wounds of the Eye*—

Contusions.
Lacerations.
Destruction of eyeball.
Total loss of eyeball.

In all contused and lacerated wounds, the eye should be washed out with sterile water, saline solution or boric acid solution. The instillation of a few drops of a 0.5 per cent. solution of cocain or novocain will anesthetize the cornea satisfactorily. Lack of time and inadequate light and equipment make it impractical to attempt the removal of foreign bodies embedded in the cornea.

If deep injury is suspected, dilate the pupil with 1 per cent. atropin ointment, a scale of homatropin or a few drops of atropin solution, in order to prevent adhesions of the iris.

Deliberate enucleation of the eye should not be done in the zone of the advance, because the necessary diagnostic equipment is not obtainable.

An eye which is totally destroyed should be trimmed off and orbital vessels ligated if bleeding is persistent.

Wounds of the Nose.—All wounds of the nose should be treated conservatively, in view of the importance of saving even apparently devitalized tissues for later plastic operations.

If the nose is partially torn away and the tissues do not appear markedly devitalized, a temporary suture may be applied after thorough cleansing of the wound. As a rule, however, a thin strip of adhesive properly applied will answer the purpose and allow better drainage.

All completely detached fragments of cartilage or bone should be removed, but any partially attached fragment must be conserved.

Dependent drainage should be obtained by placing the wounded man on his side.

All dressings should be lightly applied and frequently changed.

Wounds of the Mouth.—The simple in-and-out wounds require surgical cleansing of the tract made by the projectile, plus the frequent use of a mouth wash (saline solution, boric acid solution, etc.).

In wounds involving the bony parts, there is usually present the wound produced by the projectile itself, plus those produced by teeth or bony fragments separated off from the upper or lower jaw.

Hemorrhage from one of the branches of the facial or temporal arteries may be profuse enough to require ligation. Wounds of the tongue may be associated with obstinate hemorrhage, and there is always the danger of edema of the glottis, which may require tracheotomy. After checking hemorrhage and trimming off absolutely devitalized tissues and detached fragments of bone, the patient should be turned as nearly on his chest as possible in order to avoid inhalation of saliva and blood into his trachea.

No repair of these wounds should be attempted.

Wounds of the Ear.—External Ear.—Almost invariably associated with wounds of the skull. Conservative but thorough cleansing of the wound should be carried out.

Middle Ear.—Irrigation, wet dressings. No exploration of the bony canal should be carried out.

Internal Ear.—Usually rapidly fatal.

Mastoid Process.—Thorough removal of all foreign bodies, bone fragments, etc.

Light packing of wound and wet dressings. In wounds of the ear involving injury to the large vessels or their branches, ligation of the carotid may be necessary. (See Hemorrhage.) The lateral sinus may be involved and will require life-saving tamponade, after thorough surgical treatment of the wound leading to it.

Wounds of the Malar and Superior Maxillary Bones.—Invariably associated with injuries of the soft parts, and frequently involve the antrum of Highmore.

They may be of the comminuting, perforating or gutter type, usually the first.

A few cases of diastasis of the superior maxillæ and of dislocation from adjacent bones have been reported.

Preserve all soft tissues as much as possible, as well as any adherent fragments of bone.

Replace, so far as possible, all adherent fragments of bone in their anatomical relationship. Remove all loose teeth.

If the antrum is involved, it should be thoroughly cleansed of all foreign bodies and loose fragments of bone and packed with gauze.

An antiseptic mouth wash should be provided and the patient instructed to use it frequently during his evacuation to the rear.

Moist dressings are preferable to dry, and the patient should be instructed to keep them moist, using his mouth wash solution for the purpose.

No reparative measures should be carried out in the zone of the advance.

Wounds of the Inferior Maxilla.—The wearing of steel helmets has had little or no effect on the percentage of wounds of the lower jaw. The wearing of the chin strap has caused fractures of the lower jaw when the steel helmet is struck by a piece of shell. It is now recommended that the soldiers be made to wear the strap behind the head instead of under the chin. The density of the bone of the lower jaw causes most of its wounds to be of the "explosive" type.

A direct bullet hit may only cause a perforation of one ramus; most injuries are comminuted or radiating fractures, or radiating fissures.

Wounds of the lower jaw are apt to be more serious, as regards disfigurement and impairment of function, than those of the upper part of the face.

The effect of shell fragments on teeth and bone is often very destructive.

The treatment at the front should be extremely conservative and at the same time efficient.

Only manifestly dead or hopelessly devitalized soft tissues should be trimmed off. Every viable piece is important in future plastic operations. Err on the conservative side.

Only fragments of bone which have no connection with surrounding tissues or which present sharp spicules should be removed. Remove all loose teeth.

Any piece of bone, however small, which is still adherent to its periosteum, should be preserved and replaced in its anatomical position—but not maintained there by any method of fixation.

If the wound is a large, gaping one, drainage is already present. In other cases, with a small wound of entrance extensive comminution of bone, and no wound of exit, dependent drainage may be established through the submaxillary fossa into the mouth.

The dressings should be moist and frequently changed because of constant contamination from nasal or buccal secretions.

The use of mouth washes should be begun promptly and continued during the evacuation of the wounded man to the rear.

A simple gauze "chin bandage" will give the necessary immobilization. No interdental wiring or splinting should be attempted.

The lateral or chest position affords dependent drainage.

Wounds of the soft parts.

Occasionally perforating or gutter wounds will be found which do not involve any of the bony parts.

In the former type, surgical cleansing of the tract and a dry dressing will suffice; in the latter type, if time permits and the wound is superficial, it may be surgically cleansed and sutured.

SUMMARY.—Wounds of the face (aside from edema of the glottis and hemorrhage) are not emergency wounds.

They are among the safest wounds which may be evacuated to the rear without preliminary surgical treatment.

Gas gangrene in wounds of the face is extremely rare; a few cases of fulminating tetanus were reported, before the prophylactic injections of antitoxin in all wounds was enforced.

All reparative work should be performed by carefully selected dental, oral or prosthetic surgeons in specially equipped base hospitals.

WOUNDS OF THE NECK.

PREVALENCE.—Owing to associated injury of the spinal cord, or to the main vessels of the neck, death usually occurs before any surgical aid can be instituted.

CLASSIFICATION:

1. Wounds of the soft parts not involving important vessels or nerves.
2. Wounds complicated by hemorrhage.
3. Lesions of the trachea.
4. Lesions of the esophagus.

TREATMENT.—

1. Wounds of the soft parts. (See General Treatment of Wounds.)

2. Wounds complicated by hemorrhage. (See Hemorrhage.)

3. Wounds of the trachea. Immediate tracheotomy should be performed in impending or actual edema.

Technic of the High Operation:

1. Patient on his back, shoulders raised, head extended.

2. Cocainize soft tissues in median line at level of middle of thyroid cartilage.

3. Vertical incision 2 inches long, from middle of thyroid cartilage toward sternal notch.

4. Expose and divide deep fascia.

5. Expose three or four tracheal rings by blunt dissection.

6. Introduce knife into trachea at lower end of wound and cut upward until three tracheal rings are divided.

7. Widen opening with forceps and slip tracheotomy tube into position.

8. Attach tapes to outer cannula and around patient's neck.

CHAPTER XV.

WOUNDS OF THE THORAX.

General Considerations—

Bayonet, bullet and shell-fragment wounds of the chest form one of the gravest types of injury, a large percentage of the men so wounded dying in a few moments.

Conversely, if the wounded man survives the first twelve hours, his chances of ultimate recovery are good.

Classification.—1. *Non-penetrating Wounds:*

Of the soft tissues: Seton wounds, penetrating wounds, lacerated and contused wounds, gutter wounds.

Of the sternum.

Of the ribs and costal cartilages.

Of the clavicle.

Of the scapula.

2. *Penetrating Wounds*—

Open wounds, with retained missile and with retained bone fragments.

Closed wounds, through-and-through, and with retained missile.

Organs involved:

Pleura.
Lung.
Pericardium and heart.
Mediastinum.
Diaphragm.
Abdominal organs, etc.

Complications.—*Non-penetrating Wounds*—

Sepsis.
Hemorrhage.
Injury to trunk nerves (brachial plexus, etc.).
Retained foreign bodies.

Penetrating Wounds—

Hemorrhage.

Sepsis.

Hernia of lung.

Emphysema of the chest wall.

Hemo-, pneumo- or pyothorax, or combinations of the same.

Wounds of pericardium or heart.

Retained foreign bodies.

DIAGNOSIS.—*Wounds of the Soft Tissues.* (See Chapter VII.) *Wounds of bony or cartilaginous parts* differ in no essential from compound fractures of the long bones. (See Chapter XX.)

Foreign bodies may be palpable but their location and number of fragments present should always be controlled by means of the skiagraph.

Penetrating Wounds.—Diagnosis is based upon the external signs of the wound, together with the presence or absence of pain, cough and hemoptysis. The skiagraph is invaluable in order to ascertain the presence of bone fragments and foreign bodies and to estimate their exact position with regard to vital organs or structures.

Pain is present whenever the pleura has been contused, lacerated or punctured. Exceptionally, in an in-and-out wound of the chest the patient complains of little or no pain.

Cough is invariably present when the pleura has been irritated or injured; often present in the absence of hemoptysis.

Hemoptysis.—The amount of blood coughed up varies within wide limits. It may last a few hours or days, stop spontaneously and recur—either spontaneously or as the result of injudicious surgical interference.

COMPLICATIONS.—

Hemothorax is characterized by:

(*a*) Shock; variable.

(*b*) Dyspnea.
(*c*) Hemoptysis.
(*d*) Increased pulse rate.
(*e*) Early rise of temperature, before sepsis occurs.
(*f*) Physical signs of fluid in pleural cavity.
1. Lessened mobility of chest wall on affected side.
2. Dulness or flatness on percussion.
3. Absent tacticle fremitus.
4. Diminished or absent vocal fremitus; may be increased over the apex.
5. Breath sounds either absent, diminished or bronchial in character.

(*g*) Aspiration and examination of fluid.

Pneumothorax is characterized by:
(*a*) Severe pain and dyspnea.
(*b*) Pulse weak and irregular.
(*c*) Affected side distended and immobile.
(*d*) Diminished or absent breath sounds.
(*e*) Tympany on percussion; bell sound on coin percussion.

Pyothorax is characterized by:
(*a*) May occur by direct extension from an infected wound of the thoracic wall, from infected clothes or shrapnel fragments or by direct infection through an injured bronchial tube.
(*b*) Physical signs of fluid.
(*c*) Constitutional signs of sepsis.
(*d*) Aspiration and examination of fluid.

Emphysema of the chest wall is characterized by:
(*a*) Edema of soft tissues around wound.
(*b*) Crackling sensation on palpation of the skin.

Lung Hernia.—Lung hernia occurs in shrapnel wounds with large tears of the pleura through which lung tissue protrudes. General appearance and emphysematous feeling of the herniation make the diagnosis easy.

Wounds of the heart are characterized by:

(*a*) Increased area of cardiac dulness (pear shape).
(*b*) Decreased heart sounds.
(*c*) Gurgling or rustling sound if air is entering the pericardium.
(*d*) Dilated veins of neck.
(*e*) Precordial pain radiating to the left shoulder and upper left abdominal quadrant.
(*f*) Severe shock.

Retained foreign bodies: Presence and exact localization ascertained by skiagrams. (See Radiography.)

TREATMENT.—*Non-penetrating Wounds:*

Wounds of the Soft Tissues. (See General Treatment of Wounds.)

Excision and closure of wound give excellent results, when done early, with adequate excision and kept under careful surveillance.

Foreign bodies should be removed if easily accessible; if they have penetrated and lodged (*a*) under the scapula, (*b*) in the subscapularis muscle, (*c*) in the supraspinatus or infraspinatus muscles their removal should be deterred until the patient has reached the base hospital.

Wounds of the sternum are treated by thorough removal of all loose fragments after excising the skin wounds. Closure of wound without drainage.

Wounds of the Ribs and Costal Cartilages.—Erosions, grooves or contusions require the same treatment given to soft tissues. Fragments of comminuted bone or loosened or displaced cartilages should be removed.

Wounds of the clavicle are especially dangerous owing to the proximity of the subclavian and axillary vessels and nerves (see Hemorrhage), and are treated by the removal of all loose spicules of bone and trim off all sharp points which might injure the underlying vessels.

Primary closure of the surgically cleansed wound depends on the time which has elapsed before treatment is instituted.

When in doubt, it is safer to drain, as sepsis in the supraclavicular fossa is extremely dangerous.

Temporary immobilization of the clavicle is obtained by the application of a Velpeau bandage.

Wounds of the Scapula.—Excise tract of wound, remove all spicules of bone, curette traumatized bone.

Primary closure or drainage must be decided separately in each case. Immobilize the shoulder (adhesive strips, Velpeau, etc.).

Penetrating Wounds:

(*a*) *Open Wounds:*

Remove all loose pieces of bone, trim edges of wound.

If visible or readily accessible, foreign bodies should be removed at once. No immediate search for foreign bodies should be instituted.

In all wounds of the pleura an expectant line of treatment should be the rule. Close the wound so far as possible, without disturbing blood-clots, apply an occlusive compress and keep the patient under observation for a few days.

In injuries of the lung, the same careful surgical treatment of the external wound should be carried out. If the pleura is full of blood, the collapsed lung usually ceases to bleed. By early withdrawal of a hemothorax, either by aspiration or thoracotomy, the lung will expand before thrombosis of its injured vessels has occurred, and the hemorrhage is liable to return. For the same reason a pneumothorax should not be aspirated.

The expectant treatment will consist in surgical cleansing of wound, rest in semireclining position, morphin for restlessness and marked dyspnea and liquid food.

Injury to the Internal Mammary Artery: It occasionally happens that the bleeding does not come from torn pleura or lung tissue, but from an injury to the internal mammary artery. This type of injury will be manifested clinically by external hemorrhage through the wound and the presence of a combined extra- and intrapleural hematoma.

This complication is treated by enlarging the wound vertically or laterally in the third interspace, 1 cm. from the sternal border (resection of a small portion of the second or third costal cartilage may be necessary in order to reach the vessel). When the vessel is brought into view it is doubly ligated.

Extrapleural clot is removed and the wound closed with or without drainage.

Open Wound Injury of the Pericardium or Heart is treated as follows:

Careful surgical treatment of external wound, including removal of all foreign bodies and loose fragments of rib.

Evacuation of hemopericardium and removal of foreign body.

Draw the heart forward with two fingers of left hand, holding it very gently. Close the heart wound by deep interrupted sutures of fine silk. Close the pericardial wound in the same manner, without drainage. Place and leave a drain in the mediastinum for forty-eight hours.

Close the external wound if possible, leaving only enough space at the sternal border for the mediastinal drain to pass out.

Wounds of the diaphragm are discussed in the chapter on Wounds of the Abdomen.

Hernia of the Lung demands the following treatment:

Cleanse the external wound according to general directions. If lung tissue is gangrenous, ligature and removal of the distal portion with scissors or the actual cautery are indicated. In non-gangrenous cases, reduction of the hernia is fairly easy. Guard against entrance of air into the pleural cavity by pressing a gauze sponge into the wound as the hernia is being reduced.

Close the wound without drainage unless infection of the pleura is present.

Closed Wounds of the Thorax:

1. Through and Through: After cleansing and closing of the external wounds, expectant treatment should be the rule. Aspiration of a hemo- or pneumothorax should not be attempted in the zone of the advance.

Operative interference is only indicated when there are symptoms of injury to the pericardium or heart.

2. With Retained Missile:

(*a*) In the Pericardium or Heart Muscle: Immediate removal according to technic laid down under treatment of open wound of pericardium. A chondroplastic flap involving the sternal ends of the second and third costal cartilages will amply expose the pericardium.

(*b*) In the Pleura or Lungs: Removal should be attempted if time and equipment permit; otherwise evacuate the case to the base hospital. The steps in this removal are:

Localization of foreign body by means of *x*-rays.

Patient remains on *x*-ray table for the operation without shifting his position.

Use the wound of entrance, or make a small skin incision between the ribs and on level with the object.

Long, thin bullet forceps with right-angle handle is introduced, hugging the upper border of the lower rib; it is gradually pushed through the parietal and visceral pleuræ into lung tissue.

By means of the fluoroscope, determine the relative positions of the object and the jaws of the forceps.

Close jaws of forceps tightly on the object and extract same.

Close incision without drainage.

Conclusions (Adopted by Interallied Surgical Conference 1917):—1. Penetrating wounds of the thorax caused by war projectiles have a mortality of 20 per cent. in the zone of the armies.

2. The immediate mortality is heaviest, due to hemorrhage

and asphyxiation. Shock is a large factor in the causation of immediate or early death.

3. Late fatalities are usually due to pleuropulmonary infection.

4. Pathological anatomy shows that pulmonary tissues are subjected to the same lesions that are found in other war wounds. The mechanical disturbances are the same, the infections identical, but pulmonary tissues show the greatest resistance to the latter; unfortunately, pleural infections, acquired either from without or from the pulmonary wound, increase the danger of the lesion.

5. Two rules should dominate the treatment: early intervention and absolute immobilization of the patient.

When shock is present, it should be treated with the patient in the reverse Trendelenburg position and the head well propped up.

The medical (expectant) treatment will heal a large percentage of thoracic wounds which present no immediate or secondary complications.

Surgical intervention is indicated in parietal lesions and in primary and secondary complications.

In all cases, complete surgical treatment of the thoracic wound (wounds of soft tissues, fractures of ribs of the scapula, etc.), is as absolutely necessary as it is in all war wounds.

A. *Immediate Complications:*

(1) Open Wound of Thorax.—Closure of the thoracic wound is imperative, obtainable either by primary suturing or, if the wound is too extensive, by occlusive plugging.

(2) Hemorrhage:

(*a*) With Open Thorax.—Direct hemostasis of the lung should be obtained, either by gauze tamponade or by suture of the bleeding pulmonary tissue itself.

(*b*) With Closed Thorax.—If it seems evident that the shock is not the cardinal factor in a given case; if arterial tension continues to drop in spite of the general treatment of shock, and the symptoms must be attributed to hemorrhage, the ideal operation is a thoracotomy with direct hemostasis of the pulmonary lesion. The indications for operation in closed wounds of the thorax are very rare. The operation itself requires an expert surgeon and a first-class surgical equipment.

(3) Hemothorax.—(*a*) The presence of a hemothorax justifies aspiration, in order to relieve the phenomena of mechanical compression. In order to produce pulmonary collapse, and thus avoid the danger of secondary hemorrhage, air and oxygen can be injected either during or following the withdrawal of the blood.

(*b*) In the presence of a febrile hemothorax, repeated aspirations should be performed, in order to examine the fluid bacteriologically.

B. *Late Complications:*

(1) Persistent Aseptic Hemothorax.—This type should be treated by repeated aspirations, in order to stimulate pulmonary expansion. Small quantities of oxygen, injected in the pleural cavity during or following these aspirations, may be useful.

(2) Pyohemothorax.—If the bacteriological examination of the fluid shows undoubted infection, thoracotomy is absolutely indicated.

(3) Purulent Pleurisy.—Follow the same line of treatment as in pyohemothorax. If drainage is necessary, it should have its exit posteriorly and low down.

6. Treatment of suppurative pleurisy by progressive sterilization (Dakin-Carrel solution (Depage); ether (Lardennois).

In recent or chronic suppurations, progressive sterilization, followed by secondary suture of the thoracic wall, should be the method of choice. Suturing should be performed even in the presence of a still existing pleural cavity. Closure of the wound is the best means of obtaining rapid expansion of the lung and obliterating the pleural cavity (Depage).

7. Whenever an early operation is indicated, intrapulmonary projectiles should be removed at the same time if conditions are favorable.

8. Under all circumstances, the avoidance of pleuro-pulmonary infection through direct surgical treatment of the pulmonary wound (extraction of foreign bodies, suture of the pulmonary wound with or without excision of same), seems logical. This question should be carefully studied.

9. Hemopericardium should be treated along the same lines as hemothorax.

CHAPTER XVI.

WOUNDS OF THE ABDOMEN.

1. General Considerations.—In the entire field of military surgery there is no more dramatic demonstration of the danger of dogmatic assertion, than can be obtained by a study of the evolution of abdominal wound treatment. During the early months of the war, when the French sanitary service found itself unable to cope with the situation, and influenced also by some early operative failures, the rule of "non-interference" in the treatment of penetrating wounds of the abdomen was adopted. Even suprapubic puncture and drainage was omitted. Morphin, Fowler's position and proctoclysis were relied upon exclusively. The results were so discouraging that the rule was first relaxed sufficiently to allow a suprapubic puncture and drainage to be instigated. This immediately decreased the mortality to a slight degree. Gradually, one surgeon after another began to operate on all penetrating wounds of the abdomen, a practice they have maintained ever since.

The British surgeons did not permit the pendulum to swing back as far as did that of their French colleagues! On the French side, the following tabulation, reported at the Société de Chirurgie of Paris in December, 1915, speaks for itself:

Total number of cases observed, 588.

Not operated upon, 322; deaths, 288; mortality, 80 per cent.

Operated upon, 266; deaths, 161; mortality, 60 per cent.

Surgeon Tarvis, operating in the same locality, with the same equipment and with the same average lapse of time between the occurrence of the wound and the operation, tabulated his results as follows:

No operation, 8 cases, 8 deaths, mortality, 100 per cent.

Suprapubic drain, 15 cases, 12 deaths, mortality, 80 per cent.

Radical laparotomy, 11 cases, 6 deaths, mortality, 55 per cent.

In the *British Medical Journal* of March 10, 1917, Lockwood and his colleagues tabulate the results of 500 cases of intra-abdominal lesions which came under their personal observation. Of these, 356 were operated upon with a total mortality of 52 per cent. The 144 cases not operated upon gave a mortality of 95 per cent. No operation was deemed necessary in 6 cases, because of apparent absence of intra-abdominal symptoms; 12 cases were left alone because of the presence of fecal fistula. Of these 12, 8 were evacuated to the rear and their ultimate outcome not stated. The remaining 126 cases were classed as "apparently moribund;" all died.

Summary of Controversy.—The prevailing opinion on the western front is that intra-abdominal wounds should be rapidly evacuated to the nearest sanitary formation having adequate equipment and personnel for major surgery, and that immediate laparotomy is indicated in all but manifestly moribund cases. The French try to get all their cases on the operating table within six hours; the English seem to consider that the zone of operability is passed after a twenty-hour interval; von Eiselsberg (Austria, August, 1915) states that operation is contra-indicated if more than twelve hours have elapsed before the patient is admitted to the operating room. He therefore advises keeping such wounded in the dressing station for six days or longer, before transferring them to the field hospital.

Lieut.-Col. Hull (British), more conservative than most of his colleagues, considers evisceration an indication for immediate laparotomy and extravasation of urine an indication for suprapubic drainage. He seems inclined to treat all other cases expectantly (morphin, Fowler position, flexed knees, no liquids or solids per mouth and proctoclysis).

Should Shock be Treated before Operating?—Yes, if hemorrhage can be ruled out. This is often extremely difficult, if not impossible. In the absence of bloody stools, bloody urine or free hemorrhage through the abdominal wound, the pulse is the only guide, and a differentiation between the pulse of shock and that of hemorrhage is questionable. A safe rule to go by is to treat shock while operating; fewer mistakes will thus be made.

Diagnosis.—Intra-abdominal lesions can be recognized by the following signs and symptoms:

(*a*) *The Site of the Wound.*—This is often conclusive *per se;* it is well to remember that trench warfare, with bombs and hand grenades falling almost vertically and enfilading fire, have produced many wounds of the abdominal viscera with the wound of entrance in the back or buttocks.

(*b*) *Pain.*—This is variable; generally speaking, wounds of the stomach and small bowel are more painful than those of the large bowel or of solid viscera.

(*c*) *Pulse.*—Too much reliance cannot be placed on pulse rate or blood-pressure. A non-penetrating wound over the solar plexus will exhibit a pulse similar in every respect to that of a severe hidden hemorrhage. "Stimulate as you operate."

(*d*) *Rigidity of Abdomen.*—Of considerable diagnostic and prognostic value. Local rigidity indicates the establishment of a protective zone. A freely moving abdomen, though rigid, indicates a rather slight intraperitoneal injury. A flaccid abdomen is usually associated with extensive laceration of small gut and is of bad omen.

(*e*) *Facial Aspect.*—Of some diagnostic importance.

(*f*) *Vomiting.*—Endeavor to get history of vomiting prior to admission.

(*g*) *Blood in Rectum or Bladder.*—Catheterization and the passing of a rectal tube should never be omitted. Do not inject fluid into the bladder or rectum. Both procedures are dangerous and unnecessary.

TREATMENT.—Treatment should in the first place be directed against shock and hemorrhage (see Chapters on Shock and Hemorrhage). Further treatment depends on whether the injury is non-penetrating or penetrating.

(*a*) In non-penetrating wounds, whenever it is possible, excision *en masse* of all lacerated tissues and closure of the wound without drainage should be the rule.

Should symptoms of severe visceral contusion supervene, exploratory laparotomy is clearly indicated. If the wound is near the median line, the devitalized tissues should be trimmed off and the entire tract rendered aseptic before opening the peritoneum. In all wounds away from the median line, where exploratory laparotomy is indicated, the wound should be excised, heated surgically and closed up by suture, prior to making a paramedian incision for intraperitoneal exploration.

The great mobility and abundance of abdominal cutaneous tissues will permit primary closure of very extensive lacerated wounds, provided the entire tract has been rendered surgically clean. It may occasionally be necessary to make a sliding flap in order to close a very large defect.

(*b*) In penetrating wounds, treatment is of course directed against repair of the penetration, whether it be vascular or visceral, combating hemorrhage, or peritonitis or both.

An exact classification is impossible. Many missiles will involve different organs at the same time or perforate multiple loops of the same gut.

A perforating wound may traverse the abdomen from side to side, causing a mere contusion of parietal and visceral peritoneum; again it may penetrate one or more of the solid viscera and perforate several loops of small intestine.

Lacerated penetrating wounds may tear large sections of the stomach or transverse colon, the shell fragment becoming embedded in some part of the abdominal wall.

The condition of the hollow viscera at the time the wound was inflicted has a strong influence on the prognosis; other factors being equal, the greater the quantity of food contained therein, the more rapidly will general peritonitis supervene.

Wounds of the colon are extremely serious on account of the retroperitoneal cellulitis which forms an almost constant feature of this type of wound.

Wounds involving the main vessels of the liver, spleen or kidneys are usually fatal before surgical intervention can be instituted

Operative Technic.—A roentgenograph is necessary in all cases except those presenting both entrance and exit wounds, without bony involvement.

The entire track of the wound or wounds should be excised *en masse* at a distance of one-third to one-half inch from the raw surface. In rare cases with extensive "explosive" laceration of tissues, this may be impossible. If the wound is well away from the paramedian line it should be sutured immediately. When close enough to the median line, it may, after excision of lacerated tissues, be used as part of the laparotomy incision.

Make a paramedian incision, high or low as required, and sufficiently ample to permit thorough exploration of the abdominal contents.

If profuse hemorrhage is present, examine the liver, spleen, kidneys and large vessels first.

Examine the entire colon.

If unable to locate the hemorrhage, deliver the entire length of small intestine (properly protected by means of hot wet "Laps" or towels) and make a systematic search. It is usually easier to begin at the ileocecal valve and work up, an assistant rapidly "tucking back" each loop as the surgeon passes it in review.

Examine the diaphragm carefully.

Examine the anterior and posterior walls of the stomach.

The mesenteric vessels will be found to be a common source of hemorrhage.

If a retroperitoneal hemorrhage is found, as a rule, it had. better be let alone.

Treatment of Injured Viscera.—Only when the organ is grossly lacerated, still bleeding freely or its main bloodvessels damaged, should splenectomy or nephrectomy be performed. Hot packs will usually control oozing; if persistent, pack gutta-percha tissue into the gap, using free end as drain. Gauze, unprotected, should never be used, as it adheres and provokes secondary hemorrhage on removal.

Wounds of the liver, if extensive, should be closed by means of deep catgut sutures on long curved, non-cutting needles. The extreme pliability of this organ should be borne in mind and no tension placed on sutures. Gutta-percha pack and drain, often necessary.

Wounds of the colon can almost always be closed by purse-string and Lembert sutures.

Avoid resection of small gut if possible. A properly applied purse-string and Lembert suture will usually suffice. Where absolute stenosis will result from this procedure, resection must be resorted to. There seems to be little choice between end-to-end and lateral anastomosis.

Wounds of the mesentery or diaphragm should always be carefully sutured.

Foreign bodies should always be removed from kidney, spleen or liver. If lying in the retroperitoneal tissues, in the midst of a large hematoma, with hemorrhage checked, leave it alone.

Treatment of Intestinal Paralysis.—When any portion of the distal half of the colon has been repaired, before closing the abdomen, have an assistant pass a colonic tube through the rectum into the sigmoid. Gently coax the tube beyond the repaired segment and leave it *in situ* for three or four days (Lane).

When there is marked distention of small gut, select a loop as near the ileocecal valve as possible, isolate it externally by means of hot wet towels or pads and empty same by a milking process either through the wound (if present) or by means of a trocar. Close wound (or puncture) with purse-string and Lembert sutures.

When the distention is only above the wounded area, close the wound and then gently milk the gut from just above the distended area to just below the sutured segment of gut before closing the abdomen.

The Sampson-Handley method of treating peritonitis seems worthy of special consideration. For pelvic peritonitis and intestinal obstruction (ileus duplex) he advises an ileo-colostomy to the ascending colon, with a cecostomy. For general peritonitis (hypogastric ileus) he advises a jejuno-colostomy to the transverse colon, with a cecostomy.

Should Abdominal (Peritoneal) Lavage Be Resorted To?—The general tendency among army surgeons seems to be to avoid the use of normal saline or of any antiseptic solution. What the French erroneously term "ether lavage" really means the penetration of ether vapor throughout the peritoneal fossæ under tension; 1 ounce of ether is as efficient as 1 pint. The fact that ether has maintained its vogue in France for four years makes a thorough investigation of this subject most desirable.

Is Drainage Desirable?—"No surgeon has started to do abdominal surgery until he quits draining the abdomen." With few exceptions this epitomizes the general trend of present-day war surgery. Pelvic drainage is still frequently resorted to after an unsatisfactory repair of a torn bladder, and gutta-percha drains are left in the upper abdomen in wounds of the liver or spleen. More and more are surgeons coming to rely upon the strong defensive qualities of the peritoneum. The controversy is still very lively and far from being solved.

Closure of the Abdomen.—Usually in layers. If the tissues are very edematous and suggestive of gas gangrene the peritoneum alone should be closed, interrupted silkworm-gut sutures being placed through skin and rectus sheath but not tied for twenty-four to forty-eight hours, or until danger of gas gangrene is over. The Dakin-Carrel solution should be used on the gauze dressings throughout this period. Two or three strips of adhesive will prevent the danger of reopening of the peritoneum and consequent evisceration.

After-treatment.—Fowler position, knees flexed.

Proctoclysis (plain water), drop method.

Morphin for great restlessness.

Pituitrin or eserin may be tried for tympanites.

Liquids freely unless emesis contra-indicates.

If a drain has been used it should be removed within forty-eight to seventy-two hours.

Conclusions.—Wounds of the large vessels of the liver, spleen, kidney or stomach are fatal before patients can reach the operating table.

Anteroposterior wounds, especially in the epigastrium, are least dangerous; wounds from side to side, especially low down, are most dangerous.

Wounds of solid viscera are not as dangerous as those of hollow viscera.

Wounds associated with herniation of bowel or stomach give a poor prognosis.

Wounds of the stomach, colon and especially of the small intestine require careful exploration and accurate repair, but in posterior wounds involving the colon the greatest care should be taken not to convert a retroperitoneal condition into an intraperitoneal one.

Wounds of the liver, kidney or spleen should usually be treated by exploring, cleansing and gutta-percha packing if bleeding. Be sure that no hollow viscus has been damaged at the same time before closing the abdomen.

Avoid resection if possible.

The choice between end-to-end and lateral anastomosis depends entirely on the individual surgeon's custom. Wounds of the diaphragm are neither fatal nor even to be greatly feared. Careful repair gives immediate relief and excellent results.

Multiple drainage tubes are rarely necessary, usually injurious and always to be avoided if possible.

Abdominal lavage is a dangerous practice. The ether question should be fully investigated.

Never leave free unprotected gauze in the abdomen.

Resection for persistent fecal fistula should be done later in a base hospital.

Mortality Results in 500 Laparotomies.

(Captain Walters Rame and others, *Lancet*, February 10, 1917.)

	Nature of Injury.	Cases.	Mortality. Per cent.
Class 1.	Stomach, no other injury	9	33.3
	" all stomach wounds	23	65.3
Class 2.	Small intestine, sutured	64	37.5
	" all cases	96	48.0
	" resections alone	58	69.0
	" " all cases	90	72.0
Class 3.	Large intestine, sutured	45	53.0
	" all cases	119	64.0
	" colostomy	13	85.0
Class 4.	Liver, pure liver wounds	27	52.0
	" all liver wounds	58	67.0
Class 5.	Spleen, no other injury	11	45.5
	" all cases	17	53.0
Class 6.	Kidney, pure kidney wounds	10	40.0
	" all cases	20	40.0
	" nephrectomy	2	0.0
Class 7.	Bladder, pure bladder wounds	9	45.5
	" all bladder cases	25	52.0

	Nature of Injury.	Cases.	Mortality. Per cent.
Class 8.	Rectum alone	3	33.0
	" all cases	9	45.0
Class 9.	Laparotomy:		
	(*a*) No injury found	57	7.3
	(*b*) Retroperitoneal hematoma only	23	62.0
	(*c*) Bruising of intestine and hemorrhage	9	23.0
Class 10.	Cases with protrusion of intestine	16	62.5
	" " " uninjured	5	40.0
Class 11	Cases in which the peritoneum was opened by original wound but no visceral injury	10	40.0
Class 12.	Wounds of chest and abdomen	27	81.5
Class 13.	Gas gangrene of abdominal wall	11	91.0

MORTALITY RESULTS IN 1288 CASES.

(Col. Cuthbert Wallace, R. A. M. C., *Lancet*, April 28, 1917.)

Total number of cases	1288
Arrived moribund	250
Total mortality excluding moribund (per cent.)	50
Total mortality including moribund (per cent.)	60
Considered with a view to operation	1038
Operation not considered advisable	73
Total number operated upon	965
" operative mortality (per cent.)	54
" stomach mortality (per cent.)	53
" small gut mortality (per cent.)	66
" great gut mortality (per cent.)	59

Colonel Wallace summarizes the result of his observations as follows:

1. Frequency of abdominal wounds, 2 per cent.
2. Hemorrhage is the chief cause of early death.
3. The mortality mounts rapidly after a twelve-hour interval has elapsed and reaches an appalling percentage after twenty-four hours.
4. The chief cause of delay in transporting of wounded lies in the "zig-zag" construction of the trenches. When it is

remembered that the chief communicating trench is often two miles long, often almost impassable after heavy rains, the difficulties of rapid transportation can begin to be appreciated.

5. The best place for operating on these cases is about ten thousand yards behind the firing line.

6. The so-called Murphy suprapubic drainage is an absolutely useless disturbance.

7. A local drain to a suture line which is untrustworthy, in order to form a local track in case of a leak, is permissible; tubal and other forms of abdominal drain should never be used.

8. Small amounts of ether placed in the peritoneal cavity, in order to produce leukocytosis, finds favor with some surgeons. Flushing of the cavity is inadvisable.

Conclusions Adopted by the Inter-allied Surgical Conference (1917).

1. *Treatment in the Regimental Aid Station.*—As soon as a rapid, visual, diagnosis of abdominal wound has been made, 10 c.c. of camphorated oil should be given hypodermically, but no morphin. A dry sterile dressing and snug abdominal bandage should be applied, and the wounded soldier evacuated to the nearest operative center.

Great care should be taken not to miss the diagnosis of an abdominal wound, because the wound of entrance is thoracic, lumbar, or in the buttocks.

Transportation in the semireclining position is best, and these cases should be evacuated to a special surgical center, placed as near as possible to the firing lines. This center should obtain its personnel and equipment from an evacuation hospital in the same zone.

2. *Treatment in the Advanced Surgical Center.*—This center should, if possible, be underground, possess electric lights,

proper heating facilities and a mobile *x*-ray installation, the latter being indispensable.

As a general principle, every recent abdominal wound should be operated upon, except when the lesion only appears to involve the liver or kidney, without symptoms of severe hemorrhage.

The laparotomy should be performed as rapidly as possible, except when the wounded man is in shock. When there is any doubt as to the relative importance of shock and hemorrhage, it is best to operate. After an elapsed time of thirty-six hours, it is best not to perform routine operations.

It is necessary to have, as near to the firing line as possible, complete surgical centers where these wounds can be operated upon by competent surgeons.

CHAPTER XVII.

WOUNDS OF THE BLADDER, PERIANAL REGION AND EXTERNAL GENITALIA.

WOUNDS OF THE BLADDER.

Etiology.—Wounds of the bladder have not been infrequent. They may be:

(*a*) Perforating wounds from bullets (rare).

(*b*) Stab wounds (sword, bayonet, knife, etc.).

(*c*) Lacerating wounds from bombs, shell fragments, hand grenades, aërial torpedoes, etc.

In the latter type the wounds of entrance may be multiple and the fragments frequently perforate the bladder from side to side. One should suspect the possibility of an injury of the bladder in all deeply lacerated wounds of the buttock.

Symptoms.—Severe shock.

Abdominal pain radiating toward the lumbar region, the groin and external genitalia.

Violent desire to urinate; if small quantities of urine are expelled the fluid is bloody and contains bubbles of air (frothy urine).

Distended abdomen, usually without any well-defined area of tenderness.

The wound may rarely be punctiform; usually it is irregular and jagged in character, with or without concomitant fracture of the ischium, pubis or iliac bones. Urine may be detected oozing from the wound; usually it is masked by the presence of large amounts of blood.

Catheterization will either be negative or a mixture of blood and urine may be withdrawn. Injections of saline or other solutions should not be resorted to for diagnostic purposes. If the bladder has merely been contused, distention may produce a rupture of its walls; if already torn, dissemination of saline with urine and blood throughout the peritoneal cavity is disastrous.

Rectal examination should never be omitted, as it may give valuable information regarding the direction and extent of the wound.

Two radiographs should be taken, with the patient alternately in the dorsal or ventral position.

COMPLICATIONS.—Hematoma of the pelvic cavity.

Urinary extravasation:

1. Into the abdominal parieties.
2. Into the prevesical space of Retzius.
3. Into the general peritoneal cavity.

These extravasations lead to urinary phlegmons, secondary septic hemorrhages and to general peritonitis.

TREATMENT.—The prognosis of intravesical wounds is a grave one and can only be bettered through early and complete surgical intervention, because an intraperitoneal vesical wound always produces peritonitis and extraperitoneal vesical injuries lead to urinary infiltration.

Vesical wounds caused by bullets or minute shell fragments may occasionally heal spontaneously after the introduction of a permanent catheter through the urethra. This, however, is a rare outcome and does not justify an expectant attitude.

A suprapubic cystotomy is clearly indicated in practically all penetrating wounds of the bladder if the wound is in the pelvic region:

Operative Technic.—Suprapubic median incision; if the wound is near the median line, excise the lacerated tissues *en masse;* when the wound is lateral, excise the track of the wound and follow this by a median incision, which gives a better exposure of the bladder.

When the peritoneum is reached, determine whether or not the wound is intra- or extraperitoneal.

In case of an extraperitoneal wound, push the peritoneal fold upward, seize the edges of the vesical wound with forceps or sutures and explore the bladder for projectiles, which should invariably be removed. Close the vesical tear by means of two tiers of sutures. Leave a drain in the prevesical space and introduce a permanent catheter through the urethra. If the bladder walls are too lacerated for primary closure, a cystostomy is necessary, leaving the drainage tube in the upper portion of the bladder wound in order to avoid contamination of the prevesical space. Leave the drain in the bladder for at least eight days; the catheter should be changed every second day and daily irrigations of the bladder with boric acid or normal saline solution should be instituted.

In the case of an intraperitoneal wound, put the patient in the reverse Trendelenburg position. Examine the bladder and remove all fragments, blood-clots, etc.

If the wound is a well-defined one, *i. e.*, not too irregular or too lacerated, close it by a double row of interrupted sutures, the first row producing an invagination of the serosa, the second row reinforcing the first. This technic is easy if the wound is situated on the anterior or posterior-superior surface of the bladder; it becomes difficult or even impossible when the laceration is on the posterior-inferior portion, or is very extensive and irregular. In the latter cases, if the vesical wound cannot be closed, cleanse the pelvic cavity very carefully, coapt the torn vesical edges to the rectus fasciæ, and place a large cigarette drain behind the bladder. Leave a large vesical drain and a rubber catheter in the urethra. Aspiration through the pelvic drainage tube should be instituted three times daily.

In perineal wounds the rule is to find an extraperitoneal wound of the bladder. Excise all lacerated tissues in order to minimize urinary infiltration, but avoid any attempt at suturing of the bladder walls. Drain the perineal wound and introduce a permanent urethral catheter. If, following this technic, urinary infiltration should manifest itself, a cystostomy should immediately be performed.

With a concomitant lesion of the rectum, a wide excision is necessary, in order to afford free exit to all excreta. A cystostomy will usually be necessary in these cases.

Non-penetrating Wounds of the Bladder.—Several cases have been reported in which shell fragments or bullets were found embedded in the bladder wall, without penetration. The symptoms were those of a hematoma of the iliac fossa, with a loosening of the parietal peritoneum and a gradual extension into the pelvis on one or the other side of the bladder. Dysuria was the only functional disturbance noted. Treatment of these cases consists in free incision and drainage of the hematoma and removal of the projectile under fluoroscopic control.

WOUNDS OF THE PERIANAL REGION AND EXTERNAL GENITALIA.

Wounds of the perianal region, while infrequent, deserve special consideration on account of the severity of the infection which accompanies them. In addition to the common pyogenic organisms and anaërobes which gain access to the wounds, they invariably become infected by the colon bacillus group as well. These wounds are not infrequently associated with compound fractures of the sacrum, ischial tuberosities or pubis.

Wounds of the external genitalia are frequently mutilating. They are also dangerous on account of injuries to the urethra, with extravasation of urine or urinary retention.

Etiology.—In a majority of cases these wounds are caused by grenades or bombs. During surprise attacks the men may be bombed while lying down, or they are struck while passing, in a stooped position, from one trench section to another.

DIAGNOSIS.—All of these wounds are lacerated, with or without involvement of the rectum or lower sigmoid. There may be a laceration of the ischiorectal fossa on one side, with a mere contusion of the rectum, or both fossæ and sphincters may be lacerated.

Wounds of the external genitalia include those involving the penis, scrotum, testes or urethra.

Hemorrhage from the inferior hemorrhoidal vessels, from the dorsalis penis, the corpora cavernosa or the spermatic plexus of veins may be extremely severe.

TREATMENT.—1. *Perianal Wounds.*—(*a*) *Of the Soft Tissues Only.*—Check all hemorrhage by means of forci-pressure or ligature. Cleanse the wound thoroughly of foreign bodies; trim off all devitalized tissues but save as much as possible of the sphincter muscles.

(*b*) *Associated with Compound Fractures.*—Check hemorrhage. Remove all loose fragments of bone as well as all devitalized tissues.

Never attempt a primary repair of a perianal wound. Place rubber tubing in every pocket, with light gauze packing around the tubes, and irrigate with hypochlorite solution. Always give morphin or opium to lock the bowels during transportation of the patient to the rear.

2. *Wounds of the External Genitalia.*—(*a*) *Wounds of the Penis.*—Check hemorrhage; ligation of the dorsalis penis artery may be necessary. If the pendulous urethra is wounded, but the patient is able to urinate, even feebly, do not introduce a catheter. Dress the wounds very lightly with moist dressings and apply a suspensory bandage.

If the patient is unable to void and the bladder is distended, catheterize patient if possible; it will be rarely necessary to do a suprapubic cystotomy for a wound involving only the pendulous urethra.

(*b*) *Wounds of the Bulbous Urethra.*—Often associated with compound fractures of the ischial rami, tuberosities or pubis. Always try to pass a catheter through the penis into the bladder or from the wound into the bladder. If successful, retain the catheter by means of a silk suture. Provide for ample drainage of the wound and keep the dressings moist. Whenever possible, provide some receptacle for the urine while patient is being transported. If unable to pass the catheter, do a suprapubic cystotomy.

(*c*) *Wounds of the Scrotum and Testes.*—Hemorrhage may require forcipressure or ligature.

Primary castration should never be attempted unless the testis is so lacerated as to be manifestly non-viable.

Never attempt any reparative work of these wounds in the zone of the advance. They are all infected, all require irrigation and drainage; primary suture is disastrous.

Technic of Suprapubic Cystotomy.—Preparation of Field of Operation (see General Treatment of Wounds).

Moderate Trendelenburg position if possible.

Median incision three inches long, beginning at the upper border of the pubic symphysis.

Locate the linea alba and separate the muscle fibers by blunt dissection. A few muscle fibers will have to be incised at the lower end of the wound.

Identify and press back the prevesical fat; clamp or ligate any small bleeding vessels.

If the bladder is empty, great care is needed in order not to enter the peritoneal cavity. Should this accident occur, close the peritoneal wound with a double row of silk sutures and seek the bladder wall close to the superior border of the pubes.

If in doubt, seize the bladder in the median line with blunt forceps and plunge a trocar into it. If urine escapes on removal of the plunger, pull out the trocar and enlarge the opening sufficiently to introduce a soft medium-sized catheter.

Close opening around catheter by a double purse-string suture.

Close the wound with interrupted silk sutures with the catheter passing out at the upper angle of the wound in order to avoid infecting the prevesical space of Retzius, and anchor the catheter by means of adhesive strips.

Dress the wound with dry dressings and provide a receptacle for the urine if possible; otherwise anchor the catheter to one side of the body and apply a large cotton or gauze dressing over the end of the catheter.

The operation should be performed under local anesthesia.

CHAPTER XVIII.

SPINAL INJURIES.

General Considerations.—Wounds of the vertebræ and spinal cord have been rather rare, as compared to those of the cranium and brain. The salient fact, brought out by a group study of these cases, is the extreme sensitiveness of the cord to external trauma. A slight, superficial wound in the neighborhood of the spinal cord may produce a medullary lesion.

Owing to the extent of the injury inflicted by the missile and the presence of other complicating wounds a majority of these cases will be found unsuitable for operation.

When amenable to surgical relief they should be operated upon in a field or evacuation hospital.

In all spinal injury cases the diagnosis tag should always have the words "watch bladder" or "examine bladder" written on it before evacuation to the rear. This is imperative. Nevertheless, the danger of infecting the bladder through catheterization should be borne in mind. It is believed by some surgeons that an overdistended bladder, if paralyzed, will empty itself spontaneously if let alone; also that relief of intraspinal pressure by lumbar puncture will temporarily restore bladder tonicity.

The administration of urotropin (grs. v to xx every four hours) cannot be begun too early.

Wounds of the Vertebræ.—1. *Bullet Wounds.*—These usually produce perforations which may be anteroposterior, transverse or oblique in direction. The result is usually a "bursting" fracture of the bony column. The vertebral bodies are similar to epiphyses in that they offer no resistance to the impact of the bullet, but tend to pulpify without forming large fragments.

The neural arch with its apophyses, reacts like a long bone, trauma producing fractures with free or loose fragments; the latter may directly wound the cord or its meninges. Larger fragments are often displaced within the medullary canal, producing compression of the cord or of the spinal nerve roots.

These wounds are frequently associated with wounds of the pleuræ, lungs, abdomen, etc.

Partially expended bullets may occasionally pass through the soft tissues and produce various fractures of the spinous processes, laminæ, transverse processes, or of the vertebral body, with dislocation of fragments into the spinal canal.

Shell, torpedo, grenade fragments, etc., rarely produce perforating wounds of the cord. After fracturing the bony arch, these fragments are usually found either external to the vertebræ or in the spinal canal.

Meningeal and Cord Lesions.—(*a*) *Hematorrachis* (Frequent).—Either a bullet or, more frequently, a bone fragment produces a wound of the venous plexus of the cord with development of a hematoma. The hemorrhage also frequently arises from the spongy part of the vertebral body, the blood infiltrating itself between the bony canal and the dura, causing compression symptoms.

(*b*) Lacerations of the dura may be caused by either projectile or bone fragment.

(*c*) Lacerations of the pia sometimes lead to fairly severe meningeal hemorrhages.

(*d*) Medullary and root lesions.

Frequently very extensive; occasionally a complete section of the cord may be produced. Severe medullary lesions may exist without perforation of the dura, especially when the vertebral laminæ are dislocated anteriorly.

Many cases have been noted of localized medullary contusions, infarcts and hematomyelias, without any penetration of the spinal cord by the projectile.

Root lesions consist in contusions and partial or complete sections.

SYMPTOMS.—(*a*) *Syndrome of Complete Cord Section.*—Immediate, complete flaccid paraplegia, with absolute anesthesia below the lesion. If the lesion is a cervical one, a quadruple paralysis will usually be found. Superficial and deep sensibility are equally and totally abolished. Tendon reflexes are always abolished. Urinary retention is a constant symptom.

(*b*) *Syndrome of Incomplete Cord Interruption.*—Varies with the location and extent of the lesion. Anesthesia is not complete, although normal sensibility may be present in a very restricted area, such as the ano-perineo-genital region (Donnet and Denolle). Motor disturbances may only involve an extremity or group of muscles. Tendon reflexes are more often exaggerated than abolished.

In cervical lesions Pierre Marie distinguishes two distinct clinical types:

1. Precocious, Generalized Type.—Transverse perforation of the cord in the cervical region.

Immediate quadriplegia.

Involuntary genito-anal movements.

Violent neuritic pains, most pronounced near the spinal nerve roots, involving all four extremities and appearing a few hours or days after the infliction of the wound.

Retrogressive changes in a few weeks or months, the quadriplegia becoming a hemiplegia and finally a brachial monoplegia.

Retrogression of neuritic pains in the same order.

Permanent or semipermanent brachial monoplegia.

2. Limited and Progressive Type.—Anteroposterior perforation of the cord in the cervical region.

Immediate loss of consciousness.

Complete flaccid paralysis of the upper extremity on the side of the lesion.

Neuritic root pains within a few days.

Paralysis of the lower limb of same side within a few days or weeks, with gradual improvement of same.

Partial involvement of the upper extremity of the opposite side, especially of the hand, with alternating progressive and retrogressive symptoms, which finally tend to disappear.

The original brachial monoplegia only improves very slowly.

The Brown-Séquard syndrome has been noted in several cases:

Produced by a hemisection of the cord it is clinically manifested by a direct hemiplegia or hemiparaplegia with crossed hemianesthesia.

TREATMENT.—(*a*) *In the Battalion or Regimental Aid Station.*—Treat the shock. Ether cleansing of the wound and application of a dry sterile dressing.

Immobilization: The lateral prone position strapped to a suitable board or stretcher, enables transportation to be accomplished with a minimum of discomfort.

(*b*) *In the Field or Evacuation Hospital.*—A skiagraph should be immediately taken of all spinal cases. A neurological examination is necessary in order to determine whether a given case needs intervention or if it should be placed under observation.

Contra-indications to Immediate Operation are:

(*a*) Presence of a meningomyelitis.

(*b*) Hematorrachis or pachymeningitis, as these lesions frequently retrogress favorably.

(*c*) Vascular lesions (hemorrhagic infiltration, infarcts and hematomyelitic softening of the cord, in which case surgical intervention will produce no change.

(*d*) Perforating wound of the spinal cord from a bullet, with syndrome of complete section.

(*e*) Syndrome of incomplete cord section produced by a bullet wound. Spontaneous regression may occur.

Such cases should be put under observation in a base hospital.

Indications for Immediate Operation are:

(*a*) All spinal lesions produced by shell fragments require early operation in order to disinfect the wound track and prevent meningitis. If the patient's condition is poor (shock, other wounds, etc.), the operation should consist in a rapid excision *en masse* of the wound and removal of loose bone fragments, particles of clothing and shell fragments if the latter are readily accessible.

(*b*) If the patient's condition is satisfactory and the skiagraph reveals a fragment of bone in the canal, or a fracture of the neural arch, a typical laminectomy should be performed. The Italian surgeons prefer a unilateral laminectomy.

(*c*) Unbearable pain may constitute an indication for operative interference even in the absence of definite clinical findings.

Technic of Laminectomy (Adapted to War Conditions).—Localization of the projectile or bone fragment by one of the standard roentgenographic methods.

Ventral or lateral position of the patient, the head slightly lowered in order to lessen the loss of cerebrospinal fluid.

Excision *en masse* of the track of the projectile; when this is done, all instruments used for the purpose should be laid aside.

Median incision, 20 cm. long, directly over the spinous processes.

Separation of the mass of muscles on either side of the spines; incision of the interspinous ligaments; hemostasis by compression and retraction of the muscles.

Section of the spinous processes of the two vertebræ nearest the lesion; section of the laminæ in the same manner, using the ordinary bone-cutting forceps for the purpose.

If a projectile is known to be in the wound, it is wiser to use the fluoroscope or compass a second time, in order to incise the dura at the proper level.

Open the dura by a vertical median incision; introduce catgut sutures through each free edge and use them as retractors. Remove the projectile with a pair of fine forceps; gently irrigate the wound with normal saline solution and close the dural opening with catgut sutures.

Close the wound by means of heavy silk or silver-wire sutures.

Dress the wound and immobilize the spine.

Conclusions.—No operative procedures should be attempted in battalion or regimental aid stations.

The non-operable cases should be evacuated to a base hospital as soon as their general condition enables them to stand the journey.

Operable cases should be treated in a field or evacuation hospital, where they can remain until all danger of meningomyelitis has passed.

It is well to remember that slight local injuries or even contusions are often associated with extensive edema, hemorrhage, softening of the cord and ascending cavity formation. The safest guide to the severity of the injury is afforded by the form and character of the sensory disturbances and especially by the changes and modifications in the reflexes of the affected limbs (abolition of tendon-jerks, absent Babinski, etc.). Concomitant findings are subnormal temperature, slow pulse, low blood-pressure and scanty urine.

The state of tone in the muscles of the lower extremities is a good index of the progress or stationary condition of the case: Flaccid and toneless muscles indicate a severe lesion. Preservation of tone, even in the presence of paralysis is a hopeful sign. Return of tendon reflexes and of the Babinski sign gives a hopeful prognosis.

Severe indirect injuries of the spinal cord may occur from the bursting of high-explosive shells, when the back is turned toward the force of explosion, without any detectable wound, without any lesion of the bones and even without any bruising of the soft tissues. The clinical picture is that of total transverse lesion of the spinal cord at a variable level. The skiagrams reveal no signs of injury to the spinal column.

It has been suggested that the lesions are due either to a subluxation of the vertebræ, immediately reduced, or to impaction producing spinal concussion. The prognosis is bad; no improvement has been reported several months after the trauma occurred.

CHAPTER XIX.

WOUNDS OF THE PERIPHERAL NERVES.

General Considerations.—The frequency of peripheral nerve wounds has been one of the surprises of the present war. Approximately 20 per cent. of all wounds involving the limbs are associated with nerve lesions; hence the extreme importance of making routine neurological examinations in all wounds, but especially in those of the upper or lower extremities. Their early recognition will either enable the surgeon to attempt a primary suture or, if sepsis contra-indicates the operation, to note the lesion on the diagnosis tag before evacuating the wounded man to the rear. Furthermore, the early application of suitable splints and massage will obviate or retard contractures and muscle atrophy.

In view of the fact that nerve lesions are often unrecognized, it has seemed best to briefly review the most practical diagnostic points in a neurological examination, and to outline the main symptoms of the commoner peripheral nerve lesions. An early and accurate diagnosis will avoid useless electrotherapy and massage of muscles whose nerve has been totally severed, and, conversely, will avoid useless freeing of nerves which have simply been compressed, irritated or which are undergoing spontaneous *restitutio ad integrum*. Of equal importance is the differential diagnosis between organic nerve lesions and functional paralyses or impotence. It is only by making an early diagnosis and recording it on the diagnosis tag that the severity and probable end-results of the lesion can be estimated, and exact functional prognosis formulated and proper treatment instituted.

Frequency of Involvement.—An analysis of 628 cases by Tinel and Déjerine (*les blessures des nerfs*), added to similar reports made by other surgeons and neurologists, gives the incidence of frequency as follows:

1. Musculospiral nerve (radial).
2. Ulnar.
3. Median.
4. Sciatic and its branches (exterior popliteal).
5. Brachial plexus.
6. Lumbosacral plexus.

ETIOLOGY.—Peripheral nerves may be wounded either directly or indirectly. Direct wounds are caused by bullets, bayonets, shell fragments or splinters of bone, causing lacerations, crushing injuries, punctured wounds or complete sectioning of the nerve trunk. Very small shell fragments may penetrate the nerve sheath and lodge in nerve tissue, producing partial or complete paralysis The nerve may be contused as by shock of a bursting shell, or compressed by a bone fragment or the weight of rocks, sand or dirt resulting from a mine explosion. Contusion of the nerve may be followed by an interstitial hemorrhage leading to loss of function. Finally the brachial plexus has been strained and even torn by sudden violent traction, following mine explosions, etc.

PATHOLOGY.—Briefly stated, the following macroscopic lesions are encountered:

(*a*) Contusions associated with hemorrhagic infiltration of the nerve sheath, followed later in some cases by a fibrous infiltration which replaces the blood-clot. This type of lesion is manifested clinically by nerve irritation phenomena (neuralgic pains).

(*b*) Compression of a nerve trunk, extending for a variable distance, usually involving a few of its fibers and manifested clinically by partial motor or sensory disturbances over a relatively small area.

(*c*) Lacerations, crushing injuries or perforations of the nerve, involving all or only a portion of its fibers, with late formation of an interstitial, total, central or lateral neuroma, the clinical picture being extremely variable.

(*d*) Complete or partial section of a nerve, with late interposition or cicatricial formations resulting in total motor, sensory of mixed paralysis of the parts involved.

DIAGNOSIS.—(*a*) *By Direct Examination of the Wound.*— The mere site and extent of the wound may be sufficient to make a diagnosis of probable nerve lesion. In the surgical treatment of the wound, the injured nerve will often be encountered. While excising all devitalized tissues, one should constantly have in mind the nervous and vascular anatomy of the parts in order to avoid injury to these vital tissues.

(*b*) *By Clinical Examination.*—The attitude of the limb is often pathognomonic of the lesion (wrist-drop, claw-hand, foot-drop, etc.).

Voluntary motility; possible errors:

(*a*) Atony of a muscle may closely simulate paralysis.

(*b*) Complete or partial ankylosis of a neighboring joint may lead to confusion.

(*c*) Malingering: In all suspicious cases, test the muscle with the faradic current. In the absence of a cerebral lesion, malingering is recognized whenever normal faradic reaction of the muscle or group of muscles is present.

Testing of Reflexes.—(*a*) Every peripheral muscle paralysis is associated with disappearance of its reflex. Whenever a paralyzed muscle reacts to its reflex the disturbance is either due to a central lesion or is functional in character.

(*b*) In peripheral paralyses the phenomenon of "inversion of reflex" (Déjerine) is frequently observed. The paralyzed muscle does not respond but its neighboring or antagonistic muscles contract. For instance, in a triceps paralysis percussion of the olecranon will cause a contraction of the biceps.

Objective Examination of Muscles.—(*a*) Muscle Atrophy.— This sign only appears two or three weeks after the occurrence of the lesion; hence it is of little diagnostic value in advance sanitary formations.

(*b*) Muscle Tonus.—By muscle tonus is meant the latent, permanent contraction of a normal muscle at rest. In complete section of a nerve, muscular hypotonus manifests itself rapidly; in simple nerve compressions a certain degree of tonus remains.

(*c*) Mechanical Contractility of Muscle Tissue.—It is important to distinguish between muscle tonus and "idiomuscular reflectivity." Percussion of a normal muscle causes a local, transitory swelling of the muscle sheaths, a genuine contraction to which the term idiomuscular reflex is given. This reflex is always exaggerated in peripheral nerve lesions, *i. e.*, the contraction of the paralyzed muscle is slower and lasts longer than in the normal (mechanical myodiagnosis of Sicard). With the appearance of muscle atrophy this symptom tends to disappear.

(*d*) Pressure Sensitiveness of the Paralyzed Muscle.—In total paralyses, pressure over or pinching of the muscle is painless; one of the most valuable symptoms of nerve irritation is the pain elicited by this test.

(*e*) Fibrous Shortening of the Muscle.—While nerve compression, and especially nerve section, is clinically manifested by hypotonus, flaccidity and progressive lengthening of the muscle, nerve irritation is almost always followed by shortening of the muscle through a fibrosis of its elements (this sign will only be occasionally observed in advance sanitary formations, but should be kept in mind).

Trophic and Vasomotor Disturbances.—These are always late manifestations and will merely be mentioned for the sake of completeness. Trophic disturbances are either absent or very slight in nerve sections or severe nerve compressions; they are almost constant in nerve irritations. The most important are:

(*a*) Glossy skin.
(*b*) Hyperidrosis.
(*c*) Dyshydrosis.
(*d*) Ichthyosis.
(*e*) Cutaneous desquamation *en plaque.*

Vasomotor disturbances are almost constant late manifestations of all nerve lesions. Among them may be mentioned:

(*a*) Paleness of skin (rare).
(*b*) Cyanosis and redness (common).
(*c*) Edema (usually due to posture and inaction).
(*d*) Ulceration.
(*e*) Thermic disturbances.
(*f*) Hypertrichosis (nails).

Sensory Examination.—The simple pin examination is usually sufficient. Three zones can be differentiated:

(*a*) Zone of complete anesthesia (superficial and deep).

(*b*) Zone of superficial anesthesia with preservation of deep sensibility.

(*c*) Zone of superficial hypesthesia. The permanency and immovability of the anesthetic area is one of the most valuable signs of complete nerve interruption.

Objective Examination of the Nerve Itself.—(*a*) Pressure Sensitiveness of the Nerve.—Pressure over the nerve trunk is painless in all cases of section or severe compression; it is extremely painful in case of nerve irritation.

(*b*) Pressure formication (*fourmillement*) is a late manifestation. If slight pressure or percussion of the nerve causes formication, it indicates the presence of young regenerating axis-cylinders. The fixity of formication at the level of the lesion, and its total absence below the lesion, indicate complete nerve interruption. Occasionally this symptom may appear as early as the fourth week, and persists throughout the entire regenerative period (eight to twelve months).

Electrodiagnosis (Faradism, Galvanism).—These methods are of little practical value in the zone of the advance.

Absence of faradic irritability always accompanies complete peripheral nerve lesions. It constitutes one of the earliest signs of the reaction of degeneration and only reappears late, after voluntary muscle contractions have manifested themselves. There are only two exceptions to this rule:

(*a*) Very recent paralyses where the reaction of degeneration is not yet present.

(*b*) In cases of slight nerve compression (Erb), where the nerve and muscle are excitable below the seat of the lesion, while the nerve above the lesion does not respond.

The galvanic current reveals a diminution or absence of excitability of the nerve itself while there is only a slight hypoexcitability of the muscle.

Clinical Syndromes.—The most important and most difficult problem to solve in peripheral paralyses is a determination of the lesion. On its correct interpretation depends the indication or contra-indication for surgical intervention. Déjerine and Mouzon have been able to describe four fundamental syndromes: those of interruption, compression, irritation and regeneration.

(*a*) *Syndrome of Interruption.*—This is present in cases of complete nerve section, of severe compression, of laceration or of crushing of the nerve trunk followed by the formation of a fibrous cicatrix. Clinically it is characterized by:

1. Immediate and complete paralysis of the corresponding muscle or group of muscles.

2. Rapid and progressive disappearance of muscle tonus.

3. Progressive, regular and massive muscle atrophy.

4. Reaction of degeneration appearing gradually within two or three weeks and progressing to its complete classical manifestation.

5. Immediate, complete and stationary anesthesia of the innervated zone.

6. Absence of spontaneous or provoked pain both in the nerve and muscle.

7. Absence of formication on pressure over the nerve below the lesion.

8. Absence of trophic changes (as a rule).

(*b*) *Syndrome of Compression.*—By nerve compression is meant a local disorganization which temporarily obtunds the physiological conductivity of the nerve fibers without death of these same fibers. It is clinically manifested by:

1. More or less complete paralysis; usually as complete as in the syndrome of complete section.

2. Less rapid and less intense muscular atrophy.

3. Preservation of muscle tonus (relative).

4. Partial and incomplete reaction of degeneration, appearing late and progressing more slowly.

5. Anesthesia which is variable in extent and intensity.

6. Absence of painful sensations on pressure over the nerve, with frequent retention of muscle pain.

7. Absence of formication.

8. Almost total absence of trophic disturbances.

(*c*) *Syndrome of Irritation.*—Severe neuritic type (mixed nerves only):

1. Paralysis always present but often incomplete, with only partial reaction of degeneration.

2. Variable degree of muscular atrophy.

3. Preservation of muscle tonus as a rule.

4. Painful sensory disturbances appearing some time after the appearance of motor paralysis. The pain may be spontaneous, resembling that of burns, or it may be pricking or stinging in character; it is increased by movements, by muscular contractions, by heat, cold or light contact of clothes, bed-sheets, etc. Cutaneous hyperesthesia is also present, often associated with tactile and thermic hypesthesia. All of these cutaneous excitations are very painful, poorly localized, poorly differentiated, diffuse, irradiating and lasting for a few seconds at a time.

Trophic changes are extremely severe. Extreme dryness of the skin, with fibrous infiltration and lamellar desquamation; profuse fetid sweating or classical glossy skin; claw-nails with cracks, fissures, striations, etc., conical atrophy of digital extremities, marked contractures and fibrous ankyloses are frequently encountered in the later stages.

Mild Neuritic Type.—An attenuated form of the severe form.

Simple Neuralgic Type.—This is caused by slight contusions or compressions of a nerve. It is manifested clinically by more or less acute pains, radiating along the course of the nerve, increased or provoked by extension of the limb (median, sciatic). There is no anesthesia but rather a slight hyperesthesia; no paralysis but a weakness of the muscles involved, without any change in electrical reaction.

Intense Neuralgic Type (causalgia of Weir Mitchell). Characterized by violent burning pains, especially in the nerve-endings (palm of the hand, plantar surface of the foot), increased by movements, pressure, thermic and atmospheric changes, violent emotions, etc. There is no paralysis but trophic changes are common (glossy skin).

The Syndrome of Regeneration (late) rarely begins before the fourth or fifth week and is manifested by:

1. Reappearance of formication on pressure.
2. Return of electric reaction.
3. Reappearance of muscle tonus and muscle sensibility; return of voluntary motion.
4. Diminution and disappearance of anesthetic zones.

Differential Diagnosis.—This is strictly limited to a consideration of traumatic peripheral nerve lesions. The most important differentiation lies between nerve wounds and functional paralyses, the latter being very frequent and often puzzling. Following war wounds, typical hysterical paralyses are often encountered and should be recognized by the following common characteristics:

1. Paradoxical character (manifest disproportion between

the location and severity of the wound and the extent of the pseudoparalytic troubles).

2. The paralysis does not correspond to any definite anatomical area; it may involve an entire limb or segment of limb. *Functions rather than movements are paralyzed.*

3. The accompanying anesthesia is massive, absolute and paradoxical (segmental anesthesia).

4. There is no loss of tonus or of reflexes; there is no muscular atrophy, and trophic disturbances are unknown.

5. The electric reactions are normal or nearly so.

6. Mentally, the attitude of the wounded soldier is very characteristic: He shuns all effort; he has no desire to get well; he is mentally and physically inert.

It is well to remember also that pseudoparalyses may occur after prolonged inactivity (immobilization); as the result of severe pain; as a sequence of contractions of antagonistic muscles and by autosuggestion, in cases of sensory paralyses, the patient concluding that, because he has lost the power of sensation he cannot have the power of motion in the same limb.

Ischemic paralyses may often be difficult to differentiate from nerve-wound disturbances, especially when associated with neuritic irritation syndromes. Its etiological factors are ligation or thrombosis of the subclavian, axillary, brachial, femoral or popliteal arteries; an ischemic paralysis may also result from compressive dressings or plaster casts. In general it may be recognized by the fact that it presents no peripheral nerve topography but is essentially segmental and centrifugal in type (all symptoms are accentuated distally). Cyanosis, loss of heat, anesthesia and fibrous infiltration are always present.

Treatment.—(*a*) It is absolutely essential that a careful search for nerve lesions be made at the time a wound is being surgically treated. This includes direct examination of the wound itself, plus a thorough clinical examination whenever the site of the wound is in the neighborhood of an important nerve trunk.

(*b*) Whenever a peripheral nerve trunk is found to be totally severed, primary suture of same should be performed and the fact noted on the diagnosis tag. Before intervening, however, the presence or absence of infection must be ascertained. If the wound is a recent one (four to eight hours old), and all devitalized tissues can be surgically removed, leaving a clean surface, primary suture is absolutely indicated. In a doubtful or frankly septic wound, primary suture of the nerve will lead to disaster; not only will the sutures fail to hold, but additional traumatism and the spreading of septic material along the cut ends of the nerve will result, thus rendering future reparative attempts more difficult if not impossible. Under such circumstances it is much better to treat the wound itself, noting the nerve lesion on the diagnosis tag and reserving the repair for a base hospital after sepsis has cleared up.

Technic of Primary Nerve Suture.—The entire operation must be performed with the strictest regard for asepsis, the nerve elements must be handled with the utmost gentleness, the needle and suture material must be the very finest obtainable and the nerve-ends must not be subjected to undue tension. Disregard of these fundamental points will lead to failure of the operation. It is assumed, of course, that the wound itself has previously been treated according to the rules laid down elsewhere.

(*a*) *In Incomplete Section.*—Gently trim off badly lacerated nerve tissues, saving as much of the nerve sheath as possible. Carefully preserve the continuity of all the remaining nerve fibers. Utilize the torn sheath in order to cover the nerve fibers; if there is marked deficiency of nerve sheath, utilize a piece of neighboring fascia or a segment of fascia lata with which to surround the wounded nerve and prevent cicatricial adhesions. The suture material should be non-absorbable (fine silk, linen, horse hair); the needle must not be bayonet-tipped or have cutting edges and should be of the finest curved intestinal type. Complete closure of the entire wound without drainage will give the best prognosis.

(*b*) *In Complete Section.*—Freshen the edges so that the proximal and distal axis-cylinders appear in full view; bring the edges together and suture the periphery of the nerve by means of interrupted sutures, tied with a minimum of tension. Avoid twisting the ends of the nerve on their long axis. Protect the line of sutures with a fascial sheath of pedicle type if possible, or of fascia lata if none be available in the wound area. Contact of the two sections of nerve seems necessary for complete regeneration; when this is impossible to attain, the nerve ends should be brought as close together as possible by interrupted sutures. In a few cases it may be necessary to elongate the distal end by a sliding graft before sutures can be placed. The end-results in the last method are not encouraging because a portion of the nerve is sacrificed. If used, it is best to completely detach the segment of elongation and to suture it, end to end, to the two nerve segments. Whatever be the method of suture, the nerve must be protected from cicatricial adhesions by a covering of fascia. Matas (New Orleans) uses dental rubber instead of fascia with good results.

Nerve grafting, by heterogenous end implantation has, so far, given equivocal results.

Technic of Secondary Suture.—Reopen the wound if it has been sutured or has closed up; carefully search for the proximal and distal ends, using blunt dissection as much as possible in order to minimize fresh traumatism. Watch for any sign of muscle contraction which would indicate that some fibers of the nerve are still intact. It is often easier and safer to search for the normal nerve above and below the lesion, gradually working toward the latter and carefully freeing the lacerated ends from all fibrous tissue. Save all viable nerve elements if the section is incomplete, *i. e.*, preserve the continuity of nerve fibers wherever any are found. Thoroughly freshen the edges and suture as in primary suture. Protect the repair with a fascial sheath. One should guard against pseudocontinuity of nerve fiber in cases of total crushing or tearing of the nerve. The flattened, irregular and loose band of tissue found between the crushed nerve segments is often entirely composed of fibrous tissue. If such be the case, a clean section of nerve tissue must be made, exposing the axis-cylinders, before suturing. In all end-to-end suturing of nerves, it is important not to twist either the proximal or distal segments on their long axes, as by so doing defective regeneration may result, *i. e.*, motor fasciculi may be coapted to sensory or *vice versa*.

Results of Nerve Suture.—Primary suture of a totally severed nerve gives a good prognosis if the operation is delicately performed in an aseptic field, with careful hemostasis, and the wound remains clean.

Secondary suture of a totally severed nerve two to six months after the wound was inflicted, still gives a fair prognosis. In incomplete sections, at least partial restoration of function is the rule.

Conclusions.—(*a*) Over 50 per cent. of all war wounds of peripheral nerves have regenerated spontaneously (60 to 70 per cent. according to Tinel-Déjerine). This illustrates the importance of careful visual and clinical examination before surgical procedures are resorted to.

(*b*) If complete section of a nerve is diagnosed, the sooner it is sutured the better, provided the field of operation is clean or can be made clean. Secondary suture may, however, be undertaken as late as twelve to fifteen months after the infliction of the wound (Tinel).

(*c*) Exploratory incisions (secondary), carefully and aseptically performed, cannot injure the nerve and may reveal conditions amenable to surgical help.

(*d*) The freeing of a nerve embedded in fibrous or bony tissue will frequently restore its function.

(*e*) Regeneration of the musculospiral and external popliteal nerves seems more rapid and certain than that of other nerves.

(*f*) The ulnar, median and great sciatic nerves regenerate very slowly.

(*g*) After liberating or suturing a wounded nerve, mobilization and massage of the scar of the wound must be started as soon as its healing is complete. The same is true of faradization of the muscles involved; it should be begun early and continued until regeneration is either complete or the case has come to a stand-still.

SYMPTOMS OF THE COMMONER PERIPHERAL NERVE LESIONS.—(*a*) *Musculospiral Nerve.* 1. *Motor Syndrome.*—Semiflexion of forearm, wrist-drop, semiflexion of fingers, abductor paralysis of thumb, paralysis of supinator brevis.

An important point to remember is that the paralysis of the finger extensors only involves the first phalanges; the middle and distal phalanges are still able to extend on the proximal, through tendinous bands which pass from the interossei to the long extensors. Orthopedic appliances destined to correct wrist-drop need only extend the proximal phalanges (Tinel).

2. *Sensory Syndrome.*—The sensory disturbances are very slight as a rule. Anesthesia of the posterior part of the arm is rare because the internal cutaneous branch is only involved in lesions of the axilla. The external cutaneous is more often involved, but, clinically, one only finds a slight zone of hypesthesia over the external aspect of the arm and the posterior aspect of the forearm. In the hand, the clinical picture encountered is a zone of anesthesia involving the dorsal surfaces of the first and second metacarpals. It is in this area that the symptom of formication is present.

(*b*) *Ulnar Nerve.*—1. *Motor Syndrome.*—Paralysis of the dorsal and palmar interossei muscles is the one distinctive clinical picture produced by ulnar involvement. These muscles are flexors of the proximal phalanges on the metacarpals, and extensors of the middle and distal phalanges on the proximal. Flexion of the fingers is accomplished by a rolling in movement, the two distal phalanges flex first, followed by flexion of the proximal. Flexion of the proximal phalanges with extension of the two distal ones is impossible, *i. e.*, the patient cannot maintain his fingers at right angles to the hand. There are many other points of minor importance, but their elucidation is not essential, and requires a minute study only possible in a base hospital.

2. *Sensory Syndrome.*—On the palmar surface, anesthesia of the entire little finger and inner half of the ring finger; on the dorsal surface the little ring and inner half of the middle finger are involved.

(*c*) *Median Nerve.*—1. *Motor Syndrome.*—Loss of abduction and of flexion of the thumb with maintenance of adduction. The wounded man can hold an object between the first phalanx of the thumb and the base of the index finger, but he cannot hold it between the tips of the thumb and any of the other fingers. The thumb also assumes a position of slight external rotation. Flexion of the two distal phalanges of the index finger is lost.

2. *Sensory Syndrome.*—The zone of total anesthesia is usually limited to the palmar aspect of the thumb and both surfaces of the index finger, it markedly decreases as one approaches the zone of sensory innervation of the radial and ulnar nerves.

(*d*) *Branches of the Sciatic Nerve.*—1. *External Popliteal Nerve.*—(1) *Motor Syndrome.*—Loss of extensor movements of foot and toes (steppage gait).

Loss of internal rotation of foot.

Loss of abduction, outward rotation and extension of outer border of foot.

Gradual loss of plantar arch (flat-foot).

The simplest way to recognize a paralysis of the external popliteal nerve is to have the patient sit on a chair and ask him to raise the tip of the foot from the ground while keeping his heel in position (Pitre et Testut).

(2) *Sensory Syndrome.*—Anesthesia of the antero-external aspect of the leg and of a portion of its posterior aspect; anesthesia of the dorsum of the foot with the exception of its internal border and of the distal phalanges of the toes. Anesthesia is not constant or complete as a rule.

2. *Internal Popliteal Nerve.*—(1) *Motor Syndrome.*—A lesion of the internal popliteal nerve produces a paralysis of all of the posterior muscles of the leg and of all of the plantar muscles, manifested by loss of flexor movements of the foot, loss of flexion of the toes and a breaking down of the inner portion of the arch of the foot. In walking, the patient does not lift his heel from the ground and cannot raise himself on the tips of his toes. When seated, he cannot lift his heel by leaning on his toes (Pitre et Testut). The tendo Achillis and plantar reflexes are abolished. When at rest, the foot and toes are in extension or hyperextension.

(2) *Sensory Syndrome.*—Anesthesia of the posterior-inferior aspect of the leg (lower third), of the external border of the foot and external portion of its dorsal aspect up to a line which joins the third interdigital space and of the dorsal surfaces of the distal phalanges of the toes.

Posterior Tibial Nerve.—A continuation of the internal popliteal, it is frequently wounded or severed in perforating wounds of the leg or lacerated wounds of the ankle and its lesions are frequently unrecognized. The clinical picture is usually that of paralysis of the plantar muscles and partial anesthesia of the plantar surface of the foot. There occurs a rapid atrophy of the plantar muscles increasing the concavity of the plantar arch (hollow foot, *pied creux*). The toes assume a peculiar claw shape; the first phalanges are in hyperextension while the two distal ones are strongly flexed.

Paralysis of the Sciatic Nerve.—This involves all of the posterior thigh muscles in addition to the syndromes of internal and external popliteal nerve lesions. The same steppage gait is seen, atrophy of the limb is massive and severe, sensory, trophic and vasomotor disturbances are more marked. The chief characteristic of sciatic lesions is the frequency of partial lesions and of dissociated syndromes. One frequently observes a complete paralysis of the internal popliteal with little or no involvement of the external popliteal.

(*e*) *Brachial Plexus.*—Wounds of the brachial plexus may involve its roots, its primary or secondary trunks or divisions of the latter. The clinical picture will present variable and frequently complex syndromes.

1. *Root Syndromes* (Roots and Primary Trunks).—(*a*) Superior root group (fifth and sixth cervical).

Characterized essentially by a paralysis of the following muscles:

Deltoid (circumflex nerve).
Biceps and brachialis anticus (musculocutaneous nerve).
Supinator longus (musculospiral).
Pectoralis major (clavicular portion).
Supra- and infraspinatus.
Subscapularis.

The zone of hypesthesia extends along the external border of the arm and forearm.

(*b*) *Middle Root* (Seventh Cervical).—Essentially a musculospiral nerve paralysis, with the exception of the supinator longus muscle, which remains intact. The triceps is weakened but not entirely paralyzed because it receives nerve fibers from the sixth cervical. The sensory disturbance is restricted to a thin band of slight hypesthesia extending along the dorsal aspect of the forearm and the dorsi-external portion of the hand.

(*c*) *Inferior Root* (Eighth Cervical and First Dorsal).—Characterized by paralysis of the flexores digitorum, the flexor carpi ulnaris, the interossei and of the thenar and hypothenar muscles. It practically corresponds to an associated paralysis of the median and ulnar nerves, with flattened hand if section is complete, or monkey paw (*griffe simienne*) if there is only a neuritic irritation. The sensory disturbance is limited to a band of hypesthesia involving the internal aspect of the forearm with the exception of a triangular area innervated by the second and third dorsal roots.

2. *Trunk Syndromes* (Secondary Trunks and Branches).—(*a*) *Superior Trunk.*—Corresponds to a peripheral paralysis of the musculocutaneous and external root of the median nerves (involvement of the coracobrachialis, biceps and brachialis anterior muscles).

(*b*) *Posterior Trunk.*—Combined circumflex (deltoid muscle) and musculospiral nerve paralysis.

(*c*) *Inferior Trunk.*—Corresponds to a combined paralysis of the ulnar, internal root of the median and internal cutaneous nerves. With paralysis of the internal root of the median nerve there is found an involvement of the flexors of the fingers without any lesion of the palmaris longus, or of the pronator radii teres. When the external root of the median is affected, the pronator radii teres and palmaris longus muscles are especially involved.

(*f*) *Lumbosacral Plexus.*—Rifle and shrapnel bullets, fragments of high-explosives, etc., producing compound fractures of the lower dorsal or lumbar vertebræ, or penetrating the spinal canal; crushing injuries of the sacrum (mine explosions) and penetrating wounds of the pelvic cavity, all tend to involve the roots of this plexus.

1. *Lumbar Roots.*—(*a*) *First and Second Roots.*—Largely sensory in character. Section of these roots produces a slight weakness of the psoas, quadratus lumborum, lower portion of the transversalis and anterior thigh muscles. The zone of anesthesia includes the outer portion of the buttocks and anterior aspect of the thigh.

(*b*) *Third and Fourth Roots.*—Essentially motor nerves. The triceps, pectineus, sartorious, together with the adductors and internal rectus, are all involved in the lesion.

(*c*) *Fourth and Fifth Roots.*—Clinically manifested by a weakening of the glutei, of the tensor of the fascia lata, of the posterior thigh muscles and especially of the anterior tibial. The anesthetic zone extends obliquely across the external aspect of the thigh, the antero-internal aspect of the knee and the inner side of the leg and foot.

2. *Sacral Roots.*—(*a*) *First and Second Roots.*—Essentially the syndrome of sciatic-nerve involvement, with the exception of the tibialis anticus. In the foot the adductors of the big toe and the interossei are completely involved. The anesthetic zone occupies the posterior aspect of the buttocks, the external aspect of the knee and leg, and the dorsal and plantar aspects of the foot as far as the first intermetacarpal space. The tendo Achillis reflex is abolished.

(*b*) *Third Sacral Roots.*—Sensory disturbances only; the anesthetic area forms a triangular space occupying the internal part of the buttocks and posterior part of the thigh down to its middle third.

(*c*) *Fourth and Fifth Roots.*—Manifested clinically by paralysis of the sphincters (incontinence of urine and feces). Anesthesia of the inner portion of the buttocks, the perineum, penis, and the postero-inferior portion of the scrotum will usually be found.

The only important differentiation lies between lumbosacral root lesions and lumbosacral hematomyelia. The latter may follow severe injuries of the vertebræ, but also occurs as the result of contusions and concussions following the bursting of mines, mortars, high-explosives, etc. (*paralysie par vent d'obus*). The sudden compression and decompression following these explosions causes multiple medullary hemorrhages. Differentiation is obtained by remembering that hematomyelia is a more diffuse process than could be found in a root lesion. "Dissociation of sensibility" is present and can be regarded as pathognomonic (painful and thermic anesthesia, with retention of tactile and deep sensitiveness).

CHAPTER XX.

GUNSHOT AND OTHER WOUNDS OF JOINTS.

General Considerations.—Joint wounds are of frequent occurrence on the western front. Only a small percentage of them are caused by rifle or mitrailleuse bullets; they are, as a rule, produced by fragments of high-explosive shells, hand grenades or bombs, causing extensive lacerations of soft tissues and bone. Their management has varied from one method to another principally in an endeavor to overcome the disastrous effects of infection. It may be safely stated, however, that the radical operative measures adopted during the first year of the war, have given way to more conservative measures. This result has been achieved through:

(*a*) Shortening of the time element. With rare exceptions, the wounded soldiers are now able to reach an adequately equipped surgical formation within eight hours, being therefore operated upon while the infection, if present, is still localized.

(*b*) Better individual hygiene both as regards the body and clothing of the soldier. The compulsory bath, new underwear and sterilization of the uniform before and after each six-day period in the trenches has been of almost incalculable benefit to the French army.

(*c*) Immediate immobilization and extension of the joint at the regimental aid station, even when no other treatment than an ether cleansing of the wound and the application of a dry sterile dressing is possible.

(*d*) Immediate and complete operation in the most advanced surgical formation consistent with the terrain, activity of the sector and available skilled personnel.

(*e*) Better understanding of joint synoviæ and of the mechanical principles of drainage.

As the knee-joint possesses the most complicated synovial membrane in the body, its wounds have been harder to treat satisfactorily and the ultimate results have been more serious than those of other joints.

Excision (Resection) versus Esquilectomy.—The chief controversy has been over the relative advantage of early primary resection of the joint and conservative removal of completely detached or aperiosteal fragments (esquilectomy). In favor of early excision may be adduced the following arguments:

(*a*) All loose fragments of bone and the articular surfaces are removed, leaving an even, clean-sawn surface rather than jagged ends of bone.

(*b*) Very free mechanical drainage is thus established.

(*c*) Good control of septic processes.

(*d*) Lessened convalescence (only true in the presence of sepsis).

(*e*) A possible movable joint (only desirable in elbow- and wrist-joint injuries).

The advantages of primary conservative esquilectomy are:

(*a*) Preservation of all viable articular fragments.

(*b*) Proper drainage, easily obtainable if the arthrotomy incisions are anatomically correct.

(*c*) Preservation of a portion at least of the articular surfaces and of the synovial capsule.

(*d*) Secondary excision is always possible and the results of late excision are usually superior to those obtained by the primary operation.

It is now definitely established that, as a primary operation, in the absence of marked sepsis, esquilectomy should always be preferred to excision.

Established Facts Regarding Joint Wounds in General.—(*a*) The wound of the soft tissues surrounding the joint is vastly more difficult to deal with than the articular cavity itself, and demands the most scrupulous care on the part of the surgeon.

(*b*) The synovial capsule itself is capable at times of dealing unaided with a severe grade infection.

(*c*) There is a strong tendency toward localization of an infection, even if it has invaded a portion of the joint, the remaining portion of the capsule may remain free.

(*d*) Ether, acting as a gas under tension, penetrates all parts of the synovial cavity of a joint more rapidly and more thoroughly than any other antiseptic. Its use in joint wounds is now well-nigh universal in all of the Allied armies as a cleansing agent, antiseptic and promotor of local and general hyperleukocytosis. It is used in the form of wet dressings, intra-articular injections and intermittent instillations. A 2 per cent. ether solution in lukewarm tap-water is used with success by Captain Bowen, R. A. M. C.

(*e*) Rubber-tube drainage left *in situ* for days is not only useless but harmful.

(*f*) A gunshot or shell fragment wound of a joint, treated early and properly, forms one of the best wounds for primary suture.

(*g*) Following primary surgical intervention, extension and immobilization are all important until the success of primary closure of the wound is assured.

Removal of Foreign Bodies in Joint Wounds.—(*a*) If the *x*-ray shows the metallic body to be intra-articular, it is best to remove it as a primary routine measure. This rule would not, of course, apply to cases where primary excision or amputation is indicated.

(*b*) Where the foreign body is extra-articular, unless it is readily accessible and can be removed without further traumatizing of the tissues, it should be left *in situ* and an expectant attitude assumed.

Anatomical Forms of Joint Wounds.—1. Wounds in which the articular lesion merely represents an element of a wholesale destruction of the limb in the neighborhood of the joint.

2. Articular fractures proper, including the majority of joint wounds. A projectile may be present in the synovial cavity or in the adjacent bone; or, having passed through the joint, it may be arrested in the ligaments or soft tissues outside. One or more bones may be involved, giving rise to multiform types of fracture.

An impression or gutter in the articular or non-articular surface of the bone may be made by the passage of the projectile.

The projectile may become embedded in the surface of the bone; fissures may and usually do radiate from the osseous cavity.

The projectile may be lodged in the substance of the bone, forming a cul-de-sac with or without fissuring. The latter condition is dependent on a lack of thickness in the shell of compact bone.

The projectile may have passed through the bone with or without fissuring. The latter possibility is only likely to be realized where the cortex of the bone is thin, as in the lower extremity of the femur. Where the compact layer is thicker, as in the upper end of the tibia, penetration is almost invariably accompanied by fissures.

One or more fragments of bone of varying size, from a small splinter to a large block such as a femoral condyle may become separated with or without dislocation.

Fissures may pass for a considerable distance into the shaft of the bone.

There may be much comminution of one or more of the osseous extremities.

3. Penetrating wounds of the joint without fracture, in which the projectile may or may not remain in the synovial cavity.

TREATMENT.—(*a*) *General Considerations.*—An *x*-ray diagnosis is imperative in all cases before any radical surgical procedure can be contemplated.

Shock may postpone an operation otherwise indicated.

The age of the wound is a factor of the greatest importance. Given the necessary surroundings and personnel, the earlier the primary or prophylactic form of treatment is applied, the better. During the first ten to twelve hours infection tends to be limited to its original focus of entrance. Tuffier even reports results almost uniformly good from operations performed as late as the third day of the injury. It is, however, best to drain all doubtful cases after a delay of twelve hours.

Marked toxemia, complicating an intra-articular wound may, in rare instances, necessitate amputation as the only rapid means of removing the source of infection.

A strictly conservative line of treatment is preferable to half-hearted operative measures.

Consistent with the patient's general safety, every effort must be made to anticipate unnecessary orthopedic disability.

First Aid.—At the regimental aid station, under the least satisfactory surroundings, it is best to limit the treatment to a simple ether cleansing of the wound after trimming off the surrounding clothing with scissors, without exposing too much body surface during the process. Treat the shock if present. Check hemorrhage by packing a sterile dressing in the wound, and immobilize the joint with extension in order to minimize the spread of infection. The modified hinge-joint Thomas arm or leg splint, reinforced if necessary, meets all requirements, including ease of transport by stretcher. It must be remembered, however, that immobilization loses its value as soon as all danger of infection has vanished. Early active mobilization is advocated in the evolution of all joint wounds. Gosset, Willems and Derache advise immediate immobilization; Depage and Tuffier prefer immobilization for eight to ten days, followed by active mobilization. For transportation purposes, immobilization lessens shock, lessens pain, minimizes hemorrhage and limits infection.

Expectant Treatment.—The perforating in-and-out type of wound, with punctiform cutaneous apertures of entrance and exit, give a very good prognosis. It is usually sufficient to cleanse the skin around the wounds and to immobilize the joint. The injection of ether or formalin-glycerin is strongly advocated by many surgeons.

Penetrating wounds, in which a rifle bullet or fragment of shell has lodged in the substance of an articular extremity after passing through the synovial cavity, creating an insignificant wound of entrance and no obvious fissuring of bone, may be treated expectantly.

1. If the removal of the foreign body entails considerable derangement of the joint and enlargement of the osseous tract, it had better be let alone. The clinical course of the case should be carefully watched and bacterial examinations of the joint fluid should be made. An early rise of temperature does not necessarily mean infection. It is often caused by simple effusion and disappears upon aspiration of the joint. Aspiration should be followed by the injection of an equal amount of ether. The extrasynovial wound should be excised and drained.

2. If the foreign body is readily accessible it should be removed, the joint flushed out with ether and the wound closed without drainage.

Primary Operative Treatment.—At the nearest adequate surgical formation, all joint wounds, with the exception of those classed under expectant treatment, should be operated upon within six to eight hours, not later than ten to twelve hours if closure of the wound is contemplated. Under this heading are included the following measures:

1. Treatment of cases in which there is a lesion of the soft

tissues more extensive than in the punctiform wounds of the "expectant" type, but with little or no bony defect and in which the joint contains no foreign body:

(*a*) Excise the wound *en masse* up to the synovial sheath; check all hemorrhage by forcipressure or ligature.

(*b*) Trim off the torn edges of the synovial sheath.

(*c*) If there is free blood or a hematoma in the joint, remove it by expression or by means of gauze sponges.

(*d*) Irrigations or antiseptics in the joint are not necessary and should be avoided.

(*e*) Suture the gap in the synovial membrane with catgut or transplant fascia to cover in the defect.

(*f*) The external wound can usually be closed up without drainage. Watch the clinical course of the case and, if necessary, reopen the wound and apply Dakin-Carrel or ether dressings.

(*g*) Immobilize the joint in extension until the external wound has healed up. If the wound is drained, passive and active mobilization should be begun immediately.

The British surgeons are more reluctant to operate in these cases than are their French colleagues. Their rule is only to operate when the wound is extensive, when there is a laceration of articular tissues, when the projectile is still in the wound and, especially, when there is an articular fracture.

2. Treatment of cases in which the joint contains a foreign body with or without fracture, and cases in which comminution of bone is associated with an open wound of the joint: In this type there is a focus of infection within the joint; there may be a path of infection from the exterior; there may be a potentiality of mechanical derangement of the joint. An estimation of the relative importance of these findings will justify a range of operative treatment which will vary from the simple extraction of a foreign body to a typical resection of the joint, or even to an amputation. In general

terms, the operative technic should include the following steps:

(*a*) Excision *en masse* of all lacerated tissues.

(*b*) Trimming of lacerated edges of the synovial membrane, saving all viable portions.

(*c*) Esquilectomy of all aperiosteal fragments and of all completely detached fragments of bone and articular cartilage.

(*d*) Reposition of all displaced but adherent bony fragments.

(*e*) Mechanical cleansing of the joint cavity followed by ether irrigation.

(*f*) Removal of all foreign bodies revealed by the *x*-rays either prior to or during the course of the operation.

(*g*) Curettage of the cavity in which the projectile was lying and swabbing of cavity with ether.

(*h*) Closure of the synovial defect by suture of its membrane or filling in of the defect by a fascial flap, preferably of the pedicle type if possible.

(*i*) Primary drainage of the joint itself should never be resorted to.

(*j*) Drainage of the external wound if the bones are badly comminuted or the wound is over twelve hours old.

(*k*) Dry dressing or Carrel-Dakin instillations as indicated, with immobilization and extension.

Primary Amputation.—Exarticulation or amputation as a primary measure may be indicated by:

(*a*) Wound of the joint with laceration of the main blood-vessel.

(*b*) Extensive multiple lacerations of the limb and joint with or without fracture.

(*c*) Severe comminution of both articular surfaces with double epiphyseal fracture and severe infection.

(*d*) Articular infection plus multiple wounds lowering patient's resistance.

(*e*) Injury to the main nerves forms a very serious complication but, *per se*, will rarely warrant a primary amputation.

Primary Resection.—Primary resection of the joint is too radical in the large majority of cases, but may have to be resorted to in the following conditions:

(*a*) Severe localized comminutions of the lower end of the femur and upper end of the tibia in knee wounds.

(*b*) Where there is total destruction of both articular surfaces by the missile.

(*c*) In comminuted fractures of the shoulder-, elbow- or hip-joints with destruction of articular surfaces.

In all excisions it is important to save all viable synovial membrane and to keep the ends of the bones separated by extension if infection is present. In the absence of infection, where ankylosis is sought, the bones should be kept in apposition with the limb immobilized in the best functional position obtainable.

Results of Operative Treatment in Purulent Arthritides.

(Auvray, French Army, April, 1917.)

Knee	34
Elbow	32
Shoulder	20
Ankle	12
Wrist	7
Hip	4
Sacro-iliac	2
Total number operated upon	111
Total number of deaths	8
Mortality	7 per cent.

Method of treatment and results:

(*a*) Knee: Arthrotomies 21 (20 recoveries, 1 death); resections, 4 (2 recoveries, 1 amputation for infection; 1 death).

(*b*) Elbow: Arthrotomies, 5 (all recovered).
Secondary resections, 9 (all recovered).
Primary resections, 18 cured; 1 death; 17.
(*c*) Shoulder: Secondary resections, 18 (1 death).
(*d*) Ankle: Resections, 10 (all cured).
Amputations, 2 (1 recovery, 1 death).
(*e*) Wrist: Resections, 7 (all recovered).
(*f*) Hip: Resections, 4 (all recovered).

Auvray does not state whether the resections of the ankle, wrist or hip were primary or secondary operations; three deaths are not specified.

STATISTICS OF COLONEL GILBERT BARTLING (BRITISH).

Knee-joint wounds with bone injury	438	
Knee-joint wounds without bone injury	407	
Total number of knee-joint wounds operated upon		845
Knee-joint wounds excised and closed		322
Knee-joint wounds excised and closed requiring further operation, 25.5 per cent., or		82
Wounds excised and packed		336
Wounds excised and packed requiring further operation, 38.4 per cent., or		128
Knee excisions		42
Arthrectomies, partial or total		15
Excisions or arthrectomies requiring secondary amputation, 22.8 per cent., or		13
Total number of deaths after excision or arthrectomy, 22.8 per cent., or		13
Amputations without excision		151
Mortality after amputations without preliminary excision, 32.4 per cent., or		49
Total amputations, 19.4 per cent., or		164
Total mortality, 8.5 per cent., or		72

CONCLUSIONS (Inter-Allied Surgical Conference Paris, November 5, 1917).

(*a*) The aseptic evolution of osteo-articular lesions, if operated upon with an average delay of ten to twelve hours, leads to a maximum degree of conservatism in the surgical treatment of intra-articular fractures.

(*b*) Epiphyseal or partial epiphysiometaphyseal fractures (trabecular fractures, incomplete perforation, etc.) should at present be treated by removal of blood-clots, foreign bodies, etc., curettage and primary closure of the wound.

(*c*) Epiphyseal fractures, T-fractures or other partial epiphysiometaphyseal fractures should be treated by arthrotomy with replacement of partially loosened fragments, or arthrotomy with esquilectomy (partial atypical resection), of all aperiosteal or completely loosened fragments, and primary suture of the wound.

(*d*) Primary excision of a joint is only admissible under the following exceptional conditions:

1. Marked comminution of articular surfaces. This indication is more definite when dealing with shoulder and hip injuries than with those of the elbow, knee or instep.

2. The former practice of performing a primary joint excision, in borderline cases, in order to obtain a better functional result; must not be superseded by conservative methods such as arthrotomy with esquilectomy or partial atypical resections.

Defective functional results can be met by a secondary late orthopedic excision, the result of which will generally prove to be better than those obtained by a primary excision.

(*e*) Primary amputation is indicated in crushing injuries and total destruction of the main arterial vessel.

(*f*) Immediate active mobilization appears to be an indispensable part of the operative treatment and seems to have given results which are better than those obtained through immobilization (Willems).

(*g*) Excision is still justifiable in infected intra-articular fractures.

CHAPTER XXI.

SPECIAL FEATURES IN THE TREATMENT OF JOINT WOUNDS.

WOUNDS OF THE SHOULDER-JOINT. — *Anatomy.* — The shoulder-joint has as its framework three bones: the clavicle and scapula above, forming the shoulder girdle, and the humerus below. All three radiate from the joint; the clavicle toward the front, the scapula toward the back and the humerus downward, forming the basis of the shape of the shoulder. The tip of the acromion process is always readily palpable; 2.5 cm. directly inward from it, the outer end of the clavicle will be found, forming a more or less prominent ridge. In front of the deepest part of the concavity of the clavicle and 2.5 cm. below it is the coracoid process, better felt by pressing the fingers flat on the surface rather than digging them in. Beneath the acromion process is the greater tuberosity of the humerus.

The shoulder-joint is between the glenoid cavity of the scapula and the head of the humerus. The glenoid cavity is a shallow excavation, allowing very free movements of the head of the humerus. The capsular ligament is very loose. It is attached above to the edge of the glenoid cavity, the anatomical neck of the scapula and the rim of the glenoid ligament; below it is attached externally to the anatomical neck of the humerus at its articulating surface. There are two openings in the capsular ligament: one for the long tendon of the biceps and the other communicating with the subscapularis bursa. In suppurations within the joint, pus tends to find vent first through these openings. The coraco-humeral, glenohumeral and glenoid ligaments are strengthening bands reinforcing the capsular ligament.

Treatment of Special Features.—In compound fractures of the head of the humerus the wound should be enlarged if necessary and all completely detached fragments of bone removed. The long tendon of the biceps should be carefully preserved. Drain the wound freely and immobilize by means of a modified Thomas splint, a triangle splint of the Mittledorff type or the universal arm splint of Wilson. In comminuted fractures of the surgical neck of the humerus, conservative removal of completely detached fragments should be tried first; if this is not sufficient the head of the humerus should be removed. A fracture through the shoulder-joint and surgical neck of the humerus, requiring complete primary excision, needs no splinting after the operation. The weight of the limb maintains extension and separation of cut surfaces of bone. Ankylosis is always preferable to a flail-joint. Where this end-result seems probable the arm should be kept slightly abducted forward and slightly rotated inward, thus assuring a much extended range of movement at a more useful radius; such range of motion is brought about by the action of the scapula. The same splints described above will maintain the arm in its proper position.

WOUNDS OF THE ELBOW-JOINT.—*Anatomy.*—With the forearm flexed at a right angle, the prominent olecranon process of the ulna can be seen and palpated. Projecting on each side are the two condyles of the humerus, nearly on the same level, the internal being more prominent and a trifle higher. A line joining them crosses the long axis of the humerus at an angle of 90 degrees, but makes an angle of only 80 degrees with the forearm. When the elbow is flexed at a right angle a line drawn parallel with the humerus and prolonged through the two condyles will cut the tip of the olecranon. With the elbow extended the tip of the olecranon can still be felt with the inner condyle to its inner side. Between the two is a deep groove in which lies the ulnar nerve. To the outer side of the olecranon is a deep pit; in the bottom of this pit at its lower portion, 2.5 cm. below the tip of the olecranon can be felt the head of the radius. If the thumb is placed upon it and the hand rotated the head of the radius can be felt turning beneath.

The elbow-joint is between the humerus above and the ulna and upper surface of the radius below. The articulation between the upper end of the radius and the ulna forms the superior radio-ulnar articulation and does not belong to the elbow-joint proper. The ulna articulates with the trochlea and the radius with the capitellum. The elbow-joint is a pure hinge-joint. The articulation between the capitellum and the upper surface of the head of the radius is a ball-and-socket joint. The shape and continuity of the upper extremity depend upon the articulation of the ulna with the humerus; if the radius be removed from the elbow-joint the forearm would still be held in its proper relation to the arm, but if the ulna be removed the stability of the joint would be lost and the forearm would move in any direction, laterally as well as anteroposteriorly. It is for this reason that injuries involving the internal condyle and trochlea are more disabling than are those of the external condyle and capitellum. When the forearm is completely extended it bends outward from the elbow at an angle of 170 degrees. This is called the "carrying angle;" it is frequently lost in fractures of the elbow.

The capsular ligament is thin and readily distensible anteriorly and posteriorly; it is thick and unyielding laterally where it is reinforced by the strong lateral ligaments. The superior radio-ulnar articulation is surrounded by the orbicular ligaments, which encircles three-fourths of the head of the radius and is attached at its ends to the anterior and posterior edges of the lesser sigmoid cavity of the ulna.

Treatment of Special Features.—In the removal of loose bone fragments it is advisable to err on the conservative side in dealing with fragments of ulna or internal condyle; a fractured head of the radius should be removed, as it is difficult to drain the orbicular ligament. Fractures through the elbow or just above the condyles, without marked comminution, should be treated by the Jones method, *i. e.*, dressed and immobilized in hyperflexion. The condition of the distal circulation should be watched very carefully; marked hyperflexion of the elbow is only possible in children. Drainage is easily obtained and maintained; primary amputation, even in the presence of injury of the brachial artery, is rarely necessary, as collateral circulation is ample. If resection is indicated, preserve the periosteum and capsule so far as possible. Traumatic excision of the elbow-joint has been very frequent, so frequent, in fact, that regimental surgeons have even been accused of operating upon these cases in the first-aid stations. This type of wound is produced while the soldier is shooting; both elbows are crooked and exposed, and a shell fragment sweeping across the angle carries off condyles and olecranon, or large portions thereof. Ankylosis in semiflexion, with the forearm midway between pronation and supination is preferable to flail-joint. It is, however, remarkable how compensatory contraction of the biceps and triceps will overcome a large loss of continuity of bone. A splint of the Wilson universal type will answer all requirements.

Wound of the Wrist-joint.—*Anatomy.*—Just above the joint there is a swelling on each side caused by the expanded lower end of the radius on the outer side and the head of the ulna on the inner. Alternate abduction and adduction of the hand will accentuate these prominences. Just beyond these there is a constriction as the wrist passes into the hand. Following the radius down on its outer side one can feel the tip of the styloid process, a most important landmark. On the inner side of the wrist can be felt and seen the prominence made by the head of the ulna. The inner and posterior surface of the cuneiform bone can be felt immediately below the head of the ulna; with the hand abducted and adducted the cuneiform bone can be felt to move while the ulna remains stationary. On the palmar surface of the wrist, immediately below the ulna, can be felt the distinct bony prominence of the pisiform bone. About 2 cm. below and to the radial side of the pisiform is the unciform process of the unciform bone.

The wrist-joint is formed by the radius and triangular cartilage above and the scaphoid, semilunar and cuneiform bones below. The capsular ligament is composed of an anterior and a posterior portion, strengthened by two lateral ligaments. The fibers are attached above to the lower edge of the radius, below to the first row of carpal bones. There is no communication between the wrist-joint and the joints of the carpus; hence a wound limited to the former will tend to remain localized provided the annular ligaments and tendon sheaths are not involved. Should infection spread to and invade the synovial membrane of the carpus it will readily spread from one bone to another, as the joints of the carpus all communicate with one another with the exception of the pisiform. A discussion of wounds of the wrist-joint would be incomplete if it did not include a short description of the tendons, fasciæ and annular ligaments. The anterior (flexor) tendons on the wrist occupy four different planes. As it approaches the wrist the deep fascia divides into two layers. The superficial layer is continuous below with the palmar fascia. The deep layer covers the flexor sublimis digitorum and passes downward beneath the flexor carpi radialis and brachioradialis muscles. It is continuous below with the anterior annular ligament and then merges on the radial side with the postérior annular ligament to form the sheath of two of the extensor muscles of the thumb. The anterior annular ligament is attached on the ulnar side to the pisiform and unciform bones, and on the radial side to the trapezium and scaphoid. The flexor muscles pass under the annular ligament embraced in two sheaths.

The posterior (extensor) tendons on the wrist, with the exception of the brachioradialis, pass beneath the posterior annular ligament. The latter is attached externally to the postero-external edge of the styloid process of the radius and internally to the posterior surface of the styloid process of the ulna, the internal lateral ligament, the pisiform and adjacent carpal bones. Beneath the posterior annular ligament the extensor tendons pass through six compartments, each lined with a separate sheath which extends for a short distance above and below the joint. The deep fascia of the forearm is continuous with that of the arm above and the hand below. It forms a complete covering for the muscles and sends septa between them. When infection involves the deep tissues of the wrist the pus, being hindered from going externally by the fibrous septa between the various layers of muscles as well as the deep fascia itself, tends to burrow up the forearm. If in the upper portion of the forearm, it tends to point to the antecubital fossa. If lower down, it tends to come to the surface on the radial side between the flexor carpi radialis and brachioradialis or toward the ulnar side between the palmaris longus and flexor carpi ulnaris. The palmaris longus, flexor carpi radialis and median nerve form a barrier anteriorly which forces the pus to one side. Posteriorly pus may follow the course of the ulnar nerve, appearing behind the internal condyle. The fibrous septa of the various muscles hinder the progress of pus laterally and the attachment of the deep fascia to the ulna prevents its passing around the arm at that point. Should infection from the thumb travel up to the flexor longus pollicis tendon, when it reaches above the wrist it is directly beneath the tendon of the flexor carpi radialis. In such a case an incision should be made along the radial (outer) edge of the tendon, taking care not to wound the radial artery. If pus passes up beneath the anterior annular ligament it shows itself above the wrist between the palmaris longus and flexor carpi ulnaris tendons and should be drained in this location. If it is necessary to drain beneath the flexor muscles an incision is made along the side of the ulna and a forceps passed under the tendons to the skin on the radial side, where a counter-opening is made and the drain inserted.

Treatment of Special Features.—All loose fragments of the articular surface of the radius should be removed and all fractured carpal bones removed *in toto*. Conservation of injured carpal bones is poor surgery. A long dorsal incision between the tendons of the extensor longus pollicis and extensor indicis gives the best access to the carpus and provides ample drainage. Wide splitting of all infected tendon sheaths should be the rule. When ankylosis can be avoided early passive movements are desirable. When ankylosis is feared the forearm and hand should be splinted in marked supination for mechanical drainage, with the wrist in dorsiflexion, in order to preserve the grasping power of the hand.

WOUNDS OF THE HIP-JOINT.—*Anatomy.*—The crest and anterior superior spine of the ilium can be readily felt. The posterior superior spine of the ilium, marked by a dimple, is opposite the middle of the sacro-iliac joint. The tuberosity of the ischium is 12 to 15 cm. below the posterior superior spine of the ilium. A line joining the posterior superior spine and the tip of the great trochanter forms the posterior iliotrochanteric line of Farabeuf. It marks the posterior edge of the gluteus medius muscle. The ischiotrochanteric line (from tuberosity of ischium to tip of greater trochanter) is crossed at the junction of its inner and middle thirds by the sciatic nerve. The greater trochanter is marked by an eminence in thin people and a depression in plump or fat people. Its tip is opposite the center of the head of the femur and is on a level with the spine of the pubis. The Roser-Nélaton line passes from the anterior superior spine to the tuberosity of the ischium, crossing the tip of the greater trochanter. Bryant's triangle, drawn with the patient lying on his back, consists of a perpendicular, falling from the anterior superior spine to the table, a line joining the latter to the tip of the greater trochanter and a base line running horizontally from the trochanter to the perpendicular line. In fractures of the neck of the femur the base of the triangle is shortened as compared with the base of the triangle on the sound side.

The hip-joint is formed by the acetabulum and cotyloid ligament above and the head of the femur below. Its function is mobility and support. The joint is air-tight and holds the femur in place by suction. The teres ligament is a weak mass of synovial and connective tissue, rupturing easily at 14 kilos; its function is to distribute the synovial fluid and act as a lubricating agent. The capsule of the joint is composed of a thin sac with three strengthening ligaments (iliofemoral, pubofemoral and ischiofemoral). The posterior and lower portion is weaker than the anterior and upper portion. The weak points are: (*a*) between the arms of the iliofemoral ligament anteriorly; (*b*) between the pubofemoral and inner edge of the iliofemoral ligament. A bursa here separates the iliopsoas from the joint and often communicates with the joint; (*c*) between the two branches of the ischiofemoral ligament on the lower posterior part of the neck.

Treatment of Special Features.—Simple arthrotomy or arthrotomy and esquilectomy will provide ample drainage. Resection is rarely indicated as a primary operation. The wound leading to the joint should be excised *en masse* and the cavity either drained by dependent drainage or Carrel instillation tubes installed. Drainage may be obtained through a lateral incision over the posterior iliotrochanteric line. The fibers and tendon of the gluteus maximus are cut in the line of the incision, exposing the posterior edge of the gluteus medius, which is to be pulled forward, and the pyriformis, which is to be drawn backward or loosened from its insertion into the trochanter, thus exposing the capsule of the joint. Should anterior drainage be necessary an incision is made directly downward from the anterior superior spine, pulling the sartorius and rectus inward and the tensor faciæ femoris and gluteus medius and minimus outward, thus exposing the capsule. Whenever ankylosis is liable or likely to result the limb should be immobilized in a position of extension, slight abduction and outward rotation. The Jones abduction frame fulfils all requirements, except that it makes transportation of the wounded man extremely difficult on account of the spread of the lower extremities. A Thomas splint, reënforced by an ordinary long external splint, will usually have to be used for transportation purposes.

WOUNDS OF THE KNEE-JOINT.—*Anatomy.*—The bony landmarks are the patella, the two condyles of the femur, the tibia and the fibula. The outer edge of the patella is slightly more prominent than the inner. Midway between the patella and the tubercle of the tibia is a palpable groove which indicates the line of the joint and the position of the semilunar cartilages. Opposite the level of the tibial tubercle, postero-externally, the head of the fibula can be palpated. The joint on the outer side is 2 cm. above the head of the fibula. Posteriorly with the leg in extension, the condyles of the femur are palpable, the inner one being more prominent. The tubercle of the tibia is situated 4 cm. below the patella.

The knee-joint is between the condyles of the femur above, the tibia below and the patella anteriorly. It is composed of two separate lateral parts, the condyle and tuberosity of each side forming practically a separate joint. (This explains the possibility of limiting infection to a portion of the joint and is an important point to remember.) The capsular ligament and its strengthening bands are firmly attached below to the tibial tubercle, but the attachments above are far removed from the joint surfaces. Owing to the great thickness and strength of these bands, pus from within the joint tends to pass around them into the more readily distensible posterior pouch of the capsular ligament. Hence the absolute necessity of posterior drainage in all severe infections. With the limb in extension, the bulk of the patella is above the articular surface, its upper edge being separated from the anterior surface of the femur only by the thin capsular ligament. This explains why effusions into or infections of the joint bulge upward at this point and frequently burst through the capsular ligament with upward invasion by the septic process. Five cm. above the patella is the subfemoral bursa which, in 80 per cent. of all cases, communicates with the joint. A second weak point in the capsular ligament is below, at the margin of the tibia, and here pus may find an exit. Posteriorly one should remember that on the inner side of the joint is a bursa beneath the internal head of the gastrocnemius which usually communicates with the joint and sends a prolongation between the gastrocnemius and the semimembranosus. The crucial ligaments pass from the tibia upward to the intercondylar notch of the femur. The external (anterior) passes upward, outward and backward; the internal (posterior) passes upward, inward and forward. A ligamentous band (ligament of Wrisberg), runs from the posterior crucial ligaments to the external semilunar cartilage. Thorough drainage of the posterior pouches can only be obtained through incision of these ligaments. A mental review of these important points will be of considerable aid in instituting intelligent drainage, thus preventing upward spread of any infection.

Etiology of Wounds of the Knee-joint:

1. Rifle bullets.
2. Shrapnel fragments or bullets.
3. Fragments of high-explosive shells.
4. Bombs, hand grenades, etc.

Types of Injury.—1. Contusion of articular surfaces (spent bullets). The missile is usually found in the soft tissues. There may be a slight contusion of the underlying bone. The synovial membrane is not penetrated but the injury is sufficient to produce a serous or serohemorrhagic effusion into the joint cavity.

2. Cartilaginous scratches (gutter wounds).

3. Abrasions of the condyles or patella.

4. Incomplete fractures of the patella, of the femoral or tibial condyles or of the head of the fibula, with abrasions of the semilunar cartilages.

5. Through-and-through wounds of the joint produced by rifle bullets at moderate range which traverse the joint without doing severe injury to any of the bones, and in which infective material does not appear to have been carried into the synovial cavity.

6. Wounds of the joint with comminuted fracture of the patella of one or both of the femoral condyles (T- or Y-fractures or fissures), or of the head of the tibia. Fissure fractures are especially dangerous because the *x*-rays frequently fail to reveal their presence.

All sorts of combinations of the above types are encountered. The knee injury may form only a small part of the lesion which includes injuries to trunk nerves and arteries.

Treatment.—Wounds of the knee-joint have been harder to treat than those of any other joint. The complicated synovial membrane and especially the difficulty in maintaining drainage of its posterior pouches, has made the prognosis serious in the severe types of infection.

Type 1.—Radical surgical removal of the wound tract; removal of foreign matter and missile. If seen within eight hours, closure of the wound by suture, application of dry dressings with a very lightly applied bandage; immobilization and extension by means of a Thomas splint. If effusion occurs, aspiration and injection of an equal amount of ether is advocated, repeating the treatment daily until all systemic reaction has disappeared. The same treatment applies to types 2 and 3, except that, after removal of all foreign bodies (including missile) and thorough disinfection of the joint with ether, the synovial sheath should be closed by suture whenever possible. Drainage, if used at all, should only extend to the synovial membrane—never into the joint itself.

Type 4.—After localizing the missile, it may be removed either by enlarging the original wound or by deliberate arthrotomy.

Type 5.—When seen early (within eight hours) radical excision of the wound tract, sterilization and the production of intense hyperemia by injection of ether, suture of the synovial membrane and of the wound tract, dry dressings and the application of a Thomas splint will usually be followed by primary healing. If seen late, drainage up to the synovial membrane should be instituted.

Type 6.—The same treatment should be given as in the preceding type, but all aperiosteal or completely loosened fragments of bone should be removed, together with the missile and all foreign bodies. If effusion into the joint occurs, repeated aspiration and injection of ether will be found efficacious.

If seen late, with infection already beyond local control the treatment must be modified. Infection, which begins in the anterior cavity of the knee-joint, will spread backward within a few days, and no amount of treatment of the anterior cavity will effect suppuration of the posterior pouches and bursæ. It therefore becomes necessary to drain the latter separately.

Technic of Arthrotomy of Knee.—(*a*) *Anterior Incisions.*—Lateral incisions, one inch from the outer and inner borders of the patella and 10 to 20 cm. long, freely opening the capsular ligament. Thorough irrigation of the cavity, followed by injections of ether, should precede the placing of drainage tubes. These should extend down to the synovial membrane, but not beyond, and they should be sutured to the skin and fascia in order to prevent their slipping back into the joint.

(*b*) *Posterior Incisions.*—Drainage of the posterior pouches may be obtained by one of two methods:

1. Introduce a curved forceps through each of the anterior incisions; push the instruments along the outer and inner aspects of the femur until the points of the forceps can be palpated in the popliteal space. Incise the skin over the forceps, irrigate the pouches, explore and break up any adhesions or pockets and introduce drainage tubes to the synovial membrane, anchoring them to skin and fascia by sutures.

2. Having completed the work anteriorly, turn the patient on his face and make 10 cm. long incisions on either side, between the hamstring and gastrocnemius muscles. Identify and carefully avoid wounding the popliteal artery and vein. Over either condyle of the femur make an incision 5 cm. long through the crucial ligament and ligament of Wrisberg into the joint. Treat the posterior joint surfaces in the same manner as the anterior. In prolonged drainage cases these posterior incisions may be kept open by cutting a communication from one posterior pouch to another, cutting between Wrisberg's ligament and the crucial ligaments and passing a small rubber tube through from one posterior incision to the other. It is best, however, to rely upon irrigation and not to introduce the tube unless absolutely necessary. No attempt should be made to suture the wound until the infection is completely under control. This can best be estimated by the Carrel microbic curve. (See Dakin-Carrel treatment.)

The U arthrotomy of Duval, in which the quadriceps extensor tendon is cut above the patella, reflecting the latter downward and exposing the joint, and the median vertical transpatellar incision (obtained by a vertical incision 20 cm. long through soft tissues, followed by a sawing of the patella into lateral halves), both give ample exposure of the joint but are not suitable for drainage cases.

In severe infections, some surgeons advocate cutting both the lateral and crucial ligaments with removal of the semilunar cartilages and suspension of the limb at an angle of 45 degrees.

Many of the best English, French and Belgian military surgeons use ether both as an antiseptic and to produce transitory hyperemia.

Primary resection of the knee-joint is only indicated where the separated fragments of bone are so extensive as to render the future of the joint functionally hopeless. A flail knee-joint is never advisable; an ankylosis, with the knee in slight flexion, will be functionally more satisfactory to the patient. In comminuted fractures of the patella, a subperiosteal resection of the entire bone will shorten convalescence and give the best results.

As the correct principles of mechanical drainage come to be uniformly understood and uniformly practised, and more satisfactory methods of combating gas-bacillus infections are devised, there should be a steady decrease in the percentage of amputations as well as in the mortality.

WOUNDS OF THE ANKLE-JOINT.—*Anatomy.*—The ankle-joint is composed of the tibia and fibula above and the astragalus below. The malleoli form prominences with distinct hollows above and below them. The sharp anterior edge of the tibia, if followed down, leads to the tendon of the tibialis anticus. About 4 cm. below and in front of the internal malleolus is the tubercle of the scaphoid. The transverse line of the joint is 2.5 cm. above the tip of the external malleolus. About 2.5 cm. below and in front of the external malleolus is the peroneal tubercle of the os calcis.

The ankle-joint is a pure hinge-joint; its motion is antero-posterior except in complete extension, when a small amount of lateral motion is possible. The range of movement is

80 degrees—20 degrees flexion, 60 degrees extension. The capsular ligament is very thin anteriorly and posteriorly. It is reinforced by lateral ligaments, the internal one being the stronger. Fluid tends to find exit from the joint, first anteriorly under the extensor tendons; later it tends to pass posteriorly and make its appearance on each side of the tendo Achillis.

In all wounds seen within eight hours, excision of the entire tract with removal of all loose fragments of bone, foreign bodies and missiles, will give a fair prognosis. Compound fractures of the astragalus usually do badly and will require astragalectomy. In all severe compound fractures involving the ankle-joint and tarsus, ultimate amputation will have to be performed. In the absence of severe streptococcus or gas-gangrene infection conservative treatment should be the rule in the zone of the advance. Drainage should be obtained by ample anteroposterior incisions, the tubes passing around the malleoli above the joint line.

Wounds of the Hand.—Owing to the free blood supply, wounds of the hand, if given prompt and thorough surgical cleansing, will heal rapidly. If a wound of the hand becomes infected, pus may accumulate beneath the palmar fascia. Pus originating beneath the thick middle triangular portion of the palmar fascia will tend to point to either side, and it may show on the inner side at the hypothenar eminence, or work toward the outer side and point in the web of the thumb. It may take an upward course and pass under the annular ligament to point on the anterior surface of the forearm above the wrist. If it tends downward it escapes through the openings for the exit of the digital arteries and nerves, and shows in the web of the fingers. If it extends still farther it burrows between the distal extremities of the metacarpal bones and shows on the back of the hand. Sometimes the pus works directly toward the surface through small gaps in the fascia. In such cases a small amount of pus may accumulate above the palmar fascia and between it and the skin, so that there is a collection of pus both above and below the fascia, communicating through a hole in the fascia (*abcès en bissac*). In incising palmar abscesses the only safe way is to limit the incision to the skin and open the deep parts by inserting a closed pair of forceps and then separating its blades. Incisions should not be made nearer to the wrist than on a level with the web of the thumb, or the superficial palmar arch may be cut. Any longitudinal incisions should be made over the tendinous sheaths in order to avoid wounding the digital arteries or nerves. If the sheath of the tendons of the hand or fingers becomes infected, the pus travels along the tendon as far as the sheath extends. The sheaths of the tendons vary in their extent. The flexor profundus and sublimis tendons lie together in single sheaths, which commence at the base of the distal phalanx. That of the thumb follows the long flexor tendon up the thumb, beneath the annular ligament, to 3 or 4 cm. above the wrist; that of the little finger passes up almost opposite the level of the web of the thumb and then spreads over toward the radial side and envelops the remaining tendons of the other three fingers, forming the great carpal bursa which extends up under the annular ligament to 3 or 4 cm. above the wrist. The sheaths of the remaining three fingers extend only to the heads of the metacarpal bones, about 2 cm. above the web of the fingers. This is the usual arrangement, but the sheath of the little finger may end opposite the head of the metacarpal bone, or it may go up the entire way to the wrist as a separate sheath, in which case the great carpal bursa envelops only the tendons of the index, middle and ring fingers. When suppuration occurs in the sheath of the thumb or little finger it is much more serious because the pus tends to travel directly upward and involve the palm, and even goes above the wrist. When suppuration involves the index, middle or ring fingers, it stops when it reaches the vicinity of the metacarpophalangeal joints and involves the palm and carpal bursa only by bursting through its own sheath and breaking into the carpal sheath. This it is not likely to do unless the infection is virulent and the suppuration abundant.

Wounds of the Foot.—Abscesses of the sole of the foot are usually caused by infected punctured wounds or by the extension of infection from wounds of the toes, etc. The plantar fascia lies on the flexor brevis digitorum while the long flexor tendons lie beneath it. In the superficial form of plantar abscess the pus tends to point in four directions: (1) It may come directly up through gaps between the fibers of the plantar fascia and make an hour-glass abscess; (2) it may burrow its way forward showing between the tendons in the direction of the webs of the toes; (3) it may appear in the groove on the outer side of the foot between the flexor brevis and abductor minimi digiti; (4) it may appear on the inner side of the foot between the abductor hallucis and flexor brevis. In deep infections the pus accumulates around the deep flexor tendons and beneath the flexor brevis muscle. Its greatest tendency is to extend up the leg by following the flexor tendons behind the internal malleolus. It may also show itself in the grooves on either side of the flexor brevis, or between the tendons at the webs of the toes. In making incisions for the drainage of plantar abscesses avoid bony prominences where the skin would subsequently be subjected to painful pressure. Lateral incisions or incisions in the hollow of the foot are best and should only include the skin. Open the abscess by passing a forceps under the fascia and opening the blades widely. Through-and-through lateral drainage will shorten convalescence. Collections which point to the outer side of the flexor brevis should be opened a little distance behind the base of the fifth metatarsal bone because the external plantar artery is superficial at its inner side.

CHAPTER XXII.

TREATMENT OF COMPOUND FRACTURES NOT INVOLVING JOINTS.

General Considerations.—(*a*) Inasmuch as simple fractures are almost a surgical curiosity on the battlefield, and their treatment differs in no essential from that accorded them in civil practice, they are not considered in this work.

(*b*) All wounds complicating compound fractures require exploration, carried out as soon as possible after the receipt of the injury.

(*c*) The speed and accuracy with which compound fractures can be cleansed, drained, dressed and immobilized with extension, whenever possible, is the most important factor in the successful outcome of these cases.

(*d*) Compound fractures should be sent directly to the nearest sanitary unit possessing the personnel and equipment necessary for thorough primary treatment of such cases. Partial treatment in a succession of sanitary formations, from front to rear, is probably conducive of more harm than good.

(*e*) Immobilization should always be enforced during the evacuation of such wounded.

(*f*) The application, and more especially, the maintenance of extension during evacuation may occasionally be found impracticable, but should always be attempted.

1. If extension is maintained the patient is dissatisfied.
2. If the patient is content the extension has slackened and the malposition has returned.

3. Suspension of a compound fracture during evacuation will be absolutely impracticable while the wounded soldier is being transported by hand, by litter or hand cart; it is practical and should be enforced during ambulance, train or large conveyance.

ESSENTIAL REQUIREMENTS OF SPLINTS IN MILITARY SURGERY.—(*a*) They must be of standard pattern. It is impossible to supply sufficient splints or various particular makes. The more uniformly surgeons can confine their treatment to one pattern of splint for a given type of fracture, the more efficient will be the supply.

(*b*) They should embody the following features:

1. Relative immobilization of the fracture.
2. Adequate extension when practicable.
3. Easily cleansed (metal).
4. Easy access to the wound.
5. Capable of being slung for dependent drainage.

(*c*) Disadvantages of plaster-of-Paris splints:

1. Time element.
2. Excessive weight.
3. Septic discharges soon spoil the plaster.
4. Wounds difficult to watch and dress.

PRIMARY TREATMENT OF THE WOUND.—(*a*) Punctured in-and-out wound.—It is always safer to open up and explore, clean out and drain a bullet wound involving bone. After clearing out all débris, including all completely loose or aperiosteal fragments, many surgeons inject ether.

(*b*) Punctured Entrance and "Explosive" Exit Wound.—All lacerated, devitalized tissues should be removed *en masse*, forming a cone-shaped wound in which Carrel tubes are placed and the dressings saturated with hypochlorite solution.

(*c*) Entrance Wound of Shrapnel Bullet.—Same as in (*b*) plus removal of bullet.

(*d*) Lacerated Wound of Shell Fragment, No Exit.—Same as (*c*); special search for particles of clothing, dirt, etc.; study skiagraph for multiple shell fragments or "shell dust." Remove all foreign bodies.

(*e*) Punctured Wound Complicated by Interstitial Hemorrhage.—Better results will be obtained by making a free incision and systematically searching for the bleeding vessel, which should be double ligated when found. (See chapter on Hemorrhage.) If, as a last resort, plugging with gauze is resorted to, the case should be kept under close observation for several days. In the presence of sepsis, plugging should only be a very temporary affair; it is best to avoid it altogether.

PRIMARY TREATMENT OF THE FRACTURE.—*On the Field of Battle.*—1. Check hemorrhage, if severe, by packing first-aid dressing into wound and bandaging limb. (This is rarely absolutely necessary and is a dangerous procedure.)

2. Tourniquet rarely necessary; too often harmful.

3. Temporary immobilization.

   (*a*) Strapping to side of body.
   (*b*) Strapping to fellow-limb.
   (*c*) Thomas splint; rifle splints.
   (*d*) Short wooden splints.
   (*e*) Slings, etc.

At the Regimental Aid Station.

1. Remove tourniquet if present.
2. Remove gauze packing and treat wound according to indications.
3. Apply standard type of splint.
4. Evacuate to Evacuation Hospital.

SECONDARY (PERMANENT) TREATMENT OF COMPOUND FRACTURES.—(*a*) As a general rule the principle of prompt retention of the displacement and maintenance of extension, should be adhered to.

(*b*) Exceptions to the above rule will occur; under the following conditions the treatment of the wound should assume first place.

1. Threatening gas gangrene.
2. Multiple, inaccessible wounds.
3. Where the position and direction of the fracture may make reduction and its maintenance impossible.

(*c*) Remove so far as possible all fully detached fragments of splintered bone because:

1. They may act as foreign bodies and maintain suppuration.
2. They often hide "pockets" and prevent drainage of same.
3. They produce necrosis of muscle in which they live and thus favor bacterial growth, especially of the gas-gangrene group.
4. In certain localities they tend to cause subsequent injury to bloodvessels, resulting in secondary hemorrhage.

(*d*) Arguments against removal of bone fragments:

1. In extensive comminution of bone, after removal of fragments, the gap is too extensive to be bridged over and non-union results.
2. Parts of periosteum and some bone cells may live and help to stimulate osteogenesis.

In the presence of severe sepsis the above arguments have little practical value. The total blockage of surrounding lymph channels shuts off capillary circulation and practically all loose fragments die.

When is Primary Amputation Indicated?—(*a*) When serious and irreparable injury to the main vessels and nerves is found.

(*b*) When severe and progressive gas gangrene is present.

(*c*) When the fracture extends into the knee-joint and is complicated by serious and progressive infection of the joint.

(*d*) When there is present a combination of severe comminution of the articular ends of the bone with fracture involving the medullary cavities of the bone, severe laceration of the soft parts and septic infection.

(*e*) The "white gangrene" of the limb.

When is Secondary Amputation Indicated?—(*a*) In persistent suppuration and progressive toxemia.

(*b*) In spreading osteomyelitis as revealed by serial roentgenograms.

(*c*) Whenever secondary hemorrhage occurs which is not amenable to direct ligation of the bleeding vessel. This is especially true in compound fractures of the femur.

What Type of Amputation Should Be Selected?—(*a*) The circular flapless amputation is usually the only safe type to use in the presence of severe sepsis. It permits of ample mechanical drainage, leaves no blind pockets and enables a daily inspection of the deeper structures (bone, vascular sheaths, muscle). It allows the hypochlorite solution to reach every part of the wound. The double elliptical amputation is preferable on account of the ample skin and muscle flap.

(*b*) In order to overcome retraction of skin and muscles, and to prepare the stump for its artificial limb, a "stump pulley" should be applied.

THE STUMP PULLEY.

Method of Application (See Fig. 1).—(*a*) Four or five strips of adhesive, one or two inches wide and six inches long, are placed at regular intervals parallel to the long axis of the stump. Their distal ends should extend 2 inches beyond the skin margin. Double the last half-inch of adhesive on itself, punch an eyelet through the doubled portion and tie a piece of string or thin tape to each of the strips of adhesive. Anchor the strips by means of two circular strips of adhesive extending around the limb over them.

(*b*) Make a wire or metal ring whose diameter will be about one-half that of the stump, in order to get a convergent pull. Attach the strings or tapes to the ring at even intervals (they can be readily anchored by means of thin adhesive strips).

(*c*) The ring should be placed two feet distant from the stump and be vertical in order that the pull may be uniformly distributed.

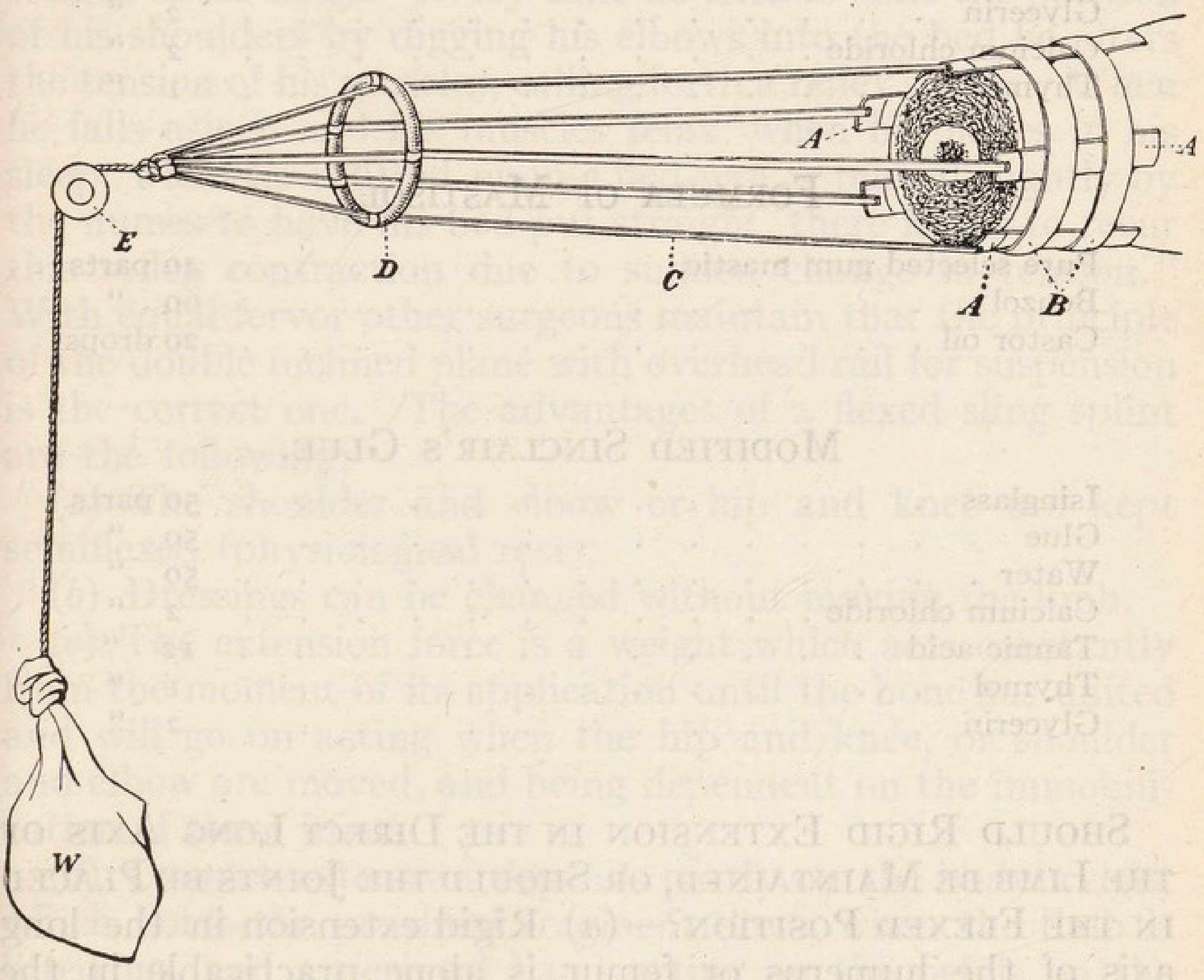


FIG. 1.—Stump pulley. *A*, adhesive strips; *B*, circular adhesive; *C*, tapes; *D*, metal ring; *E*, pulley; *W*, weight.

(*d*) At a point one foot beyond the ring, converge the strings, tie them to a small piece of cord and pass cord over a pully attached to the foot of the bed.

(*e*) Attach from 2 to 5 pounds weight to end of cord. Instead of adhesive strips, gauze may be held to the skin by means of Sinclair's glue adhesive or mastisol.

FORMULA OF SINCLAIR'S GLUE ADHESIVE.

Ordinary glue	50 parts
Water	50 "
Glycerin	2 "
Calcium chloride	2 "
Thymol	1 "

FORMULA OF MASTISOL.

Pure selected gum mastic	40 parts
Benzol	60 "
Castor oil	20 drops

MODIFIED SINCLAIR'S GLUE.

Isinglass	50 parts
Glue	50 "
Water	50 "
Calcium chloride	2 "
Tannic acid	12 "
Thymol	1 "
Glycerin	2 "

SHOULD RIGID EXTENSION IN THE DIRECT LONG AXIS OF THE LIMB BE MAINTAINED, OR SHOULD THE JOINTS BE PLACED IN THE FLEXED POSITION?—(*a*) Rigid extension in the long axis of the humerus or femur is alone practicable in the advance sanitary formations. Fractures of the shorter bones can be dressed with almost equal readiness in flexion.

(*b*) In the permanent treatment of these fractures the question is still *sub judice*. Major Robert Jones, R. A. M. C. (Liverpool), is a fervent advocate of rigid extension, *i. e.*, tuber ischii to foot, in fractures of the femur, axilla to elbow or hand in fractures of the upper extremity. His ideas concerning "muscle spasm" are quoted here *verbatim:* "It is by reflex nervous impulses, induced by changes of tension in the muscle that muscle spasm is produced. A patient lying in bed with a fractured femur cannot avoid constantly changing the state of tension of the muscles of his thigh if a weight and pulley are attached to his limb. The counterpoise is the weight of his body. Every time he tries to shift the position of his shoulders by digging his elbows into the bed he alters the tension of his muscles, calling forth a reflex spasm. When he falls asleep and his muscles relax, when he moves in his sleep, when he is lifted upon a bed-pan or moved slightly by the nurses to have his bed put straight, there is apt to recur this reflex contraction due to sudden change in tension." With equal fervor other surgeons maintain that the principle of the double inclined plane with overhead rail for suspension is the correct one. The advantages of a flexed sling splint are the following:

(*a*) The shoulder and elbow or hip and knee are kept semiflexed (physiological rest).

(*b*) Dressings can be changed without moving the limb.

(*c*) The extension force is a weight which acts constantly from the moment of its application until the bone has united and will go on acting when the hip and knee, or shoulder and elbow are moved, and being dependent on the immobilization of these joints.

(*d*) Counter-extension depends partly on the body weight which holds the proximal fragment down when the limb is lifted up, and a perineal band acting on the pelvis on the sound side, or an axillary chest band doing the same duty in upper extremity fractures. In either case these bands should be attached to the head of the bed. (This is a frank attempt to immobilize the body and confirms Jones's dictum.)

(*e*) Practically painless.

(*f*) No danger of pressure necrosis.

(*g*) Double inclined plane deemed absolutely necessary in fractures of the upper and lower thirds of the femur with bad position of the fragments.

It is unquestionably true, as Jones maintains, that a muscle which remains constantly immobilized will not contract, because its tension must remain uniform. This is clinically exemplified by the ease with which one can obtain contant relaxation of the triceps brachii or of the quadriceps extensor muscles in the treatment of fractures of the olecranon and patella respectively.

(*h*) "The distance from the tuberosity of the ischium to the popliteal space becomes appreciably longer as the leg passes from the position of extension to that of flexion." (Soubbotitch, Servian army.)

THE THOMAS KNEE-SPLINT.—(*a*) With slight modification of diameter of ring and length of bar this splint can be applied to fractures of the thigh. It anatomically secures a correct alignment. The "abduction frame" of Jones for fractures of the neck of the femur will hardly be practicable at the front on account of the added difficulties of evacuation, but represents the ideal form of treatment at the base hospital. The patient who lies on an "abduction frame" can be lifted and moved without pain, without disturbing the fracture or relaxing the extension and the dressing can be changed without interfering with the mechanism of fixation. On account of the ease with which the branches of the malleable iron rod can be bent and twisted, thus obtaining at will positions of extension, flexion, abduction, pronation or supination, the Wilson "universal arm splint" should prove of inestimable value. Its only drawback would appear to be that it requires anchoring to the chest wall by means of a plaster-of-Paris jacket. This can probably be overcome by a system of straps.

SHOULD THE ENDS OF THE BONES BE MANIPULATED IN THE REDUCTION OF A COMPOUND FRACTURE?—(*a*) Vigorous manipulations, in the presence of sepsis should be avoided, as they tend to disseminate infection.

(*b*) There is no valid objection to the application of bone-holding forceps for the purpose of maintaining alignment, while immobilization and extension are being applied.

(*c*) Extensive incisions should not be made for the primary purpose of exposing the shaft of the bone. The cone-shaped wound, produced by the removal *en masse* of all lacerated tissues, etc., should be sufficient for ordinary bone manipulations.

Mechanical Fixation of Fractures.—(*a*) During the first two years of the war all methods of mechanical fixation fell into disrepute and were almost universally condemned.

(*b*) Whether the presence of absorbable or even non-absorbable fixation material could in any appreciable manner activate the already present infection of a compound fracture is debatable.

(*c*) Under the present fairly satisfactory methods of controlling sepsis the whole question is being revived.

(*d*) The dread of latent infection has been so great that von Eiselsberg (Austria) has advocated operating on long bones at some distance from the site of the old fracture, even though the latter showed firm bony union, *i. e.*, in a case of marked shortening requiring a bone inlay he advised placing the inlay, not at the site of the fracture, but above or below it, deliberately sawing through normal shaft and placing the inlay in normal bone.

(*e*) As a rule no mechanical fixations will be carried out in any of the sanitary formations pertaining to the zone of the advance on account of lack of time and insufficient personnel.

(*f*) As this class of work belongs exclusively to base hospital formations a discussion of the various methods of fixation by absorbable or non-absorbable material is not germane to this work.

Summary of First-aid Treatment of Compound Fractures.—(*a*) They are all septic and will all need drainage and instillations.

(*b*) Be radical in the excision of devitalized tissues; healing is prolonged, not shortened by attempting to save badly bruised and infected tissues.

(*c*) Plan the incisions carefully in order to give perfectly free access to the seat of injury and to provide either ample dependent drainage or ample space for the introduction of the Carrel instillation tubes.

(*d*) If a bloodvessel appears to be seriously bruised and likely to necrose it should be double ligated, divided and the ends allowed to retract. Should the popliteal artery be thus involved, amputation becomes inevitable.

(*e*) Immobilize compound fractures thoroughly and apply extension before evacuating the wounded man to the rear.

(*f*) The loss of a limb is a surgical failure. The loss of life in a case of compound fracture is a calamity. The loss of life after amputation shows poor judgment on the part of the surgeon.

Application of the Thomas Splint.—Strapping of adhesive plaster is applied in the usual way to the sides of the limb. At the lower end of the extension strapping there is a loop of webbing to which is attached a length of strong bandage. The ring of the splint is passed over the foot and up to the groin until it is firmly against the tuber ischii. The extensions are then pulled tight, the ends turned round each side bar and tied together over the bottom end of the splint, which should project six to eight inches beyond the foot. Care must be taken to avoid internal or external rotation of the limb, the foot being kept at right angles. Local splints can then be employed, and are made of block-tin or sheet-iron, molded to fit the limb. Two transverse bandage slings suspend the limb from the side bars of the knee splint. A straight splint is placed behind the suspension bandages of the thigh and knee. On the front of the thigh another sheet-iron splint is applied, and the femur is thus kept rigid. The alignment from the hip-joint to the ankle is perfect, being dependent on a straight pull. This splint allows the patient to raise his shoulders, or even sit in bed. His own leg can be moved freely without altering the tension on his thigh muscles and there is no reflex spasm. Even if the muscles try to contract they cannot, for the ring of the splint is firm against the tuber ischii. The muscles, therefore, do not remain on the alert but become quiescent, and starting pains do not occur. Such is the difference between "fixed" and "intermittent" extension. On using this splint a little attention is necessary to prevent soreness of the perineum. The ring of the splint, being covered with leather, can easily be kept clean, so can the skin. The nurse should also several times a day press down the skin of the buttock, and draw a fresh part of the skin under the splint. To change the point of pressure over the perineum, the limb can be elevated or abducted. The dressings can be applied without in any way interfering with the work of the splint. When the fracture has occurred through the knee or upper tibia the splint is applied in the same way.

The Interallied Surgical Conference Adopted the following Conclusions Regarding Fractures.

A. Choice of Apparatus:—

1. In the treatment of a fracture caused by a projectile of war, immobilization is more important than reduction.

2. The method of immobilization used should tend to fulfil one of three conditions:

(*a*) Provisional immobilization at the regimental aid station.

(*b*) Immobilization during evacuation.

(*c*) Permanent immobilization in the proper surgical center.

So far as practicable, provisional and permanent immobilization should be identical; in either case, transportation of the wounded soldier should be feasible.

3. The final apparatus should enable one to obtain

mechanical traction, free access to the wound and the possibility of transportation.

Fractures of the Arm.—(*a*) Provisional immobilization at the regimental aid station. Splints of the Thomas type give excellent results, and their use should become more generalized.

(*b*) Permanent Immobilization.—The Thomas or other types of splint which enable the surgeon to obtain abduction and adjustment, and extension splints of other types can be used.

Fractures of the Forearm.—(*a*) Provisional immobilization at the regimental aid station: A right-angle metal trough or a simple wooden splint will be sufficient.

(*b*) Permanent Immobilization.—The forearm should be immobilized in supination, and the apparatus used should, so far as possible, allow for free mechanical extension, and a varying degree of flexion of the elbow.

The Thomas or Sinclair splints, the interrupted plaster cast with metal arches, and the Van de Velde splint, fulfil the above qualifications.

Fractures of the Thigh.—(*a*) Provisional immobilization at the regimental aid post: The best splint is the modified Thomas, with foot rest in order to prevent undue extension of the heel during stretcher evacuation.

(*b*) Permanent immobilization: The splint used should enable the surgeon to obtain extension, abduction and flexion of the limb. The Thomas suspension (Blake, Balkan), Delbet and Alquier splints fulfil all of the above indications.

The Finochietto traction stirrup is indicated in multiple fractures, in certain fractures of the lower third of the femur with considerable overriding, in extensive comminutions of bone, and whenever there seems a lack of toleration for the standard splints. The addition of a Thomas splint to the Finochietto stirrup will preserve extension and allow transportation.

Fractures of the Leg.—(*a*) Provisional immobilization at the regimental aid station. The Thomas splint, metallic troughs and wooden splints, are all good.

(*b*) Permanent Immobilization.—The type of splint used must allow for mechanical traction.

The interrupted plaster cast with extensible metal arches and a mobile posterior splint, all types of extensor-suspensory splints, and the Thomas splint, fulfil these indications.

Early walking on the limb is desirable. The best ambulatory splint for this purpose is the Delbet. In the presence of a lateral wound of the leg, the lateral plaster reinforcement of Delbet should be replaced by a metal arch.

The use of the Finochietto stirrup, alone, or with a Thomas splint, is subject to the same indications pertaining to fractures of the femur.

Fractures of the Wrist.—(*a*) Provisional immobilization at the regimental aid station.—A metal trough or wooden splint will give sufficient immobilization.

(*b*) Permanent Immobilization.—The Robert Jones splint is excellent.

Fractures of the Ankle.—(*a*) Provisional immobilization at the regimental aid station.—A metal gutter splint will meet all indications.

(*b*) Permanent Immobilization.—An interrupted plaster cast, with metal arches will give complete immobilization and can also be used in walking. The Jones metal splint fulfils the same indications.

If, at the time of evacuation, the permanent splint must be removed, a plaster cast should take its place.

B. Surgical Treatment of Fractures.—1. At the regimental aid station the treatment of fractures should include:

(*a*) Dressing of the wound.

(*b*) Immobilization.

(*c*) Immediate treatment of complications (shock, hemorrhage).

2. At the nearest surgical center, all fractures should be examined, radiographed and operated upon, if necessary.

(*a*) Extensively comminuted wounds of the limbs, and gangrenous segments of limb should, as much as possible, be amputated at the site of the fracture.

(*b*) Punctured bullet wounds (seton wounds), with small entrance and exit orifices, without intervening swelling and without any wounds of large bloodvessels, should be immobilized and the wound treated aseptically. The patient should be closely watched for at least a week, and the fracture should be operated upon if well-defined local or general infection manifests itself.

(*c*) All other types of fracture must be operated upon.

A. *Treatment of the Wound.*—The wound should be excised; the incision should be ample enough to permit of a deep exploration of the entire site of the fracture. All lacerated soft tissues and foreign bodies should be removed. (See General Treatment of Wounds.)

B. *Treatment of the Bone Lesion.*—Esquilectomy is the basis of the operation. All free bone fragments, all fragments which are merely attached to the shaft by a thin lamina of bone or piece of torn periosteum and the free end of which has penetrated into muscle tissue, should be removed. Periosteum should be preserved wherever possible. Irregular, jagged ends of bone should be trimmed off, as they constitute a source of danger to neighboring bloodvessels and nerves.

The solution used for lavage of the wound should be left to the surgeon's choice, but ether and Dakin's solution are the two most commonly used.

Following the lavage the wound may be closed by primary or secondary suture.

At present writing, primary suture of the soft tissues, in the presence of a fracture, is only exceptionally performed, and only under the following conditions: (1) An experienced surgeon; (2) a period of military calm; (3) a wound not over eight hours old; (4) a not too extensive solution of continuity of muscles or bone, even after excision of all devitalized parts; (5) an easy coaptation of the excised wound edges; (6) the possibility of keeping the patient under close observation until the wound has entirely healed.

The most favorable anatomical regions for primary suture are the face, cranium, flat bones, patella, hand and foot.

At the first sign of infection, the wound should be reopened and rendered sterile.

Secondary suturing should be preceded by progressive sterilization. The methods of Carrel and Morrison both give excellent results.

C. Fractures should not be evacuated during their stage of infection.

D. Reduction of a fracture is obtained by operation, position and extension of the limb; it should be controlled by radiographic examination.

E. Fractures which have been impossible to reduce (or in which maintenance of reduction is unsuccessful), can be treated by open operation (plates, inlays, pegs, etc.). So far as possible this type of operation should only be attempted after sterilization of the wound.

F. A uniform system of treatment, from the zone of the advance to the rear, is desirable.

G. Mobilization of the joints, muscles and tendons of the fractured limb should continue throughout the treatment of the fracture and should be inaugurated as early as possible.

CHAPTER XXIII.

SPLINTS USED IN THE ADVANCED ZONE DURING TRANSPORT.

PRINCIPLES.—The value of splints for use in advanced zones must be judged for their

1. Efficiency.
2. Simplicity.
3. Adaptability.
   (*a*) For easy access to wounds.
   (*b*) For facility in transportation.

The efficient splint must give adequate fixation and yet be capable of easy and above all, speedy application. Time is of the utmost importance in the overwhelmingly heavy work often encountered during heavy fighting.

Simplicity is essential from the point of view of supply. Splints must be easy to manufacture and economical to pack and transport. There should be no loose keys or wrenches to be lost, no screw threads to rust or mechanical adjustments to get out of order. Frequently bearers or unskilled assistants must apply them and there should be no complicated principles involved.

Adaptability should be considered at the front more for facility in transport than for ease of access to wounds. Other things being equal, the more injuries for which a single splint may be used the more adapted it is for front-line work. It is of great importance to reduce the variety of splints to a minimum.

In this connection it is well to point out that conditions often rise which exhaust the local supply of splints. The ingenious regimental medical officer constantly improvises excellent splints from boards, wire, corrugated iron, jam tins or other material found in the trenches. Too much emphasis cannot be laid, therefore, on the importance of a correct understanding of and strict adherence to the *mechanical and surgical principles involved in the application of splints.*

The following splints meet the requirements of efficiency, simplicity and adaptability for use in advanced areas. They are selected from among the splints in common use by military surgeons and are all of proved value. They are all useful in hospital as well as field work which obviates duplication of types. The list is inclusive and will suffice for all types of wound, but is not exclusive, as there are many good substitutes of proved efficiency.

They are classified in groups adapted to wounds of the various regions of the body. The description of their application is made as brief as possible, emphasis being laid on minor principles important in advanced work and often differing from hospital methods.

It must never be forgotten that war wounds are more often multiple than single. This is due to the extensive use of high explosives. Methods described for single wounds will often be impossible to carry out, and the surgeon's ingenuity must be taxed to adapt the dressing to the individual emergency.

A. WOUNDS OF THE UPPER EXTREMITY.

1. Hand and Forearm.—Straight or coaptation splints of:

(*a*) Standard sheet iron, 20 gauge, 12-, 16- and 20-inch lengths.

(*b*) Splint wood, often pieces of broken ration boxes, etc.

(*c*) Wire gauze, 6 by 36 inches in size.

(*a*) The *sheet-iron splints*, when obtainable, are the most convenient. They are already padded with felt and may be bent or twisted to conform to the shape of hand and arm. The 20-inch size is long enough to cover the extensor surface of the arm and reach beyond the tips of the fingers; the 12- or 16-inch sizes fit the flexor surface.

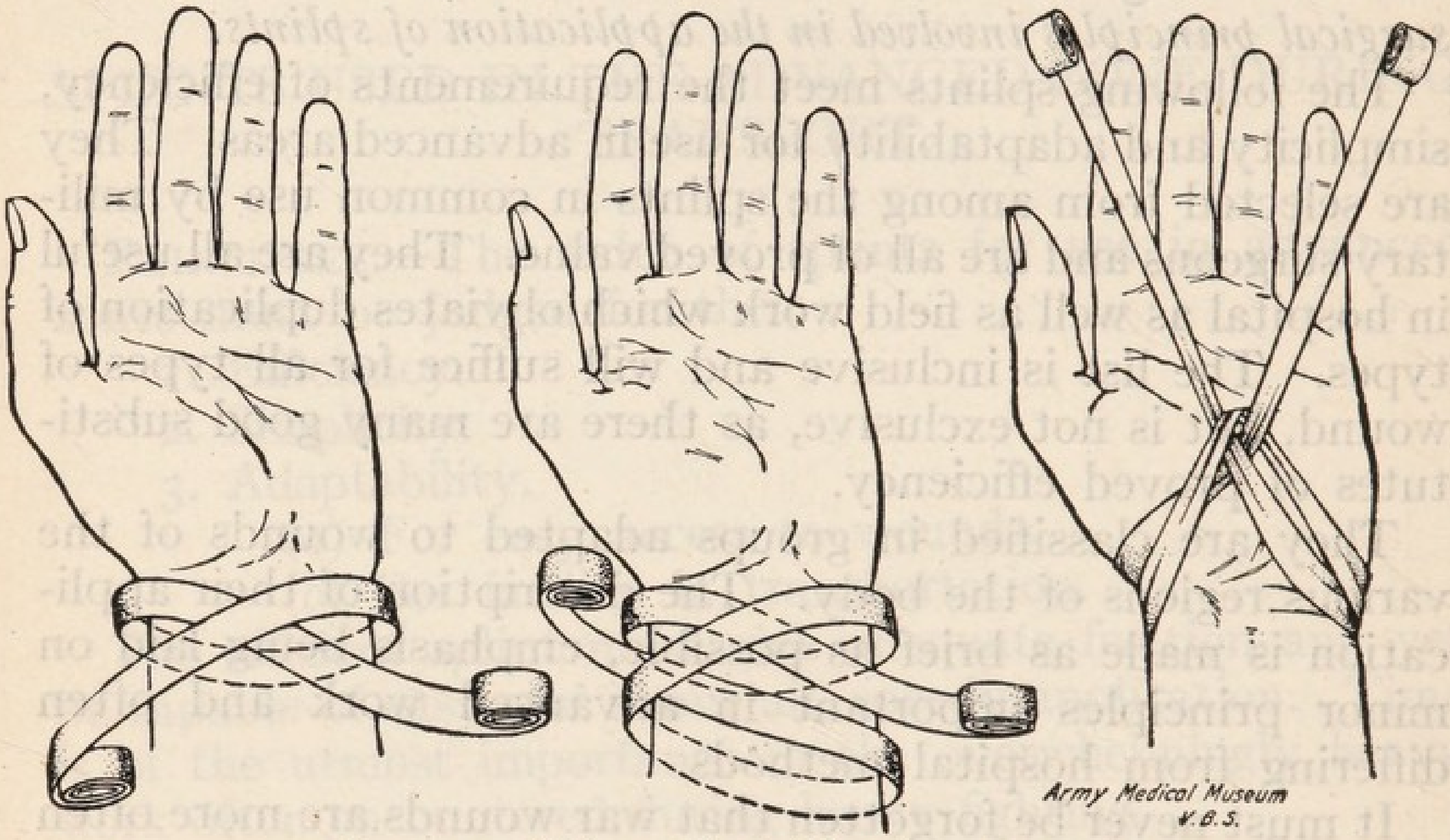


FIG. 2.—"Clove hitch" for hand traction.

For temporary dressings the cock-up splint is not necessary. If the supply of straight splints is sufficient it is always well to use two, posterior and anterior, as better fixation can thus be secured and there is less danger of the dressing becoming too tight from swelling of the arm. This danger is an ever-present one in the dressing of fresh wounds. Swelling may progress rapidly and many unexpected delays may postpone redressing.

Adhesive plaster is often not available and it is well to learn to depend on strips of bandage tied about the splints to hold them securely with adequate pressure. A gauze bandage completes the dressing. The arm should be supported in a sling during transport.

(*b*) *Wooden splints* are to be applied in the same way after padding with cotton or sheet wadding.

(*c*) *Wire gauze* comes in yard lengths. It can be cut with heavy bandage shears into the size desired and the ends bound with bandage or adhesive, or it may be bent upon itself and a double thickness used. It can be molded readily to fit the contour of the arm and hand.

2. Elbow, Arm and Shoulder-joint.

(*a*) Thomas traction arm splint.

(*b*) Jones humerus traction splint.

(*a*) The Thomas splint is used in cases serious enough to require transport by stretcher. The sleeve of the soldier's blouse should be cut off and his wound dressed. Fixation is aided by traction. For rapid work this traction is secured by making a clove hitch about the wrist with a doubled length of 3-inch gauze bandage. The clove hitch should be applied with the bight about the back of the wrist and the knot on the palmar surface to avoid compression of the vessels and to keep the hand extended. It is a better hitch than a slipknot, which tightens uncomfortably when traction is applied and may cause dangerous constriction (Fig. 3).

A definite technic should be acquired in attaching the traction bands to the splint. This saves time, makes a more secure and better-looking dressing and one easier to take down at the evacuation hospital.

Technic.—Always keep firm traction on the arm. Carry one extension band over an upright, the other under the opposite upright. Then wrap the ends in opposite directions half around the notched cross-piece of the splint. Apply the desired amount of traction by pulling on the traction bands. Complete the wrap about the cross-piece and tie in a square half-bowknot. Further traction may be secured by twisting the traction bands with a nail or bit of stick on the principle of the Spanish windlass.

Cross-slings should be tied across the uprights under the arm to give it support, and a bandage should be applied evenly about the splint and arm.

The uprights of the splint should not press at any points on the wound or any part of the arm.

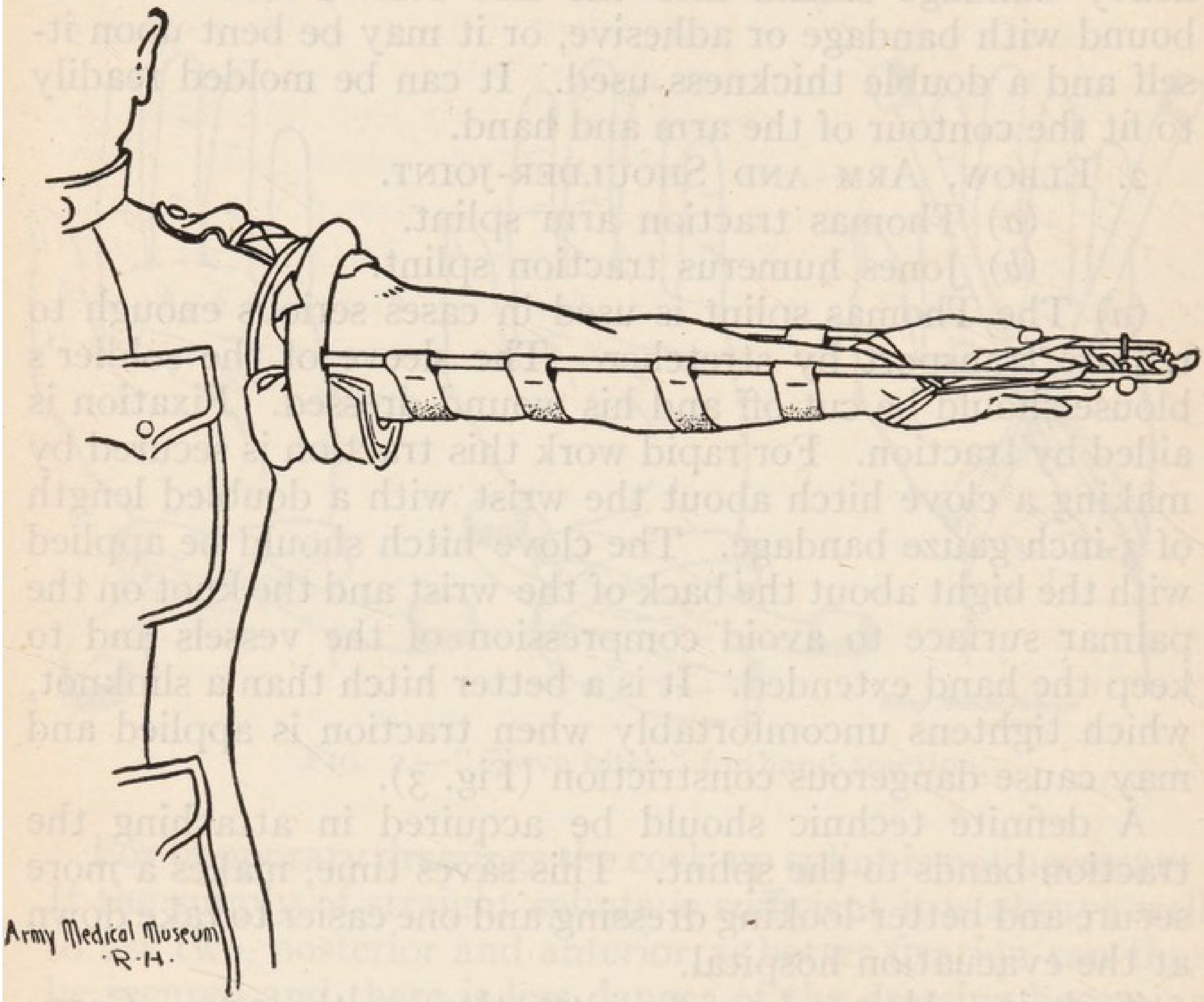


FIG. 3.—Thomas traction arm splint applied.

The axilla should be well padded with cotton to bear pressure from the ring of the splint.

The hand should not be covered by the bandage, as it must be watched for evidence of constriction by the traction hitch about the wrist.

(*b*) *Jones's humerus traction splint* is used for wounds above the elbow, particularly ambulatory cases. The wound should be dressed and the axilla padded. Short lengths of bandage

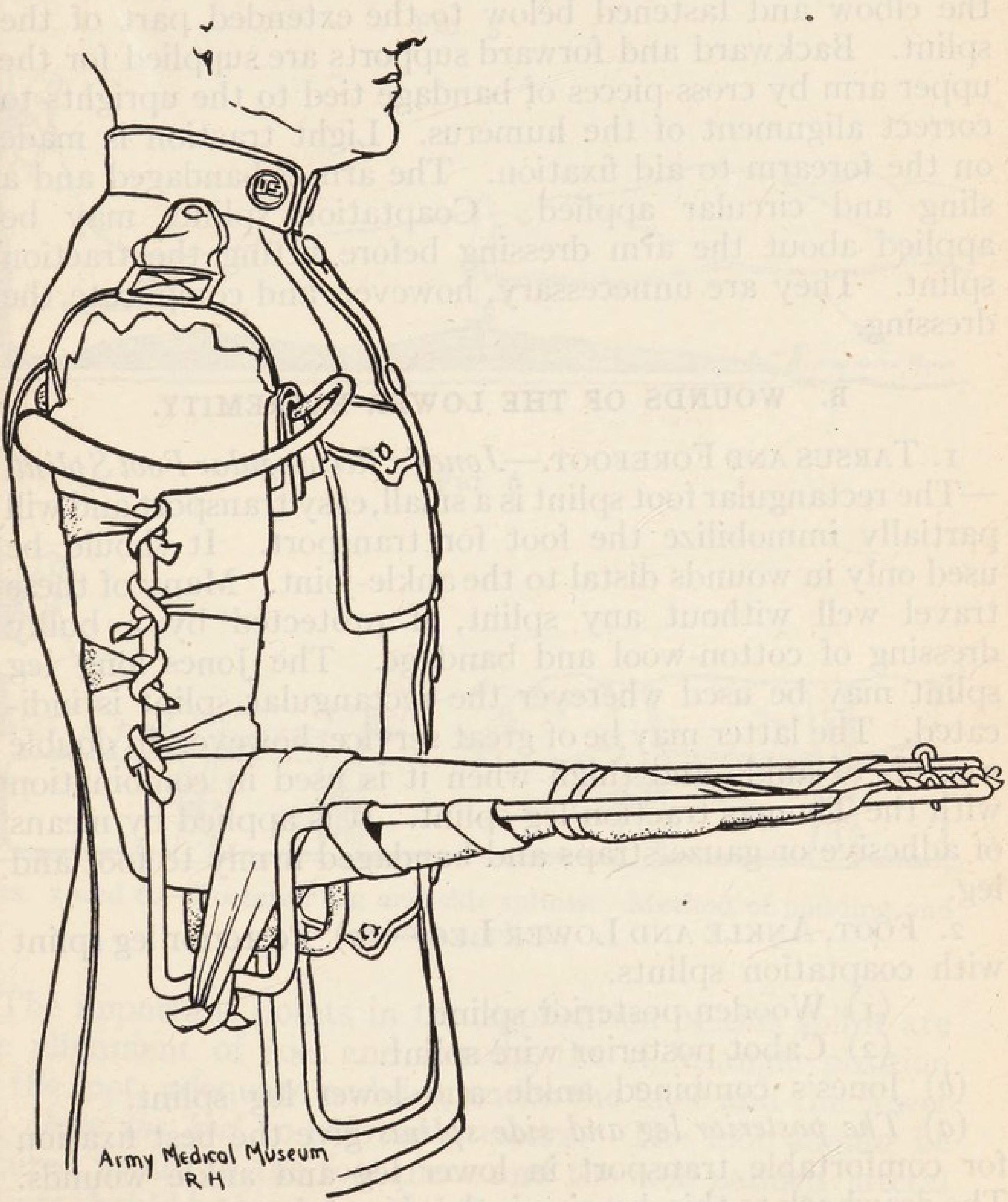


FIG. 4.—Jones's humerus traction splint applied.

are fastened across the horizontal part of the splint for forearm support. A clove-hitch extension is then applied to the wrist. Downward traction is made on the humerus by a broad bandage carried over the flexed forearm as near as possible to the elbow and fastened below to the extended part of the splint. Backward and forward supports are supplied for the upper arm by cross-pieces of bandage tied to the uprights to correct alignment of the humerus. Light traction is made on the forearm to aid fixation. The arm is bandaged and a sling and circular applied. Coaptation splints may be applied about the arm dressing before fitting the traction splint. They are unnecessary, however, and complicate the dressing.

B. WOUNDS OF THE LOWER EXTREMITY.

1. TARSUS AND FOREFOOT.—*Jones's Rectangular Foot Splint.*—The rectangular foot splint is a small, easy transport and will partially immobilize the foot for transport. It should be used only in wounds distal to the ankle-joint. Many of these travel well without any splint, if protected by a bulky dressing of cotton-wool and bandage. The Jones long leg splint may be used wherever the rectangular splint is indicated. The latter may be of great service, however, in double wounds of ankle and thigh when it is used in combination with the Thomas traction leg splint. It is applied by means of adhesive or gauze straps and bandaged firmly to foot and leg.

2. FOOT, ANKLE AND LOWER LEG.—(*a*) Posterior leg splint with coaptation splints.

(1) Wooden posterior splint.

(2) Cabot posterior wire splint.

(*b*) Jones's combined ankle and lower leg splint.

(*a*) *The posterior leg and side splints* give the best fixation for comfortable transport in lower leg and ankle wounds. The drawback to this dressing is that it requires three separate splints. However, a posterior splint should *never* be used without side splints. It gives no lateral retention and the leg often rolls quite off the splint in transport.

FIG. 5

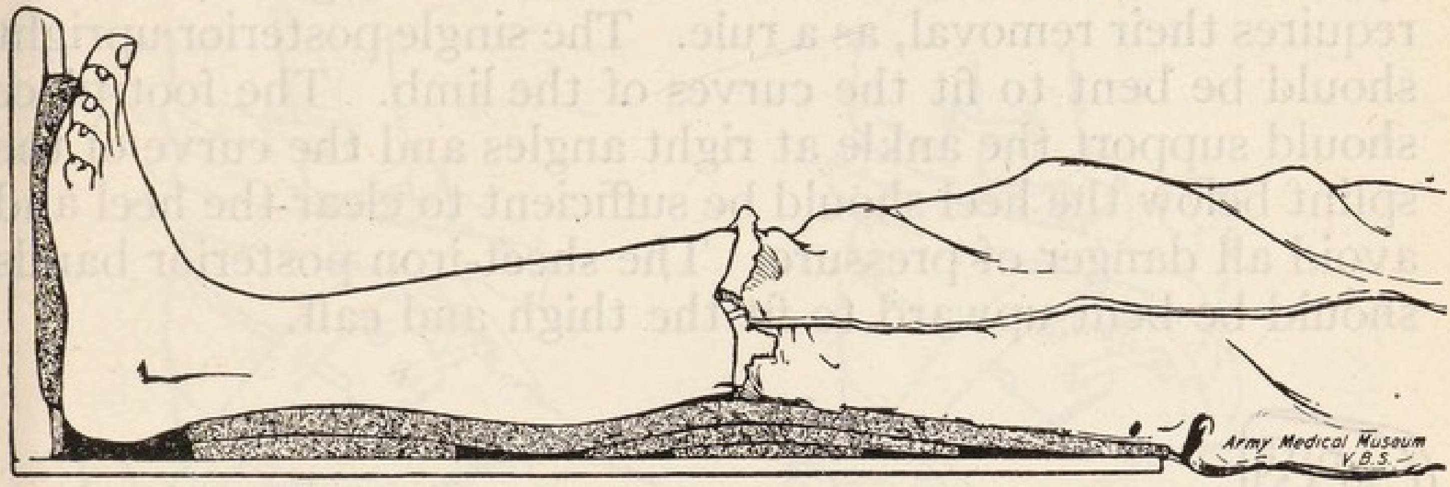
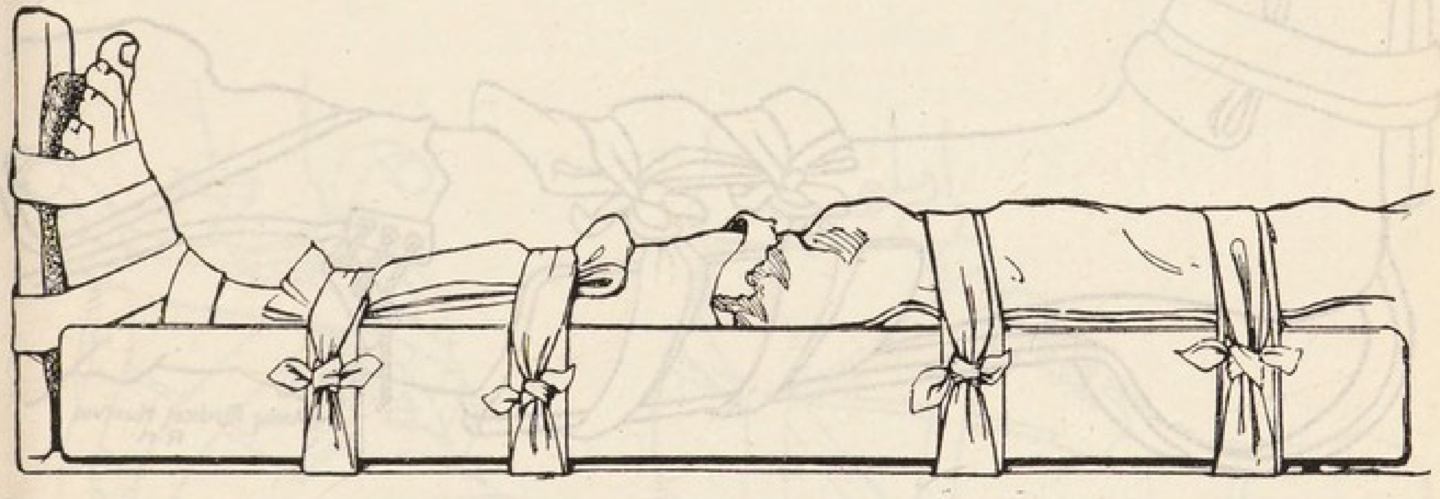


FIG. 6



FIGS. 5 and 6.—Posterior leg and side splints. Method of padding and splints applied.

The important points in the application of this splint are the alignment of toes and patella, the right-angle position of the foot, adequate padding under the knee and the lower leg *above the heel* to prevent pressure. The foot should be secured firmly to the foot-piece and the well-padded lateral splints should be bound on tightly enough to prevent rotation.

If adhesive is available, it is well to suspend the foot from the extremity of the foot-piece by means of a wide strip of plaster applied to the sole but not carried under the heel.

(*b*) *The Jones combined ankle and lower leg splint* may be applied outside the clothes. However, dressing of the wound requires their removal, as a rule. The single posterior upright should be bent to fit the curves of the limb. The foot-piece should support the ankle at right angles and the curve of the splint below the heel should be sufficient to clear the heel and avoid all danger of pressure. The sheet-iron posterior bands should be bent upward to fit the thigh and calf.

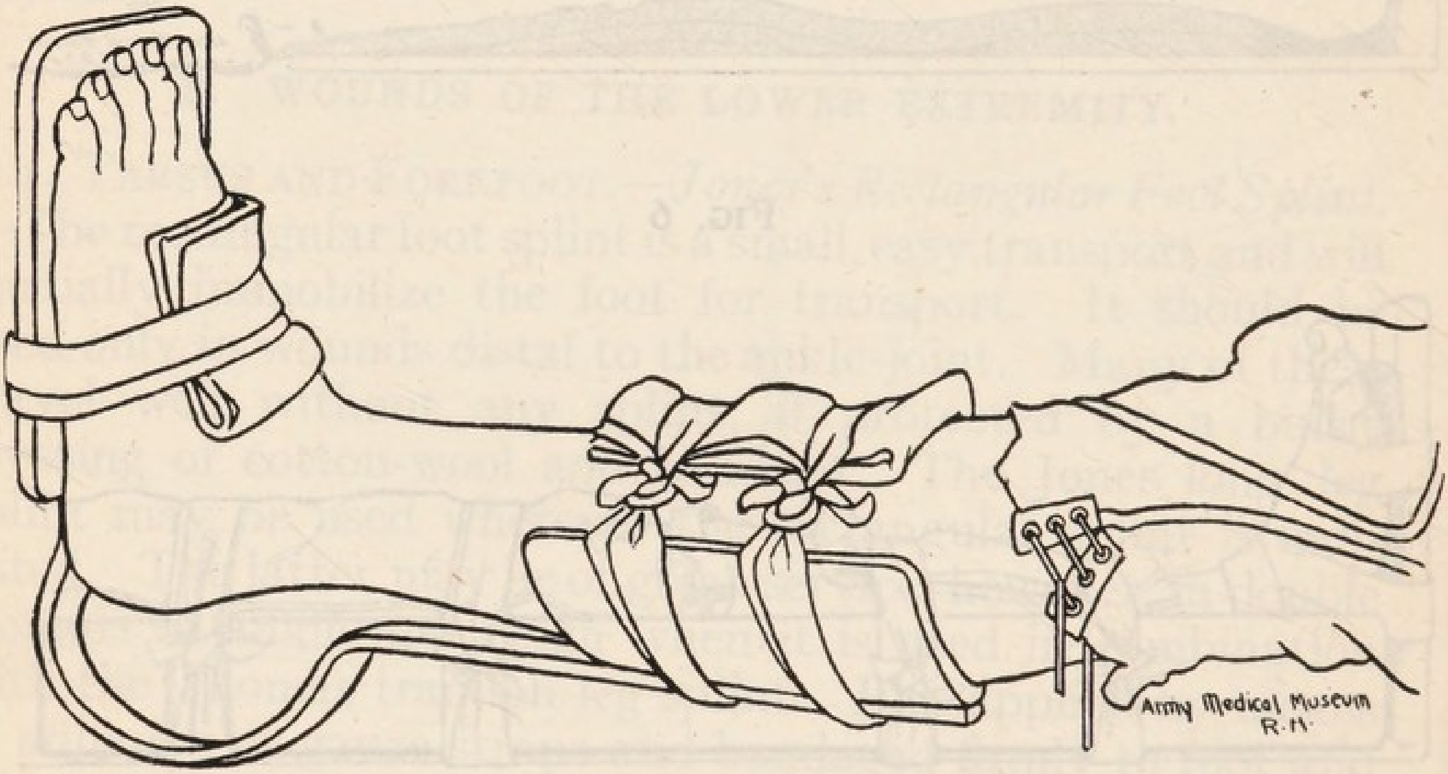


FIG. 7.—Jones's combined ankle and lower leg splint.

The splint is rapidly applied and easy to pack and transport. However, it fails to immobilize the leg complete because of the lack of lateral support, as the posterior pieces are not broad enough, particularly if the limb is covered with large dressings. This objection may be overcome by adding side splints, in which case it has little advantage over the older type of posterior leg splint. Folded blankets placed beside the leg on the stretcher make the splint more effective, acting like sand-bags to prevent rotation. It must always be borne in mind that splints in transport are subjected to

FIG. 8

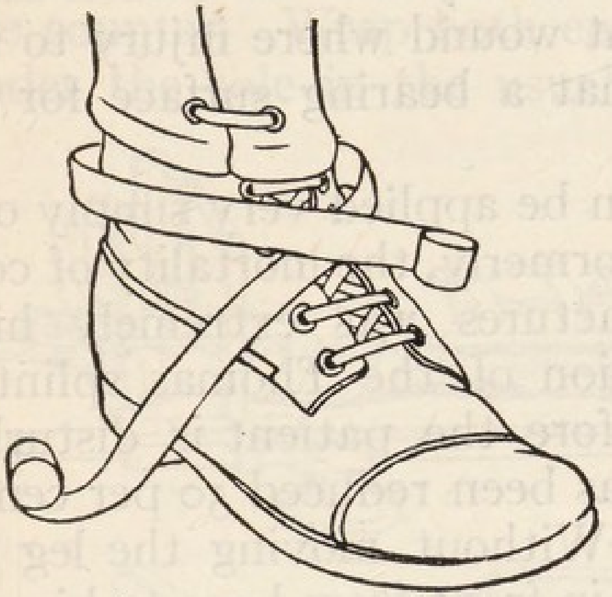


FIG. 9

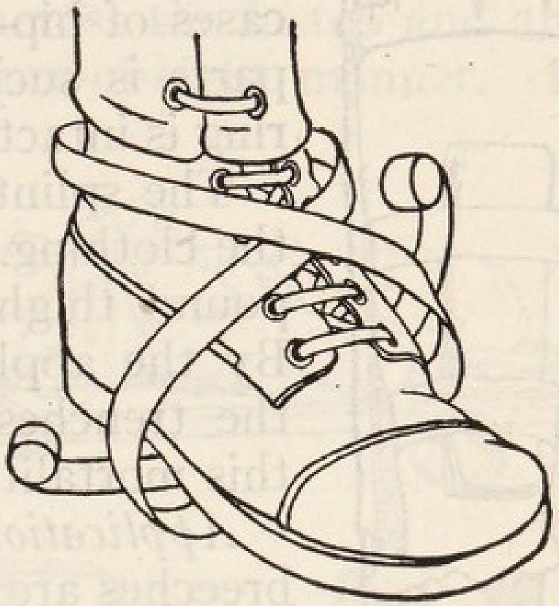


FIG. 10

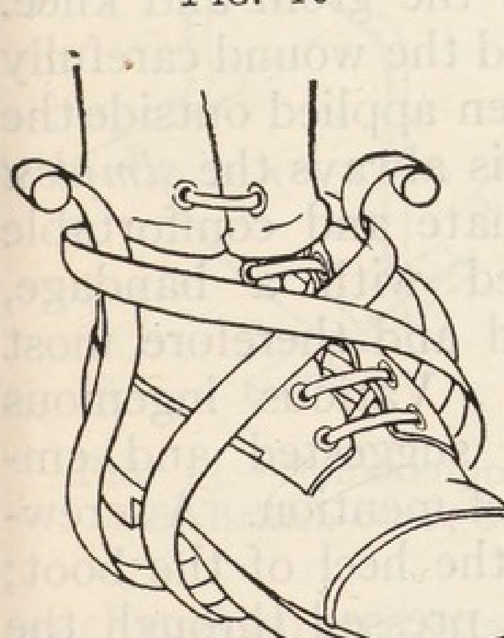
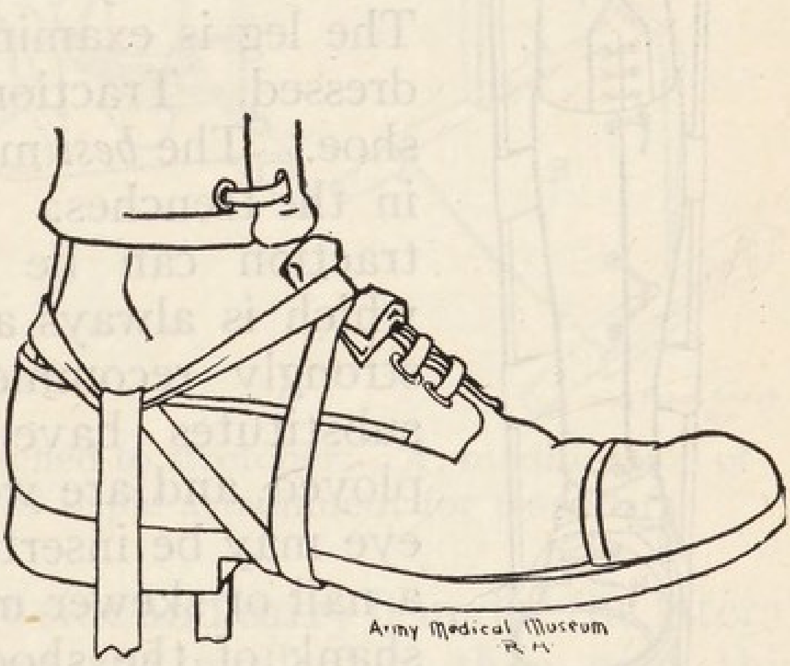


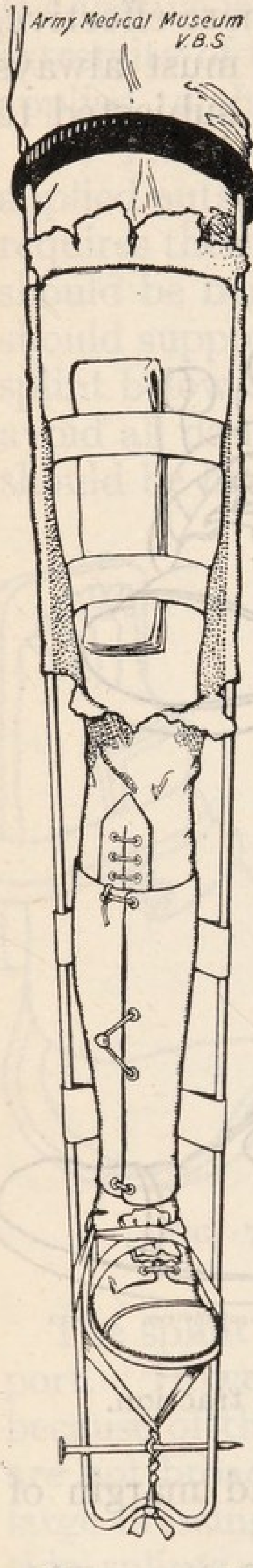
FIG. 11



FIGS. 8 to 11.—Methods of applying bandage foot traction.

unusual jars and strains which call for a broad margin of safety in their efficiency.

3. KNEE AND THIGH.—*Thomas's Traction Leg Splint.*—This is the most useful of all splints for wounds of the lower



limb. In addition to knee and thigh wounds, for which it is especially well adapted, it serves for a lower leg dressing by the addition of coaptation splints or the Jones rectangular splint. It may also be used in many cases of hip-joint wound where injury to soft parts is such that a bearing surface for the ring is intact.

The splint can be applied very simply over the clothing. Formerly, the mortality of compound thigh fractures was extremely high. By the application of the Thomas splint in the trenches before the patient is disturbed this mortality has been reduced 50 per cent.

Application.—Without moving the leg the breeches are cut in front from knee to hip and then half-way round at the groin and knee. The leg is examined and the wound carefully dressed. Traction is then applied outside the shoe. The *best* method is always the *simplest* in the trenches. Adequate and comfortable traction can be secured with a bandage, which is always at hand and therefore most strongly recommended. Various ingenious substitutes have been suggested and employed, and are worthy of mention. A screw-eye may be inserted in the heel of the boot; a nail or skewer may be pressed through the shank of the shoe and cords attached to its projecting ends; a horseshoe-shaped wire with inward facing prongs can be hooked over the welt of the shoe on both sides and a traction cord be attached to the ring of the horseshoe.

FIG. 12.—Thomas's traction leg splint, showing breeches pinned over upright and "Spanish windlass" traction principle.

These methods demand special articles, sure to be lost or mislaid, while bandage traction is always available.

The technic of its application is important. Take a doubled length of four-inch bandage a yard and a half long. Place the middle of this traction band back of the shoe just above the counter. Wrap both ends across the instep and around under the sole in the usual figure-of-eight manner. Bring

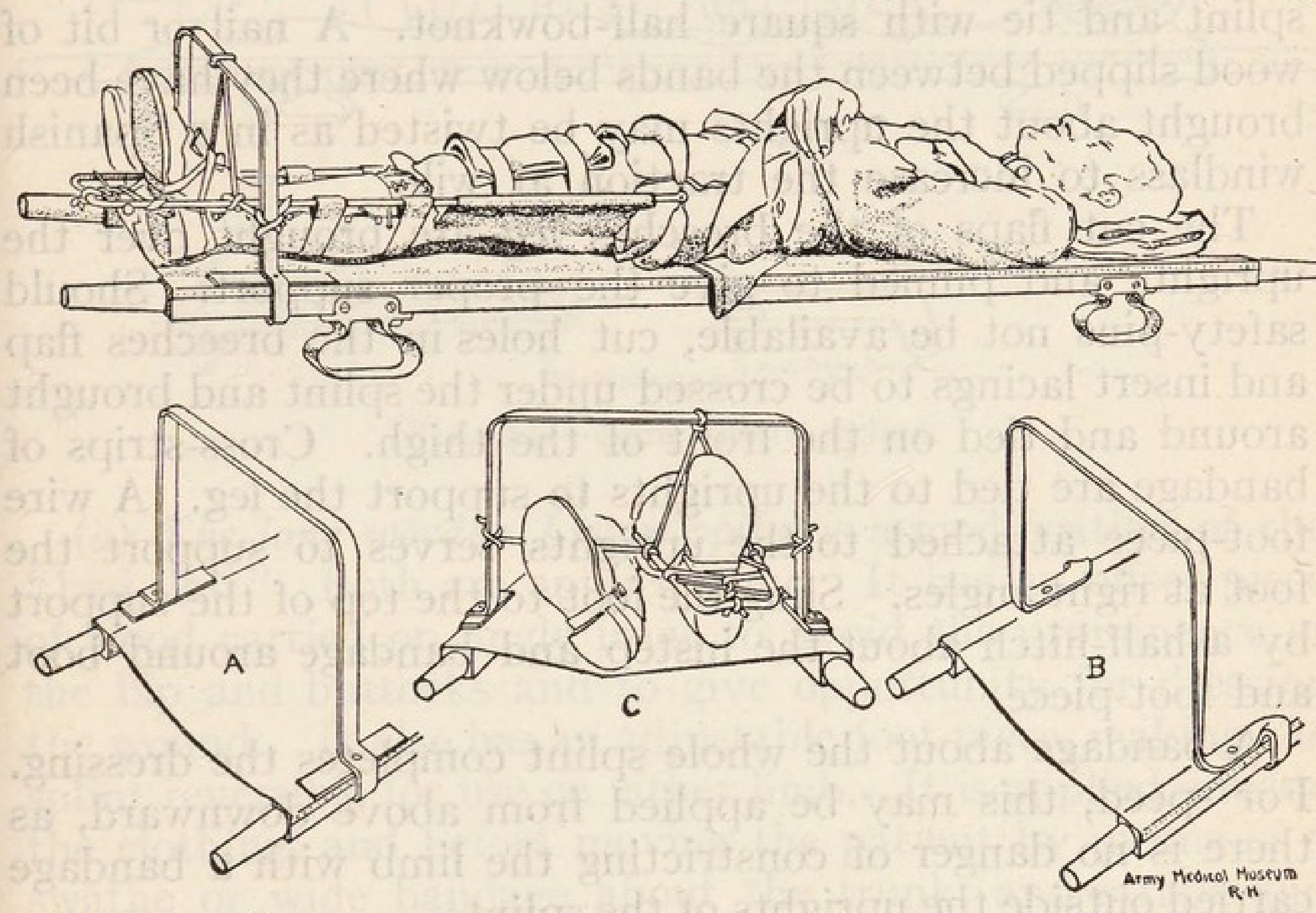


FIG. 13.—Splint support attached to stretcher: *A*, modification of *B*, British type; *C*, detail of triple attachment for transport.

each end up on its respective side and carry it under the lateral part of the bandage behind the malleolus, then over this bandage and directly downward, thus providing two lateral traction bands. The loops should be well back of the malleoli so that the line of traction is behind the ankle-joint. A generous pad should be placed over the instep beneath the crossing of the bands to prevent pressure. It must be borne in mind that grave injuries of the leg interfere with its circulation and that pressure sores may develop from incredibly slight trauma.

Slip the Thomas splint on gently and fit the ring well at the ischial bearing. Carry each traction band half-around the corresponding upright, passing one over and one under its upright, and then bring each end in opposite directions once about the notched iron piece at the lower end of the splint and tie with square half-bowknot. A nail or bit of wood slipped between the bands below where they have been brought about the uprights may be twisted as in a Spanish windlass to increase the traction at will.

The cut flaps of the breeches leg are brought over the uprights and pinned to give the proper support. Should safety-pins not be available, cut holes in the breeches flap and insert lacings to be crossed under the splint and brought around and tied on the front of the thigh. Cross-strips of bandage are tied to the uprights to support the leg. A wire foot-piece attached to the uprights serves to support the foot at right angles. Sling the foot to the top of the support by a half-hitch about the instep and bandage around boot and foot-piece.

A bandage about the whole splint completes the dressing. For speed, this may be applied from above downward, as there is no danger of constricting the limb with a bandage carried outside the uprights of the splint.

A coaptation splint is often used as a posterior splint to increase the support of the thigh. This is desirable, but by no means necessary, as the dressing as above described gives adequate and comfortable support.

Transfer to the Stretcher.—The stretcher should be provided with a heavy splint support which springs onto the side bars. The patient should be carefully lifted onto the stretcher by four bearers. The end of the splint should be slung to the cross-bar of the splint support by a bandage, so that the leg clears the stretcher, and also tied to each upright of the splint support to prevent side sway.

4. Hip and Pelvis.
   (*a*) Long Liston splint.
   (*b*) Straight "bed-slat" splint.

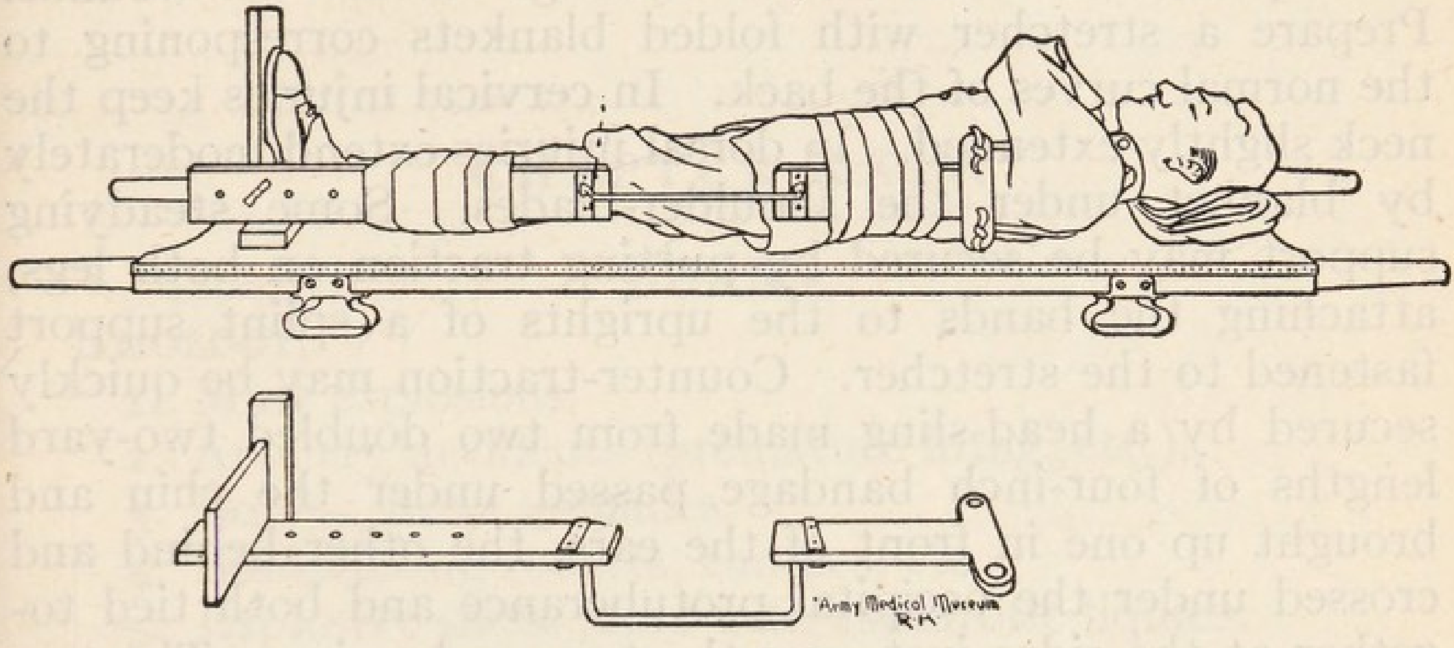


Fig. 14.—Long Liston splint.

(*a*) *The long wooden Liston splint* is a modification of the "bed-slat." Both are applied alike. It has an offset piece of wood carried on angle irons to avoid the prominence of the hip and buttocks and to give opportunity for dressing the wound. It also has an adjustable foot-piece, making the splint reversible for use on either limb. It is applied outside the clothing, and before moving the patient by means of a swathe or wide bandage about the trunk, and straps and bandages about thigh, leg and foot. Triangular bandages are useful for both swathe and thigh bandages.

(*b*) *The "bed-slat" splint* is a simple, straight board, preferably four or five inches wide, extending from the axilla to below the sole of the foot. It must be padded liberally opposite the trunk and limb to avoid too much pressure over the pelvis.

5. Spine, Cervical, Dorsal, Lumbar.—There is no splint commonly used for wounds of the spine. If a Bradford frame is available it is well to get a patient on it at once to avoid

moving him again. To do the dressing it may be necessary to turn him on his face. Be as gentle as possible and always have three or four men move him and caution him not to try to help himself. Cut off all clothing. Dress the wounds. Prepare a stretcher with folded blankets corresponing to the normal curves of the back. In cervical injuries keep the neck slightly extended. In dorsal injuries extend moderately by blanket under the shoulder-blades. Some steadying support may be secured by putting traction on both legs, attaching the bands to the uprights of a splint support fastened to the stretcher. Counter-traction may be quickly secured by a head-sling made from two doubled two-yard lengths of four-inch bandage passed under the chin and brought up one in front of the ears, the other behind and crossed under the occipital protuberance and both tied together at the sides just over the temporal region. The two bands may be fastened to the handles of the stretcher, the apparatus serving to steady the patient during transport.

CHAPTER XXIV.

BURNS.

ETIOLOGY.

1. Mine explosions.
2. Artillery accidents (premature firing, etc.).
3. Bombs, hand grenades.
4. Illuminating rockets, candles, etc.
5. Explosive shells filled with escharotic liquids.
6. "Flammenwerfer" projectors.
7. Ordinary accidental burns.

PATHOLOGY.—Ordinary pathology of burns complicated by:

1. Lacerated wounds.
2. Embedding of chemicals in tissues (phosphorus, celluloid, etc.).
3. Dirt, clothing, etc.

TREATMENT.

(*a*) Immediate.
(*b*) Subsequent.

(*a*) *Immediate Treatment.*—1. Do not scrub off the deeper layers of epidermis with soap, water and brush. This is imperative.

2. Cut away all clothing from burn, picking off pieces of clothing, etc., with a sterile forceps.

3. With small gauze sponges, soaked in commercial ether, the area beyond the burn is thoroughly cleansed of all grease and dirt.

A fresh ether-soaked sponge is then gently sopped—not rubbed—over the burnt area until the surface is perfectly clean.

Protective covering:

(*a*) Paraffin type.

(*b*) White wax type.

(*a*) Paraffin mixtures: (Ambrine modifications.)[1]

FORMULA No. 1 (LIEUT.-COL. A. J. HULL) (BRITISH).

Resorcin	1 per cent.
Eucalyptus oil	2 "
Olive oil	5 "
Paraffin, soft	25 "
Paraffin, hard	67 "

[1] "Ambrine," now extensively used by the French in the treatment of their gas burns, has proclaimed its formula, as now used, They now claim not to be using any drugs in the mixture, which is composed of 6 to 10 per cent. of gutta-percha and 90 to 94 per cent. of paraffin, melting at 55° C. The high percentages of gutta-percha are used in burns of the face where the greatest flexibility is desired. The removal of all drugs is logical, inasmuch as it seems demonstrated that paraffin will absolutely prevent dissemination of any drug mixed in with it; the addition of the gutta-percha certainly prevents undue rigidity or cracking of the protective coat. The results obtained by the "ambrine" treatment are those obtained by the application of formulæ one or two, or the soft white wax formula. The technic as applied in the special ambrine hospitals is necessarily very impressive—to a layman—but largely unnecessary. Wounds of the first degree heal through epithelial proliferation; those of the second and third degrees heal by connective-tissue proliferation. The cause of much misunderstanding lies in the fact that the ambrine people use the old Dupuytren classification of burns which describes seven degrees. They class a simple erythema as first degree; bleb formation is a second degree burn, and a burn involving the rete Malpighii is classed as a third-degree burn. They are thus within the truth when they declare that burns of the third degree heal without leaving any scar. Every case of burn of the second or third degree (according to our own classification) which I saw was filled in by scar tissue, not epithelial tissue. It is unfortunate that the undoubted advantages of a protective dressing of gutta-percha and paraffin should have become befogged by commercialism.

Melt the hard paraffin and add soft paraffin and olive oil. Dissolve the resorcin in absolute alcohol (soluble in 2 in 1), add the alcohol resorcin, and lastly add the eucalyptus oil when the wax has cooled to about 55° C. If the whole of the resorcin fails to remain in suspension, the amount may be decreased to 0.25 per cent. resorcin with good results (Hull).

FORMULA NO. 2 (MATAS OF NEW ORLEANS).

Betanapthol	0.25 per cent.
Eucalyptus	2.0 "
Olive oil	5.0 "
Paraffin, soft	25.0 "
Paraffin, hard	67.75 "

Both formulæ are solidified in the size and shape of cakes of soap, wrapped up in paraffin paper. They keep indefinitely. Both have a melting-point of 48° C.

Modus Operandi of the Paraffin Film Treatment of Burns.—Experiments recently undertaken by the Council on Pharmacy of the American Medical Association, conclusively prove that the principle of the method is mainly if not solely mechanical; the film of paraffin, being impervious, forms a protection to the exposed tissues. On the other hand, it can readily be removed *en masse* when desired. Perhaps the paraffin also forms a sort of scaffolding for the feeble granulations.

The significant properties of the films appear to concern in the first place the melting-point. This should not be much lower than 48° C. and not much higher than 53° C.

The hardness of the wax may be important. The harder the wax, the more firm is the support.

A further important property is the strength of the paraffin film (fragility). It involves two factors: (*a*) ductility, and (*b*) pliability. The more fragile films will break on bending at a relatively high temperature, while the more plastic films can be bent at relatively low temperature.

(*a*) "Parowax" (a trade name applied to paraffin marketed by the Standard Oil Co. of Indiana): "Paraffin 120° to 122° F." (put up by the same company), and formula No. 21,[1] consisting of:

Paraffin, 120° to 122° F.	97.5 grams
Olive oil	1.5 "
Asphalt	4 drops

All fulfil the above requirements. The addition of 2 per cent. eucalyptus oil, or of some other pleasant deodorant, is very grateful to most patients.

Technic.—1. Place the paraffin cake in a sterile metal container and heat over a flame. A quick and practical way of estimating the proper temperature is to thoroughly melt the entire cake, stirring occasionally with a sterile glass rod or sterile metal instrument. By waiting until the paraffin begins to show a solidifying film upon the surface, one obviates the danger of overheating.

2. With a soft cotton mop (a piece of absorbent cotton grasped in the bite of a forceps answers very well) sop—do not rub—the entire surface of the burn.

3. Place a thin layer (one-eighth inch) of absorbent cotton, cut the same size as the area of the burn, over the wound after the first layer of paraffin has been applied.

4. Cover the cotton with a second layer of paraffin. This may be more rapidly painted on by means of a broad, soft camel-hair brush.

5. Apply a thick layer of cotton and a light bandage.

6. Immobilize the area whenever possible.

(*b*) White wax type (Tarnowsky). Formula:

White precipitate of mercury . .	5 per cent.
Zinc oxide ointment	70 "
White wax	25 "

[1] Jour. Am. Med. Assn., May 19, 1917, p. 1499.

The melting-point is approximately that of the paraffin mixtures, and its application the same. Stock dressings may also be prepared with the same formula and kept on hand ready for instant use.

Preparation of Stock Dressings.—1. Sterilize by boiling a sufficient quantity of the above formula.

2. Cut strips of gauze of varying width and length.

3. Pick up each strip of gauze with a forceps, allowing it to unroll its full length; dip same in the boiling liquid; allow the excess to drain back into the vessel and drop the impregnated gauze into a sterile jar.

4. Do not pack the jar tightly. Close and seal jar as soon as full.

When required, pick up a piece of impregnated gauze by means of a sterile forceps and lay it lightly over the previously prepared burnt area.

(*c*) *Adhesive Plaster.*—Parker (Chicago) and others have used a shingling of adhesive strips to protect the burnt area. The secret of success in this method consists in carefully overlapping each successive strip of adhesive so that complete air-occlusion is obtained. The method is good because it fulfils the same desiderata, *i. e.*, it is protective and non-adherent.

Advantages of Types (*a*), (*b*) *and* (*c*).—1. Bland, non-irritating mixtures.

2. Absolute protection from the air.

3. Protection of new-formed granulations from damage.

4. Splint-like effect of the wax in holding the damaged tissue immobile and at rest.

With either type of dressing, the burnt soldier needs no further attention for twenty-four to forty-eight hours, providing, of course, that he is not suffering from other types of wounds. The soothing effect and the immediate cessation of pain through the use of either method is striking. Burns of all degrees are treated alike at first dressing.

Subsequent Treatment.—When the second dressing is made, either in the Field or Evacuation Hospital, the degree and extent of the burn and the probable additional treatment required, should be estimated. Burns of the first degree and all burns of the second degree not requiring grafting should be kept in the zone of the advance or zone of the line of communications. Burns requiring grafting, burns of the third degree, and those complicated by severe wounds (deep lacerations, compound fractures, etc.), belong to the base hospitals.

Skin-grafting will be required in second- and third-degree burns of:

1. Face, neck.
2. Hands.
3. Immediate vicinity of joints.

When Should Grafting Be Resorted To?—As soon as sloughing of burnt tissues has ceased.

The presence of slight amounts of pus is not a contra-indication.

Types of Graft.—1. Thiersch or Reverdin (superficial defects).

2. Skin-flap (deep defects).

1. Thiersch or Reverdin.—(*a*) The sooner the grafts are applied the greater the percentage of "takes."

(*b*) Grafts applied late over granulating surfaces seldom "take"; if they do they are apt to die subsequently, as the granulations under them contract and shut off their blood supply.

(*c*) Protect the grafts by applying thin strips of gutta-percha tissue over them "criss-cross"; over this lay gauze impregnated with paraffin or wax mixture.

(*d*) Do not disturb the dressing for several days.

(*e*) A wire netting cage protecting the burnt area obviates the necessity of a dressing and gives the best results. It is not always possible to devise such a cage.

2. Skin Flap.—(*a*) One-step method (transplantation).

(*b*) Two-step method.

(*a*) The entire thickness of the skin, including adipose tissue, should be used. It is only successful if done early, and if the vascularity of the burn is good and hyperemia can be maintained.

(*b*) The two-step or flap method is always reliable and should be selected whenever the location of the burn makes it possible. An interval of ten to fourteen days should elapse between the two steps and immobilization of the flap should be absolute. The margin of the burn should be trimmed vertically (at right angle to skin surface), and the flap sutured at its free margin and laterally, the sutures should be interrupted, without tension, and the wound covered with impregnated gauze which is usually not changed until the second step is completed. Be sure to allow for retraction of the flap (25 per cent. margin is a safe one to go by).

Prevention of Contractures and Disfiguring Scars.—1. By early and complete grafting.

2. By means of casts or splints.

(*a*) Immobilize in flexion, burns of:

1. Posterior surface of elbow.
2. Dorsal surface of wrist, hand or fingers.
3. Anterior patellar region.

(*b*) Immobilize in extension, burns of:

1. Anterolateral aspect of neck.
2. Anterior surface of elbow.
3. Palmar aspect of wrist, hand and fingers.
4. Popliteal space.

(*c*) Immobilize in abduction, burns of:

1. The axilla.
2. The crotch.

SUMMARY.—1. Do not scrub off the epidermal cells with soap, water and brush.

2. Leave burns of the first degree to nature so far as possible.

3. If grafting be necessary, resort to it as early as possible, even in the presence of a slight amount of pus.

4. The open-air treatment of burns of all degrees gives the best results.

5. If the open-air treatment is not practicable, always use a bland, non-adherent type of dressing and change the dressings as seldom as possible.

6. Beware of contractures and disfiguring scars. Proper splinting will always, proper grafting will often, obviate this calamity.

CHAPTER XXV.

GAS POISONING.

General Considerations.—While chemistry cannot, as yet, be said to compare in military efficiency with the extraordinary results obtained by present artillery fire, its importance can best be judged by the simple statement that the armies of one of our Allies has already suffered some forty thousand casualties through this single weapon. During the first year of the war the only cases of gas poisoning were those caused by carbon monoxide incident to the explosion of shells. This was followed by "drift gas," which depended entirely on the caprice of the prevailing winds for its effect on the Allies or its "boomerang" effects on the users of the gas. At present the drift gas is superseded by chemicals contained in high-explosive shells, the nature of the chemical employed changing as rapidly as an antidote for the same is discovered. We are thus waging a genuine "chemical war," chemical being followed by antidote in natural sequence.

While the term "gassing" is still popularly used, the solutions contained in the shells are in liquid form; but as the effects are produced by vaporization of these liquids, it has seemed best to retain the original term.

Etiology.—Cases of gas poisoning which occur in warfare may be caused by:

(*a*) Gases generated by-explosions.

(*b*) Drift gases.

(*c*) Shell gas (chemicals contained in and scattered by high-explosive shells).

(*a*) When modern explosives suddenly dissociate, the principal poisonous gas formed in large quantities (up to 60 volumes) is carbon monoxide. No harm is produced by the liberation of this gas in the open air, but in dug-outs, caves, mine galleries or deep mine craters, severe and even fatal cases of poisoning occur. During the slow combustion of explosives considerable quantities of nitrous fumes are also formed, in addition to the carbon monoxide.

(*b*) *Drift Gas.*—By "drift gas" is meant the liberation *en masse* of a gas or gas mixture, heavier than air, usually expelled from portable tanks by means of a pump and nozzle, which, propelled by a favorable wind, travels along the surface of "no man's land" and falls into trenches, dug-outs and mine craters. Bromide, chlorine, phosgene, chlorpicrin and trichlormethylchloroformate have been used by the Germans in various attacks. Their success depended largely on the element of surprise plus a fixed favorable wind. As soon as the chemical antidote was ascertained and supplied to the troops, its value as a weapon of warfare ceased. Sudden shifting of the wind frequently played havoc in the enemy trenches. At present writing, drift gas has been almost entirely discarded, at least on the western front.

(*c*) *Shell Gas.*—At present shells containing chemicals usually in liquid form, but generating toxic gases in the presence of moisture, are extensively used. During the past few months the Germans have been using dichlorethylsulphide (thiodiglycolchloride) having the formula:

$$\begin{matrix} CH_2Cl \diagdown \\ CH_2Cl \diagup \end{matrix} S$$

It is commonly called "Yperite," because it was first used against British troops at Ypres in July, 1917. Other synonyms are mustard gas (on account of its odor), vesicating gas (on account of its tendency to form blisters), etc. The liquid found in unexploded shells is dark brown in color and has an odor variously interpreted as suggesting garlic, mustard, hydrogen, cyanide, chloroform and carbylamine. After lying on the ground it forms a yellow patch which lasts thirty to thirty-six hours. The odor lasts two or three days if it has penetrated moist clothing. Decomposition of Yperite takes place especially, if not exclusively, when the compound is exposed to moisture.

Method of Use:

Yperite is contained in German 77 and 105 shells, which are specially marked with a yellow cross to distinguish them from ordinary high-explosive shells. Each 77 shell contains 285 c.c. of the liquid; the 105 shell carries 1360 c.c. When the shell strikes an object a special fuse explodes a chamber of picric acid, bursts the shell and sprinkles the liquid over a wide area. The slowness of decomposition of this infernal liquid and its ability to cause unforeseen burns can best be illustrated by the case of a French soldier whom I saw in one of the special hospitals for the treatment of Yperite casualties: Twenty-four hours after an attack this soldier was loading unused boxes of small munitions onto a truck. These boxes were assembled in a secluded gully near the firing line. Unaware of the sprinkling of liquid on these boxes, he carried them in his arms, pressed against his chest. When seen in the hospital two days later, he had typical burns of the first degree involving the chest, forearms and hands. There was a slight conjunctivitis but no respiratory symptoms.

Very recently (November 13, 1917) a new chemical has been identified in the German shells. This substance, commonly called "Arsine," is diphenylarsine-chloride. As found in the clothing of gassed men it consists of fine solid particles having a strong garlicky odor. It rarely penetrates through the clothing and can easily be shaken out or beaten out.

PATHOLOGY. — (*a*) *Carbon-monoxide Poisoning.* — Identically the same blood changes are found as in CO poisoning of civil life.

(*b*) *Drift Gas.*—Drift-gas burns of all degrees form the initial lesion and dominant pathogenic picture of these casualties. The gases affect the skin, eyes, mucosæ of the entire respiratory tract, the blood and circulatory system and, to a less extent, the digestive and urinary organs.

Occasionally, though only when the action is severe, these gases cause redness and swelling of the skin. This occurs principally on those parts of the skin which are not protected by the mask, but the same lesions are found in other parts of the body where the skin is delicate and moist (axillæ, scrotum).

Intense hyperemia of the conjunctivæ and occasionally a superficial keratitis which can be recognized by the instillation of fluorescene as a horizontal band corresponding to the narrowed opening between the eyelids.

In mild cases an intense hyperemia of the respiratory mucosa occurs; it is frequently followed by the formation of a grayish-white pseudomembrane or even a slight ulceration of the pharynx and larynx. The alveoli of the lungs become congested, with edema of the mucosa and increased secretion into the bronchioli and inflammatory exudation into the tissues of the lung.

In severe cases one finds a very marked increase in the viscosity of the blood. There is a tendency toward the formation of thrombi (pulmonary and cerebral vessels as well as those of the upper and lower extremities); small extravasations of blood occur on serous membranes (pleura, pericardium) and also in the brain and mucosa of the gastro-intestinal tract.

Disturbances of the nervous system are entirely due to circulatory changes.

Marked hyperemia with the presence of blood in the gastro-intestinal tract occur in severe cases.

Postmortem examinations have enabled observers to describe the following pathological sequence of changes:

An acute inflammation of the air passages, from the pharynx down, is followed by entire desquamation of the mucous lining with remarkable formation of false membrane (patients frequently cough up complete casts of trachea and bronchi). This membrane in addition to the actual obstructive effects produced, affords a suitable pabulum for organisms. An acute purulent capillary bronchitis is then superadded, leading to collapse of lung tissue and quickly to bronchopneumonia. (In smears from the purulent material in the bronchi, organisms of many varieties are present in the greatest abundance.) The acute emphysema, which also forms a prominent feature of the pulmonary lesion, is due to mechanical obstruction of the air passages.

The burns of the skin are almost invariably of the first degree, but marked edema of the scrotum and penis is often found. In one fatal case, an acute hemorrhagic nephritis, with marked edema of the lower limbs, was an important finding.

Histologically, the only constant and marked microscopic changes are found in the lungs and air passages. They consist of necrosis and desquamation of the mucosa of the trachea and bronchi, followed by the formation of an inflammatory membrane composed of leukocytes and fibrin. The purulent bronchitis present is due to secondary infection. Alternating areas of pulmonary emphysema and collapse are found. Where the cases survived a number of days, diffuse bronchopneumonia succeeded the bronchitis, resulting in a blocking of bronchi and collapse of the non-solidified portions of lung tissue. In the other organs, no changes of importance were observed. Degenerative changes in the center of the liver lobules were found in two cases and minute irregular hemorrhages in the white matter of the brain in several cases.

(*c*) *Shell Gas.*—In the vast majority of cases the hyperemia of the mucosæ is superficial and the skin lesions consist of erythemas and burns of the first degree. In a postmortem examination of a few of the fatal cases the most noteworthy features were:

Severe damage to the bronchi and bronchioles; the epithelial layer was entirely destroyed and replaced, for the most part by a thick layer of fibrin with débris and leukocytes, resembling a diphtheritic membrane; the deeper layers of mucosa were also affected; there were thrombi of small arterioles and considerable edema; the elastic tissue fibers were swollen.

Patchy consolidation and persistent edema of lung tissue filling the alveoli; abundant leukocytic exudate in the areas of consolidation.

A severe degree of infection, with hemorrhagic exudate in two cases.

The kidneys were acutely congested, but there were no definite alterations recognizable in the renal epithelium or glomeruli. There was no evidence of remote effects in other organs.

SYMPTOMS.—(*a*) *Carbon-monoxide Poisoning.*—Headache, malaise, nausea and emesis, dizziness, etc. The respirations are shallow, irregular and jerky, with absence of cyanosis. There is a dulling of sensibility which may pass to complete unconsciousness with widely dilated insensitive pupils and general functional failure.

(*b*) *Drift Gases.*—1. Superficial burns of the skin (rare).

2. Photophobia and lacrimation are prominent features of chlorine-gas poisoning and the symptoms appear within a few minutes. With phosgene, on the other hand, there is a latent period of a few hours to a few days which renders early diagnosis very difficult. Superficial erosion of the cornea occurs in severe cases.

3. By far the most painful symptoms are those referable to

the respiratory tract. There is an immediate sensation of dryness and burning of the throat, followed by a sensation of choking, due to a spasm of the pharyngeal muscles. Many of the early victims climbed out of their trenches in face of a heavy fire "because they had to or else choke to death."

Attacks of coughing, burning pain in the chest, a feeling of pressure and breathlessness may come on at once or after the lapse of several hours, depending on the nature of the gas, its degree of concentration and the duration of exposure. In mild cases there are signs of diffuse bronchitis accompanied by moist râles and more or less copious catarrhal sputum. In severe cases the distress becomes intolerable; the men wail and groan, struggle for air and toss restlessly about. The color of the skin varies from bluish-red to the deepest cyanosis.

Respirations are rapid and shallow; in the terminal stages they become irregular and faltering, expiratory dyspnea being a marked feature. The sputum becomes profuse, thin in character, albuminous, frothy and often blood stained. Physical examination shows the presence of an acute pulmonary emphysema, with widespread crackling râles and diminished breath sounds.

On the second or third day, a sudden rise in temperature (100° to 103°) occurs, accompanied by signs of bronchopneumonia of variable severity. The breathlessness and cyanosis become more intense and one finds scattered through different parts of the lungs, crepitant, and occasionally coarse râles. As a rule this early bronchopneumonia is due entirely to the action of the gases and not to bacterial infection. Its symptoms generally disappear after two or three days. It must be distinguished from the later, often terminal pneumonia which does not appear before the third to the fifth day. This late pneumonia is due to bacterial infection and runs its course very much as an ordinary pulmonary infection.

In the majority of cases, even in those who have exhibited severe symptoms of pulmonary edema and bronchopneumonia, convalescence is fairly rapid and the pulmonary symptoms disappear without leaving a trace.

4. The coagulability of the blood is increased during the height of the disease, diminished in the later stages, and is totally lost for a few hours after death. At the height of the illness the cardiac dulness is increased, blood-pressure falls and the pulse volume decreases until it becomes almost imperceptible.

5. Evidence of disturbance of the nervous system is frequently afforded at the very commencement of the disease. Headache, dizziness, staggering gait, muscular weakness, diminution of tendon reflexes and dulling of sensibility to complete unconsciousness, may be encountered. These symptoms seem especially to appear in cases having been exposed for a considerable period of time to low concentrations of gas which produce no immediate respiratory irritation, hence under conditions favoring the absorption of toxic substances into the blood.

6. Loss of appetite, gastralgia, nausea and emesis, are frequent symptoms. Hemorrhagic enteritis, when present, is mild and transitory in character.

(*c*) *Shell Gas.*—In both Yperite and Arsine cases there is a distinct interval of from four to sixteen hours between the actual gassing and the onset of symptoms. Both exhibit the following clinical picture:

1. Severe epigastric pain accompanied by repeated emesis.
2. Coryza of varying severity.
3. Conjunctivitis with profuse lacrimation and, in some cases, photophobia.
4. Cutaneous symptoms:

With Yperite gassing an erythema is almost constantly present, scarlatiniform in appearance, but usually strictly limited to the portions of the body which have been in contact with the liquid (axilla, scrotum, penis). The rash is coexistent with the formation of blisters of various sizes. Wherever present the patients complain of severe itching and burning sensations. In a certain percentage of cases, blistering only occurs twenty-four to forty-eight hours after the appearance of the rash.

With Arsine gassing the erythema is often lacking; it never makes its appearance before the second or third day, or even later. As a rule it only involves exposed surfaces of the body (face, neck, forearms, hands). When present the erythema is of a uniform rosy color, but may resemble measles or urticaria. As a rule pruritus is absent; blistering extremely rare.

The burns from shell gas are practically all of the first degree, but the vesication is out of all proportion to the actual damage done to the tissues. On the chest, back, forearms and hands the skin looks as though it had been singed by a flame; it is brownish black in color and its superficial layer desquamates in forty-eight to seventy hours. Vesication is particularly marked over the scrotum, perineum and penis with a tendency to severe edema of the latter. Dysuria is frequent and defecation is not infrequently accompanied by severe rectal tenesmus. Under appropriate treatment the lesions are almost painless after forty-eight hours. An examination of several hundred cases in different French hospitals brought out one salient fact, namely: the undying hatred of the enemy which this type of injury produced on the minds of the soldiers. The loss of two or three limbs was considered as natural to war; the results of the gassing were regarded as most barbaric.

5. Two or three days after the appearance of the erythema the patients begin to suffer from painful laryngotracheitis, frequently associated with a sense of constriction about the neck and occasionally complete aphonia. Severe cases will cough up pieces of false membrane or even entire casts of portions of the upper air passages.

6. Concomitant with the above is the appearance of bronchitis, which is severe but afebrile. The cough is paroxysmal and especially severe at night. The respiration rate is slightly accelerated. Tightness of the chest is a frequent complaint. In fatal cases the afebrile bronchitis is followed in a few days by a purulent capillary bronchitis leading to lung collapse and bronchopneumonia.

7. The heart is apparently not affected.

8. Urinalysis shows a marked increase of sulphate output, with frequent but transitory albuminuria.

PROGNOSIS.—The exact mortality cannot be published at present for military reasons. It was necessarily high before proper antidotes were provided for the soldiers' masks. Each succeeding chemical will naturally cause more casualties as long as it remains a surprise. New antidotes and new methods of treatment must be devised to meet every new variety of poison. A prognosis in the case of chlorine gassing can only be made in the first few hours; in the case of phosgene only after four or five days. The majority of deaths from chlorine occur during the first twenty-four hours. Many cases of phosgene gassing protested against being transported by stretcher or ambulance, only to be found dead in their cots a few hours later. The last two shell gases have, so far, given a very low mortality.

PROPHYLAXIS.—(*a*) *The Gas Mask.*—The nature and modus operandi of the antidotes in use cannot be discussed for military reasons. Suffice it to say that the use of the face mask has either nullified or reduced to a minimum all respiratory and gastro-intestinal symptoms.

(*b*) *Cellars and dugouts* give excellent protection against shell gases. Masks are often not needed in such protected places. Should Yperite or Arsine have been sprinkled in these undergrounds, powdered chloride of lime can be sprinkled over the floor or they can be cleared out by means of Aryton fans or wood fires.

(*c*) *Clothing* should be changed as soon as possible after a gas attack. If this be impossible, the dusting over of the axillæ, perineum and external genitalia with sodium bicarbonate, talcum powder, etc., is recommended.

(*d*) *Stretcher-bearers* and men who have to handle clothing, supplies, etc., in the vicinity of a gas attack should wear double thick rubber gloves.

ACTIVE TREATMENT.—(*a*) *General.*—1. *Clothing.*—Complete change of clothing, the clothes to be thoroughly dried and steamed before being used again (a simple beating of the clothes in order to shake off the solid particles of Arsine is sufficient). This is highly essential, as the retained chemical in the clothes decomposes on exposure to moisture and produces the toxic, local and constitutional effects.

2. *Rest.*—Absolute physical rest in order to obtain a maximum of physiological rest. This is the one all-important factor in the general treatment of all gassed cases, regardless of the nature of the poison used.

Gassed cases must not be allowed to walk, even with assistance, but should be carried by hand or on stretchers whenever possible. In severe cases absolute rest in the regimental aid station is preferable to the most careful evacuation. If evacuated to a field ambulance or evacuation hospital, they should be kept there until all danger of pulmonary edema has passed. A maximum of ventilation must be provided for these cases. The position of the patient should be governed by his own preferences in the matter. If he elects to lie flat on his back, rapid shallow breathing with little muscular effort is obtained; with the thorax raised, deeper inspirations are possible but at the expense of greater muscular effort (greater tissue respiration demand).

When the action of the gas has been very intense and respiratory failure seems imminent, artificial respiration may have to be resorted to. This is best done by hand, as the employment of the pulmotor has given unsatisfactory results. Where, after a battle, there are large numbers of gassed men to be taken care of, it will be impossible to give individual attention to these severe cases.

3. *Medication.*—The administration of opiates is of doubtful value except to check suffering in desperate cases; ipecac though advocated, should not be used because it is too depressing, but small, often-repeated doses of ammonium carbonate may be given as an expectorant. The administration of alkalies in large doses is advocated in Yperite cases (30 to 60 grains of sodium bicarbonate daily).

The gastro-intestinal symptoms are fairly well controlled by the daily administration of 100 c.c. of a 1 to 1000 solution of saccharate of lime.

4. *Venesection.*—Venesection is beneficial in the stage of acute asphyxia with "blue face" and venous congestion, in order to relieve the right side of the heart. In the "pale" stage of oxygen deficiency there is no indication for venesection; in fact it is probably harmful. From 200 to 600 c.c. should be withdrawn, depending on the degree of pulmonary edema already present. With the lungs flooded by blood plasma, 300 c.c. of concentrated blood would correspond to 600 c.c. of blood of normal composition. Venesection is best obtained by a surgical exposure of the vein (median basilic or median cephalic), and a clean section of one-third of its wall; even the thickest blood will then flow readily. After completing the phlebotomy, the proximal end of the vein is ligated, leaving a temporary ligature on the distal segment, in case a second withdrawal of blood should be necessary.

5. *Oxygen.*—To meet the air hunger, oxygen should be administered, according to the severity of the case, in periods of ten minutes each, from two to four periods per hour and at the rate of 6 liters of oxygen per minute. The flow of oxygen is regulated by means of the valve. When there are

many cases needing oxygen at the same time, a very practical and fairly accurate method is to take a number of ordinary "air cushions," measure their capacity as they are filled with oxygen, and regulate the outflow by means of the screw valve. Each patient thus has his own individual oxygen supply and an orderly can attend to the wants of a number of gassed men at the same time. The uninterrupted administration of oxygen is harmful; blood saturated with oxygen cannot take up any more oxygen, and the breathing of oxygen, if prolonged, has an irritating effect on the air passages.

(*b*) *Local.*—1. *Eyes.*—Sodium bicarbonate washes, repeated as often as the severity of the case demands. One per cent. cocain in ung. hydrarg. flavi (one-half strength).

2. *Respiratory Tract.*—The application by means of an atomizer, of a protective oily solution gives excellent results in the milder cases of mucous burns. Liquid albolene is satisfactory. The French use a 5 per cent. solution of gum-oil (*huile goménoléé*) or a mixture of equal parts of sterilized lime water and oil of sweet almonds (*liniment oléocalcaire*). These are either sprayed or injected into the trachea through a long curved cannula, from 2 to 10 c.c. being used at each treatment.

3. *Gastro-intestinal Tract.*—The French use the gum-oil or lime water mixture through a No. 12 or No. 14 catheter passed into the esophagus *via* the nares.

4. *The Skin.*—The British treatment of Yperite burns is by douching or bathing the skin with a solution of sodium bicarbonate or applying wet dressings of the same solution. The French treat all of their burns by "Ambrine" (see chapter on Burns), with excellent results.

8. SUMMARY.—1. Prophylaxis is largely a chemical problem of antidotes, but the value of other preventive measures must not be lost sight of.

2. The treatment should be started in the regimental aid station and pushed vigorously.

3. While the fatalities are low, as compared with the results of artillery fire, the number of men who are temporarily placed *hors de combat* by gassing, makes the treatment of these cases an extremely important one from a military point of view.

CHAPTER XXVI.

TRENCH-FOOT.

DEFINITION.—Trench-foot is essentially a primary vaso-motor ischemia clinically manifested by anesthesia of a part of, or of the entire foot, followed by a stage of subacute painful edema, which may go on to bleb formation or even gangrene. Closely related to, if not identical with, frost-bite, it was a very common condition among the troops in northern France, in Poland, in the Balkans and on the Italian front, during the first winter campaign.

ETIOLOGY.

1. Prolonged exposure to cold and moisture.
2. Immobility for long hours at a time.
3. Restricted circulation from:
   (*a*) Too small socks.
   (*b*) Tight shoes.
   (*c*) Tight puttees or spirals.
   (*d*) General exhaustion.

SYMPTOMS.—*Onset.*—Insidious; the first thing noticed is the increasing coldness of the feet with final entire loss of feeling. Except for the discomfort associated with the cold feet, pain is not complained of at first.

Active Symptoms.—(*a*) Pain, usually referred to the ankles but may extend up to the calves of the leg. Pain apt to be nocturnal in character.

(*b*) Edema of the foot and ankle.

(*c*) Extreme coldness and pallor of the skin with a light pinkish blush or mottled blue color over the toes and ball of the great toe.

(*d*) Blurred sensation, but tenderness on pressure is complained of.

The more severe cases progress on to massive edema, cyanosis, bleb formation or even gangrene.

The fact that warmth increases the pain, and the nocturnal character of the latter, should be borne in mind whenever the question of malingering is to be considered.

TREATMENT.—(*a*) *Prophylaxis*.—1. Keep the trenches as dry as possible.

2. Serve the men with warm food at least twice daily while they are in the trenches.

3. Exercise, while on duty in the front line trenches, "marking time," when the men cannot move about, should be made obligatory at stated intervals throughout the period of active duty in the front line. If possible, the men should be made to lie down (on tarpaulin) and do overhead exercises with their feet.

4. The men should carry an extra pair of socks with them and be made to change them frequently when circumstances permit.

5. Extra size shoes should be worn and an extra pair of shoes should be carried to the front line, so that socks and shoes can be changed at the same time. Boots or shoes should be dried, preferably on a rack which permits them to be so placed that the moisture will settle back of the heel where it can be sopped up.

6. The use of knee-high rubber boots has proved very satisfactory.

7. Wrapping the feet in paper, instead of putting on woolen socks, has been tried with success.

8. As charcoal braziers are supplied to the men in cold weather, they should be instructed to dry their socks and shoes against them, but under no circumstances to warm their shod feet against them, especially after the latter have become anesthetic.

(*b*) *Active Treatment*.—(*a*) *Local*.—1. Rest, elevation of limb. Remove all pressure of bedclothes by the use of a suitable cradle.

2. Exposure of the foot to the air, night and day, is the best method of treatment. The cardinal symptom of trench foot, aside from the edema, is hyperidrosis, which is intensified by the application of dressings. Heliotherapy is of inestimable value; artificial (electrical) heliotherapy is used with good results in France.

3. A dusting powder consisting of equal parts of boric and salicylic acids should be applied once daily.

4. In severe, obstinate cases a daily sponging of the feet with a 1 to 1000 formalin solution is beneficial.

5. If the blisters are small (not larger than 2 cm.) and not under undue tension, leave them alone, as they will heal with the treatment of the edema. Larger or hemorrhagic blisters should be aseptically excised and the overlying skin removed. A dressing of camphor-ether (camphor, 30 gm.; ether, 1000 gm.) laid over the blisters hastens their healing.

6. Massage of the feet should be begun early.

(*b*) *General*.—Calcium lactate, given in doses of ½ to 1 dram at intervals of four or five days is recommended on account of its beneficial effects on skin affections associated with hyperidrosis.

(*c*) *Specific*.—Whenever blisters have formed and ruptured, the usual prophylactic dose of 500 units of antitetanic serum should be given. Should ulceration develop, 3000 units should be given intravenously, repeated in a week if the ulcer persists.

SUMMARY.—Open air, rest, elevation and early massage as soon as blisters have healed will give the best results. Prophylactic antitetanic serum should never be omitted in the presence of a ruptured blister. The average period of treatment in mild cases is two weeks, and these cases should be kept in the zone of the advance. Severe cases, with edema and bleb formation, will often be incapacitated for two months or longer, and should therefore be sent to the base.

The marked susceptibility of these cases to recurrence of the same trouble should be borne in mind.

CHAPTER XXVII.

ROENTGENOLOGY IN WAR SURGERY.

LOCALIZATION OF FOREIGN BODIES IN ARMY SERVICE.

(The Standard Methods Approved by the Surgeon-General's Office, U. S. Army.)

EXPERIENCE in military service during the present war has served to emphasize the importance of rapid and reasonably accurate methods for the localization of foreign bodies. The ordinary practice of roentgenology, as a rule, has little to do with this phase of the subject. In civil practice methods could be used which required a considerable amount of time, and it was usually possible to consult with the surgeon and to repeat observations to an extent quite impossible in the present emergency. The localization of small projectiles in the eye had been developed in quite a satisfactory manner and no distinct improvement therein has been attempted. During the war abroad a variety of methods and appliances have been used and the choice of method has been left largely to the individual operator, circumstances preventing systematic attention to either mechanical equipment or special training.

According to the reports received from several excellent surgeons in active service at the front, it would be desirable and may even be regarded as necessary that all of the injured should have the benefit of an *x*-ray examination; since it has been found that there are many cases where foreign bodies split off after entry, or are in such unexpected or peculiar positions that they can hardly be successfully handled without the evidence available in such an examination.

In order to work on such an extensive scale it is necessary to consider very carefully the relation of x-ray work to surgery and to analyze the methods which are to be employed with reference to simplicity and certainty, and to pay particular attention to the reports and information needed by the surgeon in order to facilitate his work. In this connection it may be remarked that there is a distinction between the x-ray requirements in evacuation hospitals and base hospitals. In the former, speed is essential and simple apparatus must suffice. In the latter, a more complete equipment would be expected. It may be well to recognize that time will not permit the use of plates or films in the evacuation hospitals, and dependence must be put almost entirely upon fluoroscopic work. Consequently, all arrangements in hospitals near the front must conform to the conditions imposed by fluoroscopy.

As regards the methods that have been selected, it is not claimed that they are original, and no effort has been made to get any universal or entirely new procedure. After consideration of the many methods it has been deemed wise to limit *selection* to those that best meet certain requirements. Among the desirable features more or less well met by various methods we may mention:

(*a*) The apparatus required should be simple.

(*b*) The manipulation should not require an undue amount of skill.

(*c*) The time required should be a minimum consistent with reasonable accuracy.

(*d*) All operations likely to lead to error must be excluded.

(*e*) The comfort of the patient should be considered.

It must also be remembered that the operator is an essential part of the localizing apparatus. It is therefore necessary to devise methods which will relieve the operator of computation and thus reduce the chances of error, especially when an enormous amount of work is to be done under trying conditions. Among the operations giving opportunity for error even in ordinarily competent hands we may note:

1. Reading of fine scales.
2. Reading any scale in bad light.
3. Making arithmetical computations.
4. Drawing diagrams.
5. Changing from bright light to read scales and back to fluoroscopic work.

Attention has therefore been directed to such accessory devices and organization of steps as would tend to eliminate these contributing sources of error.

In limiting the number of methods for which provision is made there is no intention of denying that others may be equally useful and accurate, and it is no criticism of the methods or their advocates that they have not been selected. It was deemed more desirable to have a *few* methods for which careful provision had been made and in which men could be well drilled, but it is entirely optional which method will be used in any given case. It would be impossible to provide apparatus for all the methods that might have been proposed or advocated.

Reference to the standard methods has been made by letters instead of by the names of those responsible for their development. This is not done with any idea of detracting from the credit of the authors or of indicating novelty, since no claim of priority is made or desired, but simply because descriptions vary in the literature and might be quite confusing to the reader who tries to follow directions that do not apply to our apparatus.

Before discussing the various methods in detail it may well be pointed out that refined mathematical accuracy is not generally a requisite for good service in this connection. As Major James T. Case has remarked, "This war is not being fought with bird shot, and a localization, as a rule, to ½ cm. will be entirely satisfactory." In a few cases, such as bodies in the eye or where a small foreign body is in a particularly dangerous and troublesome place, greater accuracy may be required, but it is necessary for the surgeon to keep in mind the fact that because of the incision and the introduction of retractors there may result a considerable displacement of the projectile, and it is often difficult to connect its position with displaced skin marks. It may also be remarked that in the majority of cases a certain amount of anatomical localization should be given by experienced and well-trained roentgenologists which in many cases may be of greater value than a simple depth determination. Whether or not this is well done will determine to a considerable extent the value of the *x*-ray service, and every opportunity should be given the roentgenologist to ascertain the landmarks used in surgery and to adapt his work to the requirements of the surgeon using his data.

The various localization methods may be divided into two distinct groups; in the first of these a mark is made upon the skin and the distance of the projectile from this mark is determined. It is generally assumed that the skin mark was made at the place of emergence of the beam which formed a shadow of the projectile and that the tube focus was adjusted vertically beneath the projectile. A vertical line drawn later through the skin point can only strike the projectile if the body of the patient is placed in the same position on the operating table as it occupied during the *x*-ray examination, and careful distinction must be made between a vertical line as so described, and a line perpendicular to the surface of the skin at the marked point. The amount by which the surgeon may miss the projectile by failure to get a correct sight line increases materially with increased depth of the projectile and with its dimension. Some idea of the size of the body sought should always be given. Much greater care will always be needed in the localization of the smaller bodies.

In the other group of methods some material guide is given to the surgeon to assist him during operation, and as a rule these require more time, both on the part of the roentgenologist and the surgeon's assistants. They are naturally better adapted to the work done in the permanent or base hospitals.

After receiving reports from both surgeons and roentgenologists abroad and after conference with Major James T. Case, Director of Roentgenology with the American Expeditionary Forces, in which appliances and methods were carefully considered, it was decided by the Surgeon-General's Office to adopt and provide apparatus for the following methods:

A. Two wire, double tube-shift method.
B. Parallax method.
C. Tube-shift method with mechanical triangulation.
D. Profondometer.
E. Hirtz compass with accessory devices.
F. Canula and trocar with harpoon.

It happens that the first three of these are simple depth measurements, although B may give more than one depth, whereas the last three may be used to give more definite guidance to the surgeon during operation.

Brief descriptions of these methods will probably suffice excepting for those who are to specifically undertake the *x*-ray work and they will find detailed instructions in the revised Army X-ray Manual which is shortly to be issued.

It is assumed that the majority of the work will be done with the standard army *x*-ray table by fluoroscopic methods and with the tube below the table. The tube box is movable in two directions as in the usual trochoscope and is provided with a double shutter giving a diamond-shaped opening with the diagonals parallel and perpendicular to the lengths of the table and also with an adjustable slit, under separate control, parallel to the length of the table. The tube box runs freely and may be locked in any position against both lateral and longitudinal movement, and is also provided with a simple means for fixing the amount of tube shift for a particular purpose or for measuring any shift from a fixed position.

The fluoroscopic screen is carried by a ball-bearing carriage mounted on the table rails, and provision is made for a movement parallel to the table, for rotation about a vertical axis, and also for a vertical shift. Each of these movements may be prevented by a suitable, convenient lock. The fluoroscopic screen is perforated with a small hole through which a marking device may be inserted to mark the skin in the vertical ray. When this ray is spoken of it is assumed that the table will be substantially in a horizontal position and that a line joining the target with the center of the diaphragm will be perpendicular to the plane in which the tube may move. The opening in the screen also serves a very convenient purpose in temporarily fixing in position the scales and other pieces of apparatus which it is desired to use on the fluoroscopic screen.

Method A.—Probably the most generally used fluoroscopic method is that designated in our work as Method A. This method was proposed since the beginning of the war by Professor Strohl, of the French Roentgenological Service. It is extremely rapid, reasonably accurate, and, as it requires a minimum of manipulation it is likely to be the method of preference for work in the evacuation hospitals. In this, as in the other methods here described, it is assumed that the standard apparatus adopted by the *x*-ray division of the army will be used.

The apparatus supplied for the standard equipment includes a substantial brass frame, carrying two wires firmly attached across two opposite corners and protected by a thin sheet of aluminum. These wires move with the tube box and when the diamond-shaped shutter is wide open they cast shadows upon the fluorescent screen and these shadows, of course, move with the tube box. After bringing the shadow of the projectile to the center of the fluoroscopic screen and marking the skin through the opening provided, the operator places in position a small celluloid scale with two sliders. He then shifts the

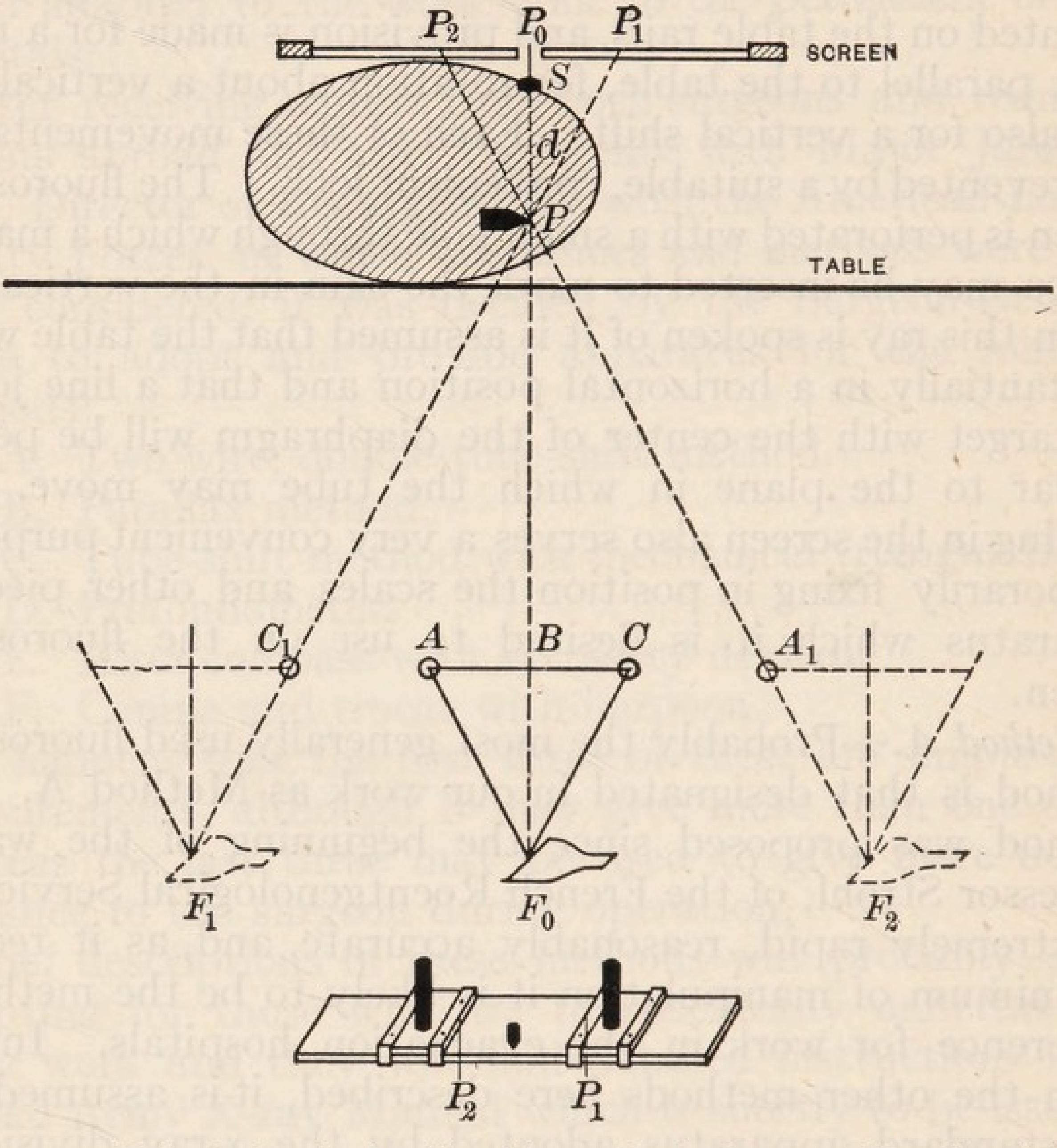


FIG. 15.—Principle of the Strohl method above. Simple slider for measurement of the distance between the two images shown below diagram.

tube until the shadow of one of the wires carried by the box coincides with the now displaced shadow of the projectile and adjusts one of the sliders to mark this position; then shifting in the opposite direction and leaving the first slider and the center of the device fixed, the shadow of the second wire is brought to coincidence with that of the projectile and the other slider fixed accordingly. The distance between these two markers is in a definite proportion to the distance from the fluoroscopic screen to the projectile in question, and by means of a properly designed scale the depth in centimeters and fractions of a centimeter can be read directly. In case the central point of the screen is not in contact with the skin where a mark is made, it will be necessary to correct for the distance between the skin and the screen. This is not necessary when the point marked is actually in contact with the horizontal screen.

On account of its extreme simplicity, and the fact that only a single measurement has to be made, and that the target-screen distance need not be known, this method has been placed first in order of preference.

The principle of method A is illustrated by Fig. 15, which shows a vertical section through the foreign body P, and the target focus F_0. B is the foot of a perpendicular from F_0 on the line AC. A and C are the two metal wires rigidly attached to the tube box and equidistant from B. Let P_0 be the shadow of P by the vertical ray. If we shift the target parallel to the screen and to the left, both A and C being fixed to the box, they must move with it and at a certain point F_1, C_1 and P will fall on the same line, and the shadow of C in the position C_1 will coincide with that of P at P_1. Likewise, shifting the target to the right will bring A_1, F_2 and P into the same straight line, F_2PP_2.

since F_1P_1 is parallel to F_0C,
F_2P_2 is parallel to F_0A
and P_2P_1 is parallel to AC

The triangles F_0AC and PP_1P_2 are similar. Consequently P_0P = depth of P below $P_0 = d$, is in the same proportion to P_1P_2 as BF_0 is to AC, or we may write,

$$\frac{\text{Depth of projectile}}{\text{image shift}} = \frac{\text{Height of } B \text{ above } F_0}{\text{distance between } A \text{ and } C}$$

The latter ratio is constant and is fixed in the set-up on the regular army x-ray table.

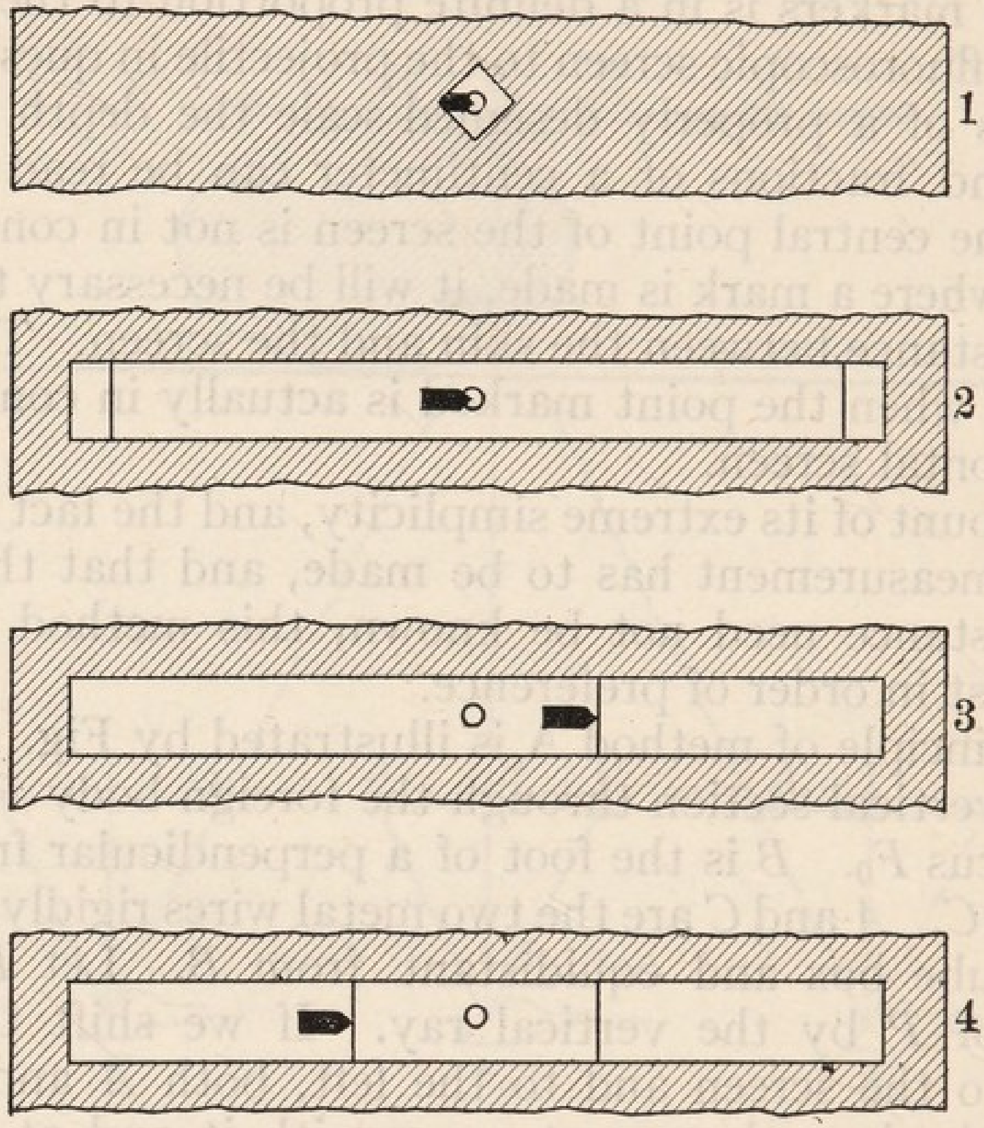


FIG. 16.—Successive appearances on fluoroscopic screen in Method A. (1) Shadow of projectile with small diaphragm at the central point of the screen. (2) Retangular diaphragm replaced by slit opening, shadow of wires at right and left. (3) Tube has been shifted to the left, bringing the shadow of the projectile and the right-hand wire to coincidence. (4) Reverse shift of the tube, bringing left-hand wire and projectile shadow to coincidence.

Hence d = image shift multiplied by a constant, k, that is,

$$d = P_1P_2 \times k.$$

If we read P_1P_2 in centimeters and multiply by k, d will be found in centimeters.

The special sliding markers, described above are shown in Fig. 15. The center-pin drops into the hole in the lead glass and prevents slipping. Fig. 16 shows the successive views on the fluoroscopic screen in this process.

To avoid multiplication a special scale is provided. The distance P_1P_2 read on this scale gives the required depth. The scale is *not a centimeter scale* but the readings give depth in centimeters and fractions thereof for a proper height adjustment of the tube.

Method B.—This method utilizes the optical principle of parallax and may be carried out with extremely simple apparatus, although a more elaborate device has been provided. If one observes the shadow of a projectile upon the fluoroscopic screen, while the tube is moving, and the projectile is very close to the screen, the shadow movement for a given tube shift will be very slight and the farther the body is removed from the screen the greater will be the extent of the shadow motion. If we adjust a suitable opaque body outside of the patient until its shadow moves the same distance for a definite tube shift as was moved by the shadow of the projectile for the same tube displacement, the auxiliary body must then be as far from the screen as the projectile whose depth is sought.

In the case of a projectile in the abdomen so far from the lateral boundary of the body as to preclude simultaneous observation of the indicator shadow and that of the projectile the adjustment of the latter may be made after the patient has been removed, *provided* the screen has been locked against vertical motion so as to remain at the same distance from the target as before. Generally, however, the indicator may be moved up and down in a plane, passing through the projectile and perpendicular to the axis of the body, close enough to the patient to permit free motion and allow both shadows to be seen at once.

By means of parallel lines ruled on a transparent piece of celluloid it is fairly easy to ascertain when equality of motion of the two shadows is secured. In the more complete apparatus furnished for this work (Fig. 19), it is possible to mark the skin at the entrance and emergence point of the vertical ray and also along a continuation of the rod carrying the

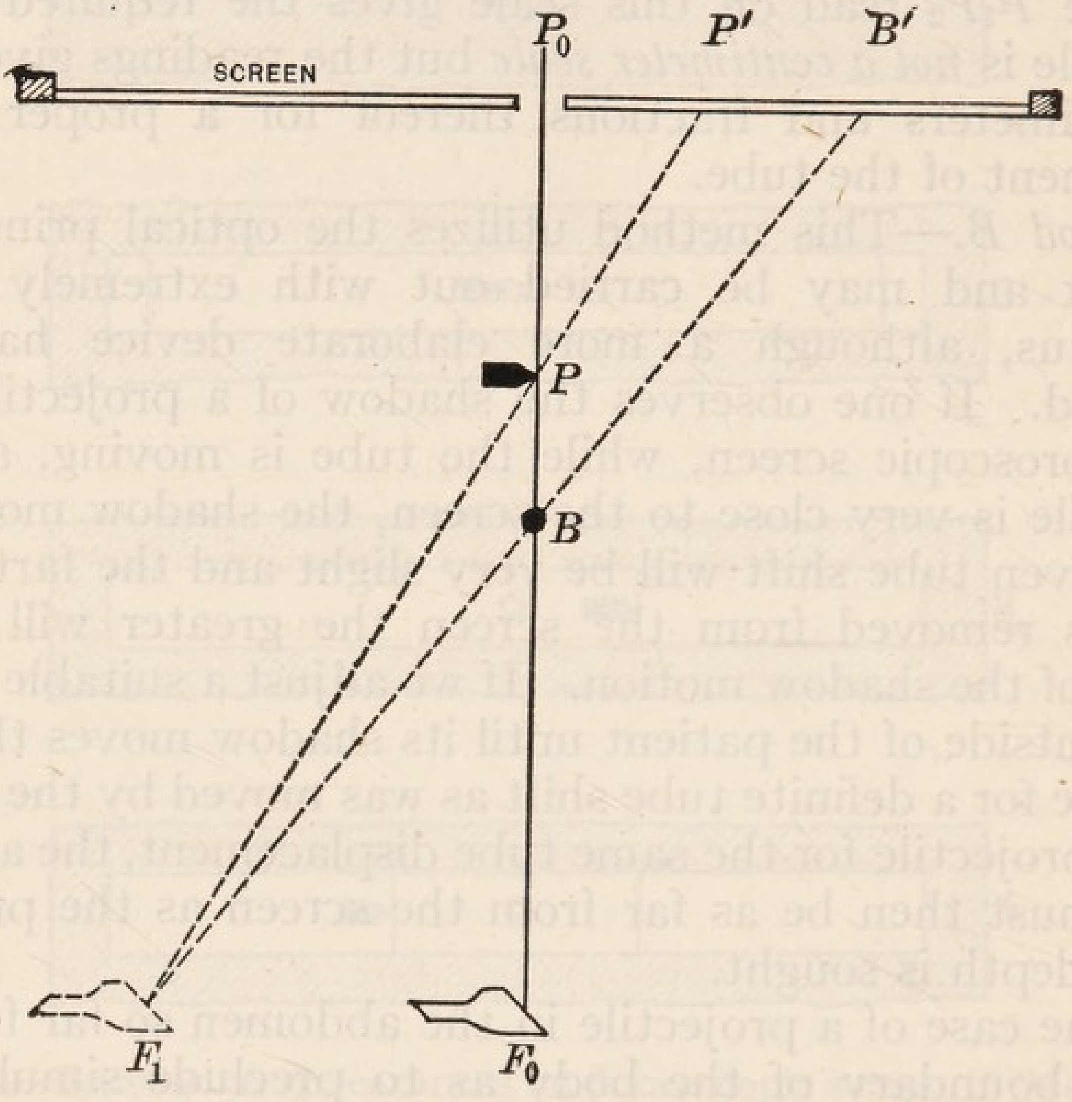


FIG. 17.—Principle of the parallax method. Auxiliary body B below P and distal from the screen shows greater shadow displacement to B'.

special indicator. This really gives three independent depths with some corresponding advantage to the surgeon.

The principle of this method is shown in Fig. 17 where F_0P_0 represents the vertical ray.

P represents the foreign body.

B represents an auxiliary body opaque to the rays and adjustable at will.

In Fig. 17 the shadows of P and B are shown as though they were in the plane of the paper, but this is not the actual case, as B will be quite outside this plane.

If, now, the target is moved toward the left to F_1, the shadows appear at P' and B', and P_0B' is greater than P_0P' *if* B is farther from the screen than P.

By raising or lowering B a position may be found where, on *shifting* the *tube*, the shadow of B and P *move at the same rate.* Then B and P are the same distance below the screen. The ruled sheet of celluloid (Fig. 18) is a convenience in making sure that P and B move the same amount when a convenient tube shift is made.

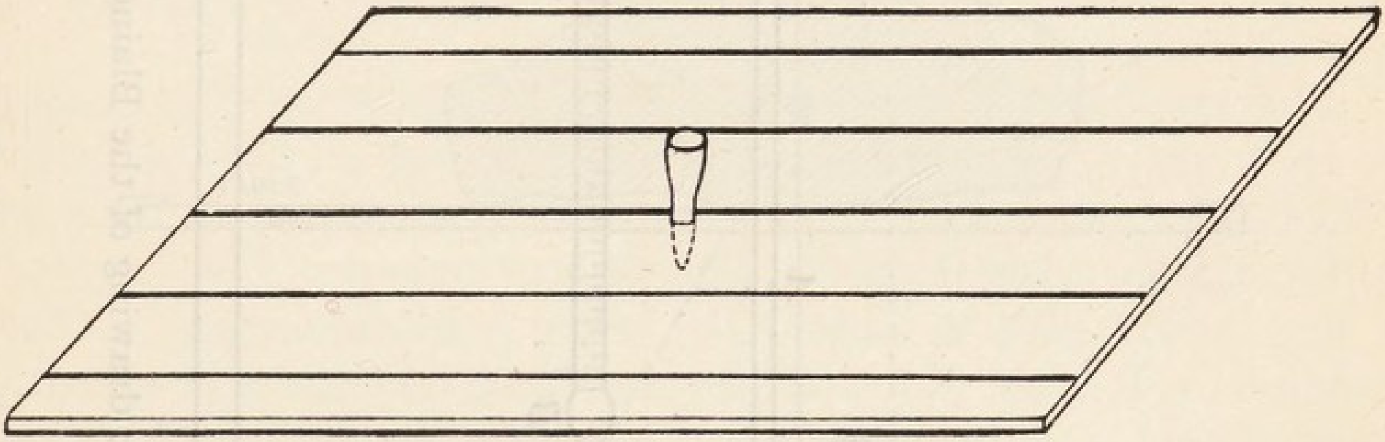


FIG. 18.—Ruled celluloid sheet to indicate equality of motion of two shadows in method B.

Apparatus.—The apparatus may consist essentially of the following (Fig. 19). A base of suitable size carries a vertical post (V). Sliding on this post are two rods at right angles to P that may be adjusted vertically at will. The upper of these is not adjustable laterally, so that the ring R is at a fixed distance from the upright V. The other rod carries a ball (B). This may be perforated to permit of a projecting skin marker. B may be shifted in two directions at will. When adjusted so that its shadow moves at the same rate as that of P, when the tube is shifted, the distance between the rods (d) is the depth of *P* below the ring *R*. This is true quite independent of the screen position.

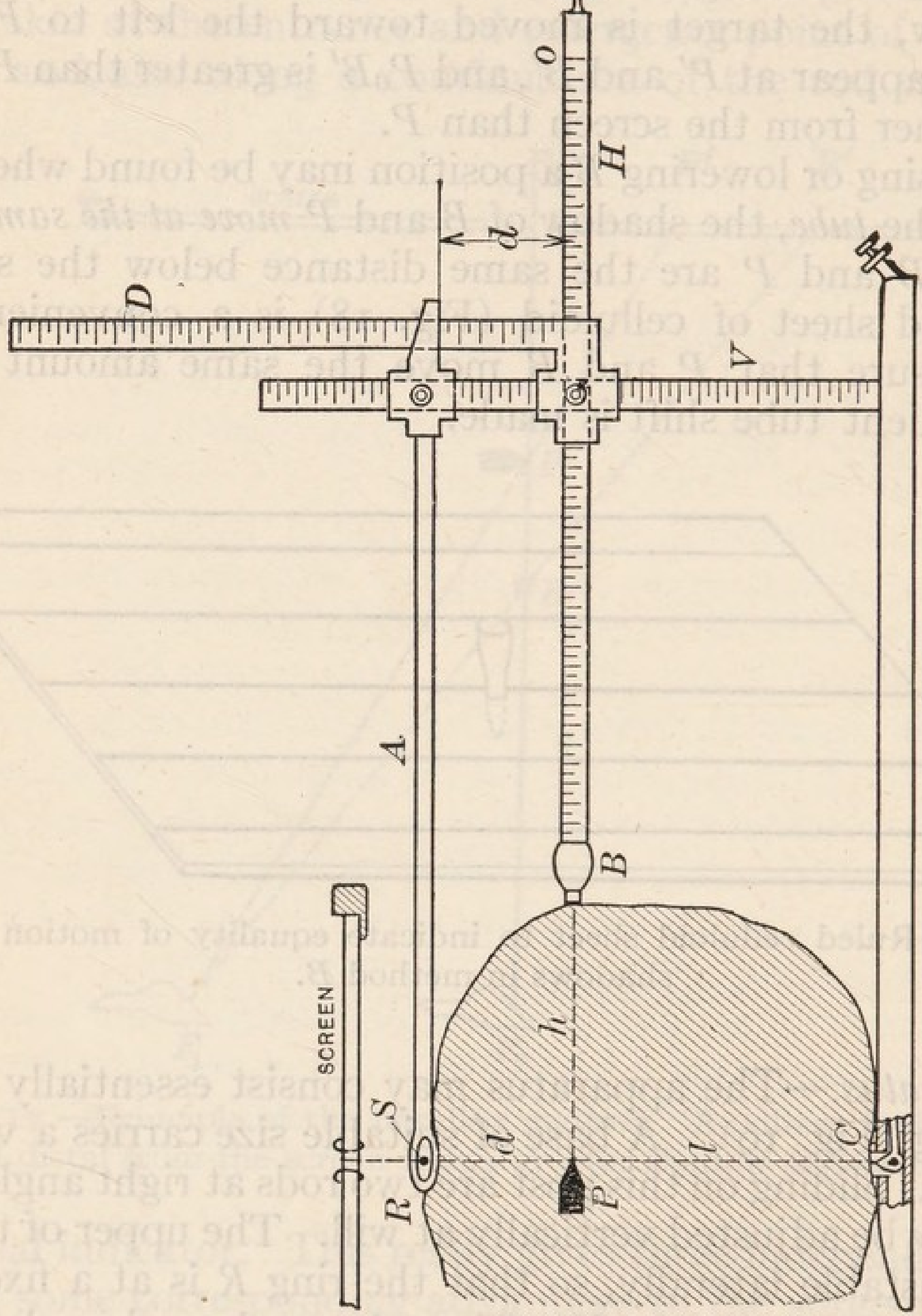


FIG. 19.—Schematic drawing of the Blaine model parallax localizer.

By using three scales *D*, *H* and *V* we may find the distance from the skin to *P* in three directions, viz., *PR*, *PB* and *PC*. In all cases *d* and *h* should be observed and *R* and *B* marked. If the opening in the base (*C*) is used in centering, *RC* and *PB* are at 90°.

Method C.—The single tube shift method with triangulation has appeared in a great variety of forms. Some of these involve the drawing of diagrams and the use of algebraic computation. In many cases the apparatus was designed to work at a fixed tube screen distance, which has certain disadvantages. The principle of the method is shown in Fig. 20.

Let F_0 be the target in such a position that the vertical ray at right angles to the plane of the tube movement projects the shadow of the foreign body (P) on the hole in the screen.

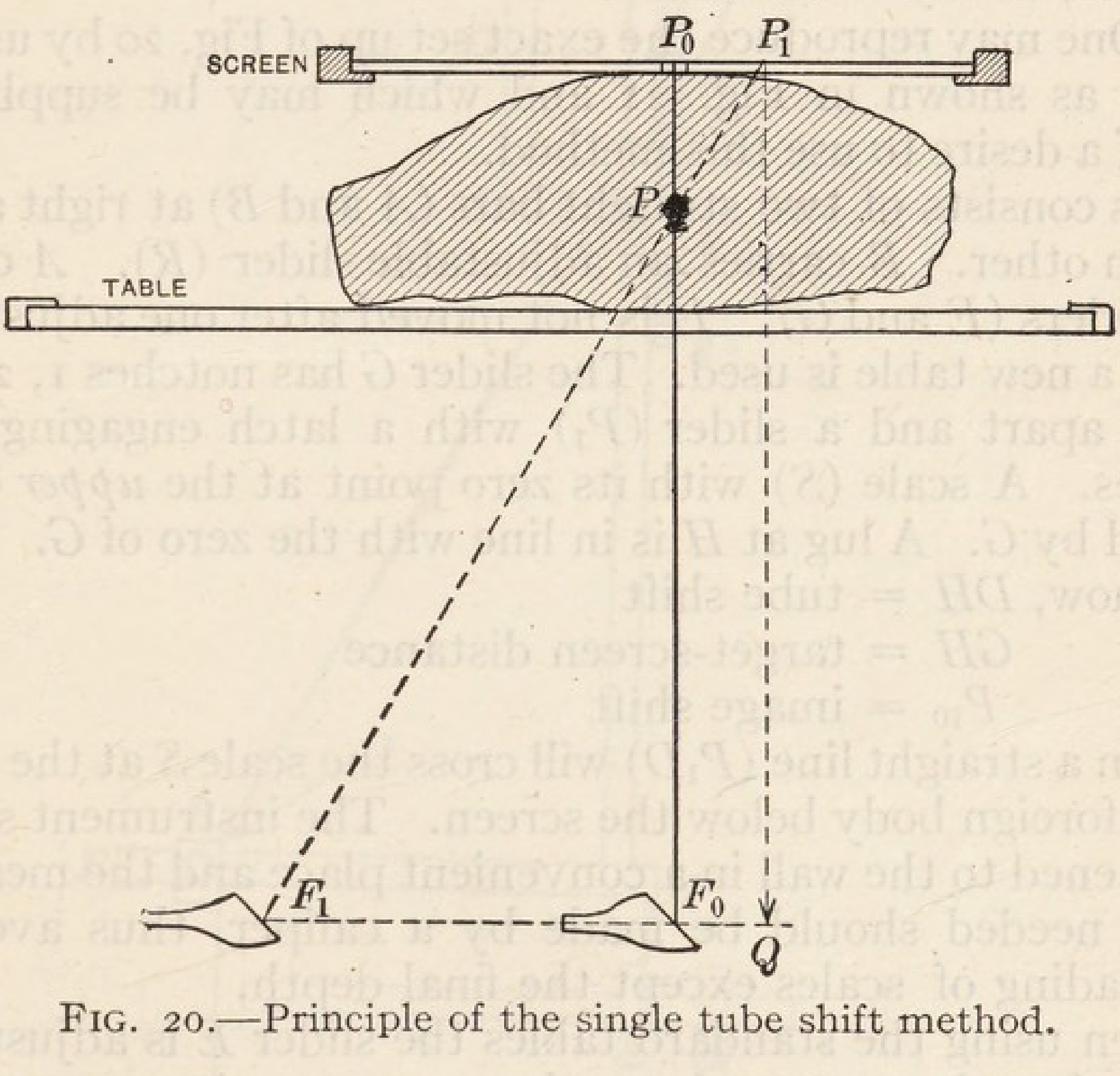


FIG. 20.—Principle of the single tube shift method.

Shifting the tube to F_1 there will result an image shift to P_1, and the triangles P_0P_1P and F_0F_1P are similar.
Also F_1QP_1 is similar to each.

Therefore $\frac{P_1Q}{F_1Q} = \frac{PP_0}{P_0P_1}$, or $PP_0 = P_0P_1 \times \frac{P_1Q}{F_1Q}$;

i. e., depth of foreign body = image shift $\times$ target-screen distance divided by sum of tube shift and image shift, or $PP_0 = P_0P_1 \times \frac{P_1Q}{F_1Q}$.

Where no auxiliary apparatus is supplied one must measure the various lengths by a scale and make a numerical computation. This may be made easier by the use of special devices.

1. One may use a fixed tube shift of 10 or 15 cm. or an image shift of an exact number of centimeters.

2. One may use a fixed target-screen distance. This is not, however, always convenient.

3. One may reproduce the exact set up of Fig. 20 by use of a device as shown in Fig. 21 and which may be supplied in case of a desire to use this method.

This consists of two straight bars (A and B) at right angles to each other. B carries an adjustable slider (R). A carries two sliders (E and G). E is not moved after one adjustment unless a new table is used. The slider G has notches 1, 2, etc., 1 cm. apart and a slider (P_1) with a latch engaging these notches. A scale (S) with its zero point at the *upper* end is carried by G. A lug at H is in line with the zero of G.

If, now, DH = tube shift
GH = target-screen distance
P_{10} = image shift

Then a straight line (P_1D) will cross the scale S at the depth of the foreign body below the screen. The instrument should be fastened to the wall in a convenient place and the measurements needed should be made by a caliper, thus avoiding any reading of scales except the final depth.

When using the standard tables the slider E is adjusted so that a length measured on the *screen-carrier support* will show how much above E we must place G in order that GH may represent the target-screen distance.

It will be observed that this instrument serves to reproduce tube and image positions as actually observed by the roentgenologist; *i. e.*, one vertical ray in which the skin is marked and one oblique ray whose intersection with the former corresponds to the distance of the projectile from the screen.

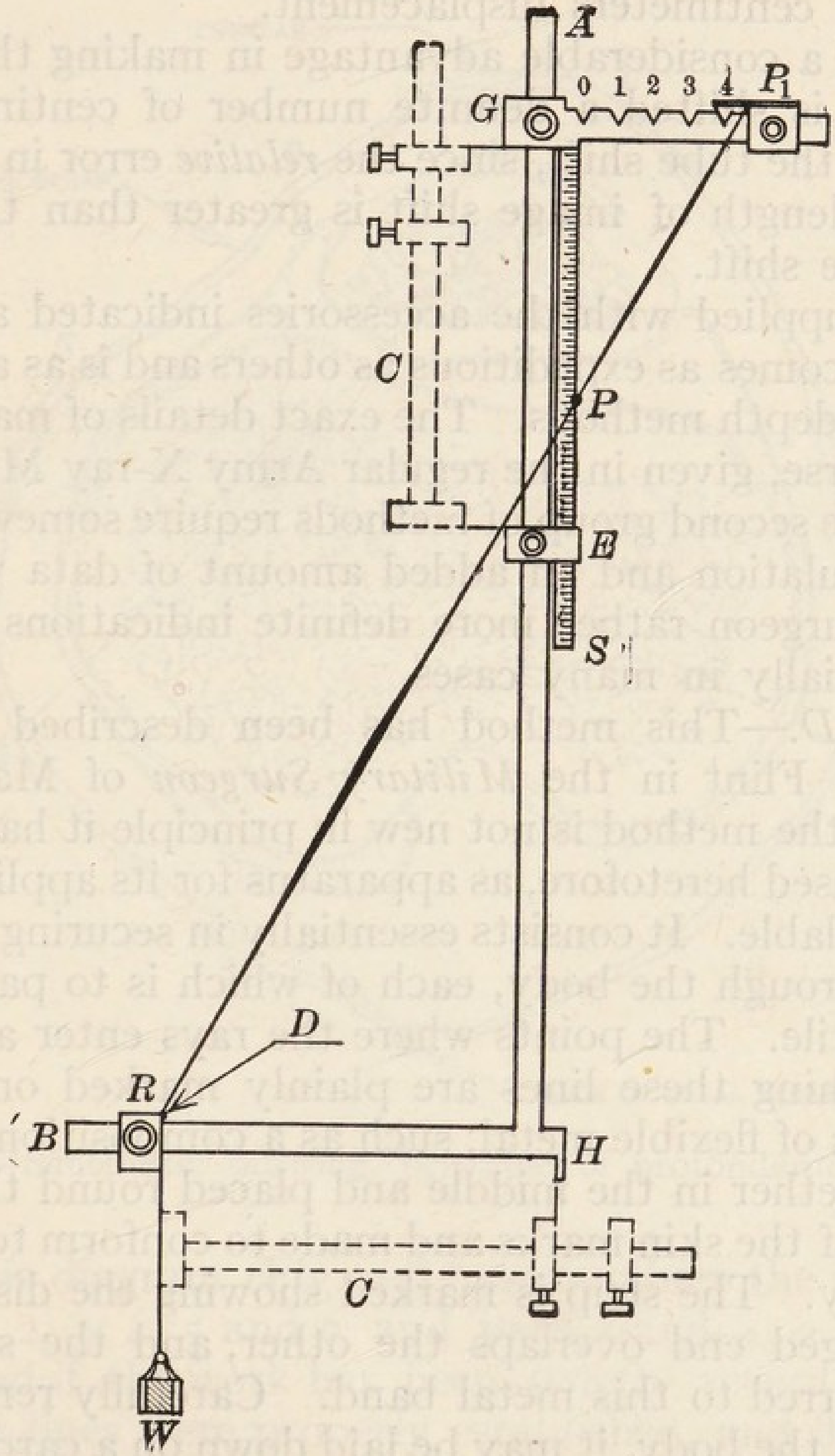


FIG. 21.—Wall meter or indicator from tube shift method, also showing method of using adjustable double-slider caliper.

An accessory device is also supplied consisting of a strip of celluloid with a pin centering in the perforation of the screen and having centimeter divisions clearly marked both ways from the center, making it quite easy to secure an exact number of centimeters displacement.

There is a considerable advantage in making the distance the image is shifted a definite number of centimeters and measuring the tube shift, since the *relative* error in measuring the small length of image shift is greater than that in the longer tube shift.

When supplied with the accessories indicated above, this method becomes as expeditious as others and is as accurate as any of the depth methods. The exact details of manipulation are, of course, given in the regular Army X-ray Manual.

All of the second group of methods require somewhat different manipulation and an added amount of data which may give the surgeon rather more definite indications and assist him materially in many cases.

Method D.—This method has been described by Major Joseph M. Flint in the *Military Surgeon* of March, 1917, and while the method is not new in principle it had not been generally used heretofore, as apparatus for its application was rarely available. It consists essentially in securing three lines of sight through the body, each of which is to pass through the projectile. The points where the rays enter and emerge in establishing these lines are plainly marked on the skin. Two pieces of flexible metal, such as a composition of tin, are hinged together in the middle and placed round the body in the plane of the skin marks and made to conform to the shape of the body. The strip is marked showing the distance that one unhinged end overlaps the other, and the skin marks are transferred to this metal band. Carefully removing the latter from the body, it may be laid down on a card or a sheet of paper, and by bringing the overlapping end to its original position a tracing with a pencil will show the outline of the body in the plane of examination. The skin mark positions are then transferred to the diagram and we have an approximate duplicate of the shape of the body and the locations of the external skin markings.

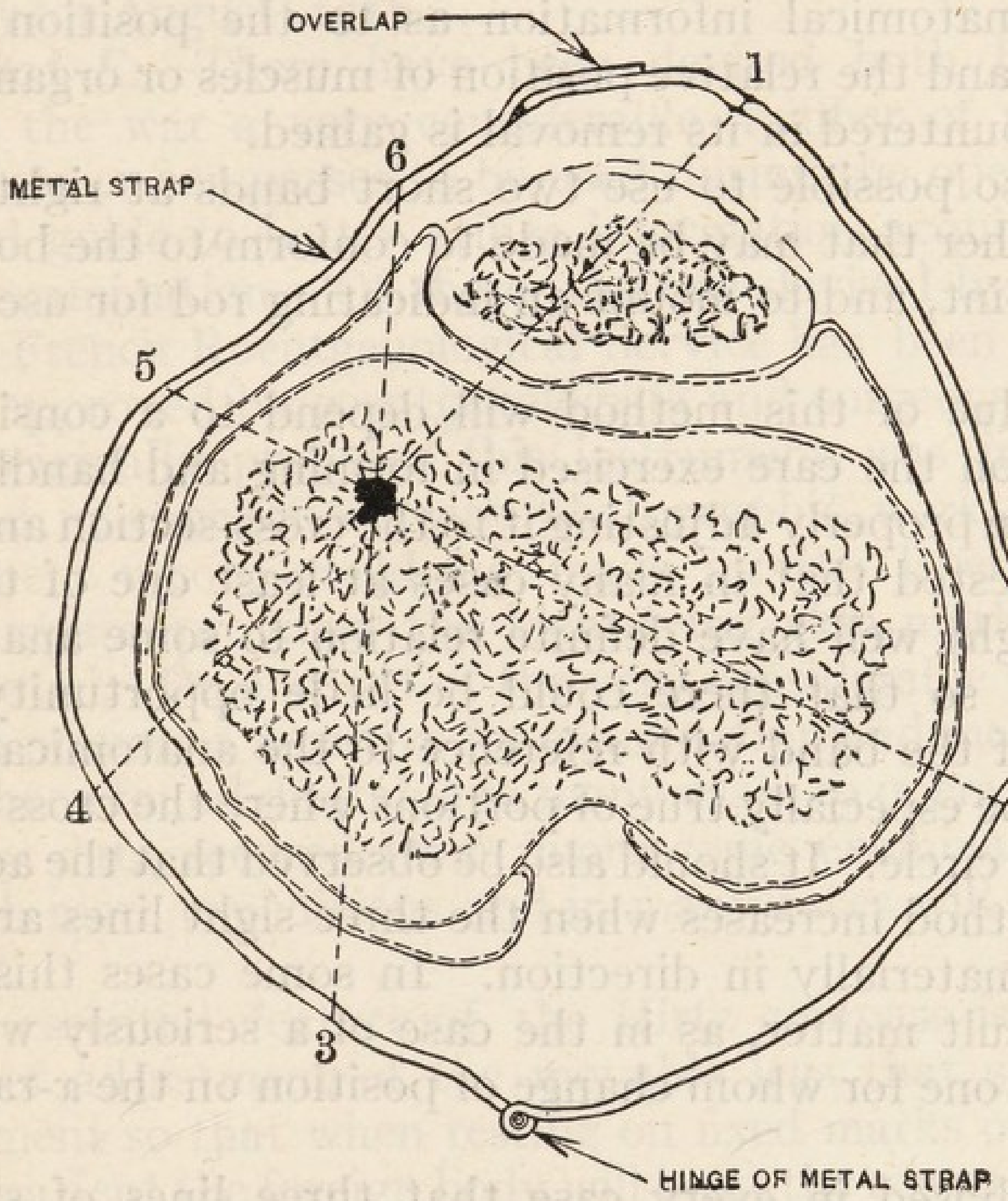


FIG. 22.—Schematic drawing, principle of profondometer strip.

If, on this diagram (Fig. 22), one numbers the skin marks in series 1, 2, 3, 4, 5 and 6, and joins 1 and 4, 2 and 5, and 3 and 6, and if the work has been strictly accurate; that is, if the sight lines were properly established, and if the shape of the body did not change by change of position when the band was put on, if the band has been properly formed and not distorted afterward, these three lines will intersect in a point; practically they are likely to form a small triangle, but with an excellent chance of the projectile being located in this small area. If one now identifies the diagram so formed with a cross-section anatomy for the same region of the body, definite anatomical information as to the position of the projectile and the relative position of muscles or organs likely to be encountered in its removal is gained.

It is also possible to use two short bands at right angles to each other that may be made to conform to the body at a desired point, and to mount an indicating rod for use during operation.

The value of this method will depend to a considerable extent upon the care exercised in forming and handling the strip and in properly adjusting it to the cross-section anatomy. It is suggested that in many cases at least one of the skin marks might well have definite relation to some anatomical landmark, so that there could be little opportunity for a rotation of the band with reference to the anatomical chart. This will be especially true of portions where the cross-section is nearly a circle. It should also be observed that the accuracy of this method increases when the three sight lines are made to differ materially in direction. In some cases this would be a difficult matter, as in the case of a seriously wounded patient or one for whom change of position on the *x*-ray table is painful.

It is advised in every case that three lines of sight be determined, marking six skin points, and for this purpose the parallax localizer furnished in the army outfit will be found very valuable, as it permits of marking the skin on the under side with the same degree of certainty as on top. It may be noted also that the method here described eliminates the necessity of using more than one distinctive skin mark, and it would do no harm, when using this method with a parallax localizer as a marking device, if at least one depth were determined as a check upon the accuracy of adjustment of the profondometer band.

Those who are especially interested will find articles by Major Flint giving more details with reference to this method in the *Military Surgeon* of March, 1917, and the *Annals of Surgery* for August, 1917.

Method E.—There have been devised both before and during the war a very considerable number of mechanical indicators or compasses to be used during the operation as a surgical guide to better utilize information acquired by the *x*-ray examination. Of these, the one devised by Dr. Hirtz of the French Roentgenological Service has been most generally approved by roentgenologists and surgeons.

As originally proposed this instrument was intended to be used in connection with photographic work whereby a permanent record could be made for the later setting of the compass, provided the identifying skin marks were not obliterated. On account of the very considerable time necessary to prepare a negative for examination and measurement, it has been found desirable in many cases to operate the compass by data secured from fluoroscopic examination which is much more expeditious and in many cases will serve fully as well.

The essential feature of the Hirtz compass is the possibility of adjustment of the movable legs that support the instrument so that when resting on fixed marks on the body of the patient the foreign body will be at the center of a sphere a meridian arc of which is carried by the compass. This arc is capable of adjustment in any position about a central axis. An indicating rod passes through a slider attached to the movable arc in such a way as to coincide in all positions with a radius of the sphere and whether it actually reaches the center or not it is always directed toward that point. If its movement to the center of the sphere is obstructed by the body of the patient the amount it lacks of reaching the center will be the depth of the projectile in the direction indicated by the pointer.

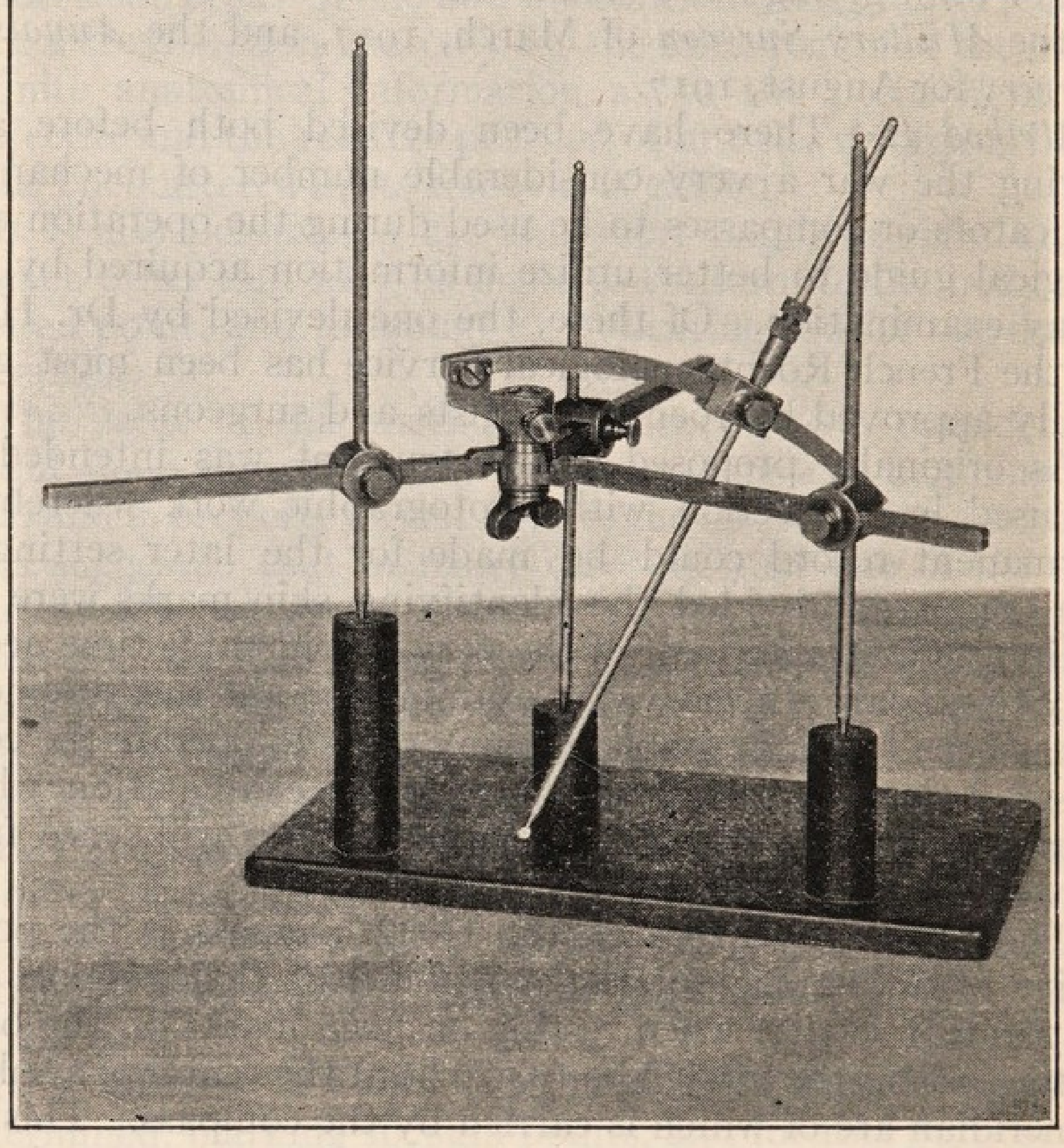


FIG. 23.—Hirtz compass.

The value of the compass lies in its wide possibility as a surgical guide, in that it does not confine the attention of the surgeon to a single point marked on the skin, with a possible uncertainty as to the direction in which he should proceed in order to reach the projectile, but gives him a wide latitude of approach and explicit information as to depth in a direction of his own selection.

The compass is shown in Fig. 23 and schematically in Fig. 24. Three metal arms respectively labelled 1, 2 and 3 in clockwise rotation are so mounted as to turn freely upon a central pivot and have their upper surfaces all in a single

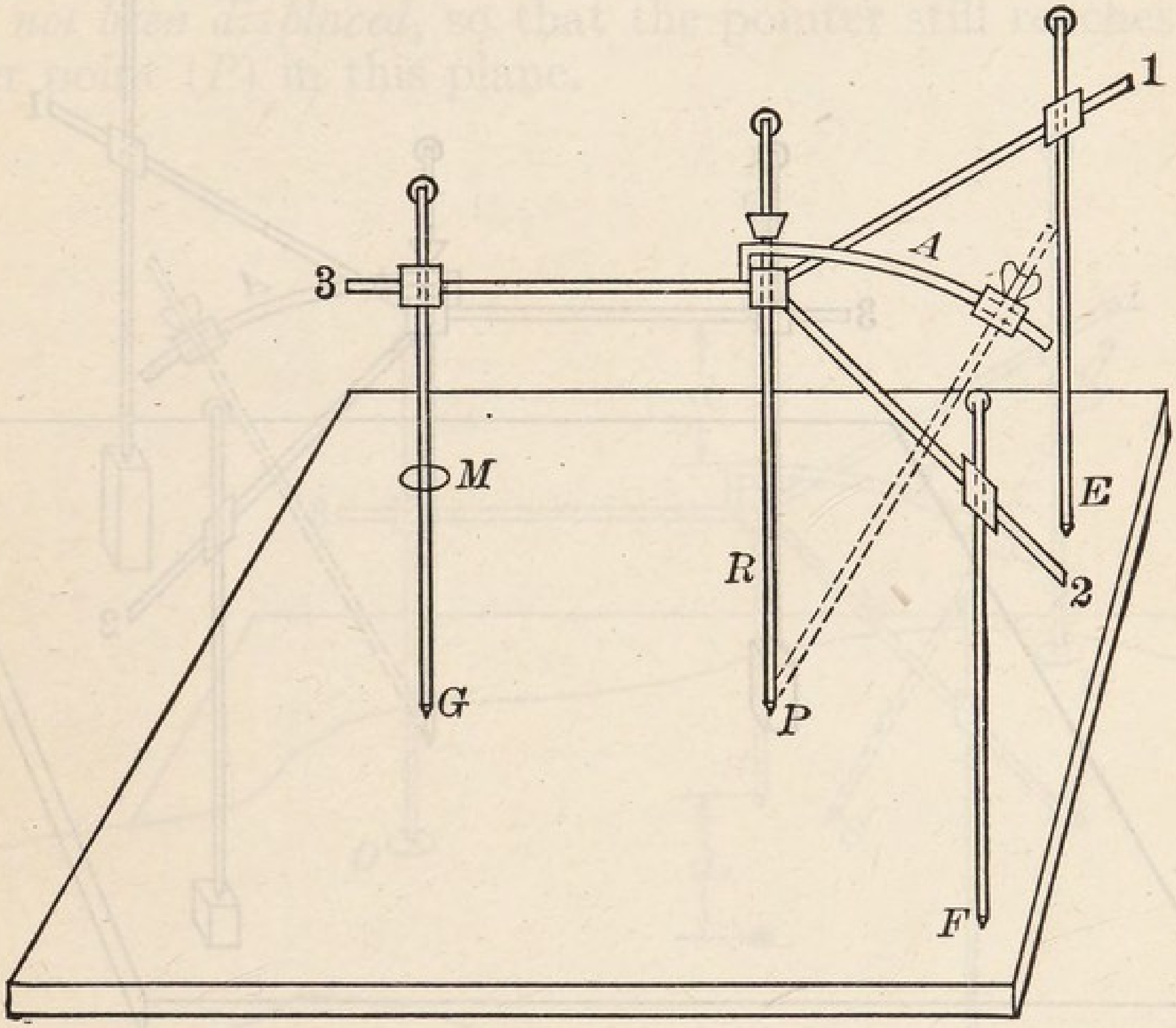


FIG. 24.—Schematic drawing of Hirtz compass with the legs adjusted at zero points and resting on a plane.

plane. Each of these arms carries a slider which may be adjusted to any position along the length of the arm. Each slider has an adjustable leg at right angles to the plane of the arms that may be held in any position by a small thumb-screw. These legs are graduated and the *zero point is not at either end of the legs*, but is a few centimeters below the upper portion which terminates in a small knob. The center post about which the arms rotate has a hole at right angles to the plane of the arms and is also shaped to carry the curved metal arc (*A*, Fig. 24). The hole in the slider on arc *A*, carrying the indicating rod, can be made to coincide with the opening through the center post.

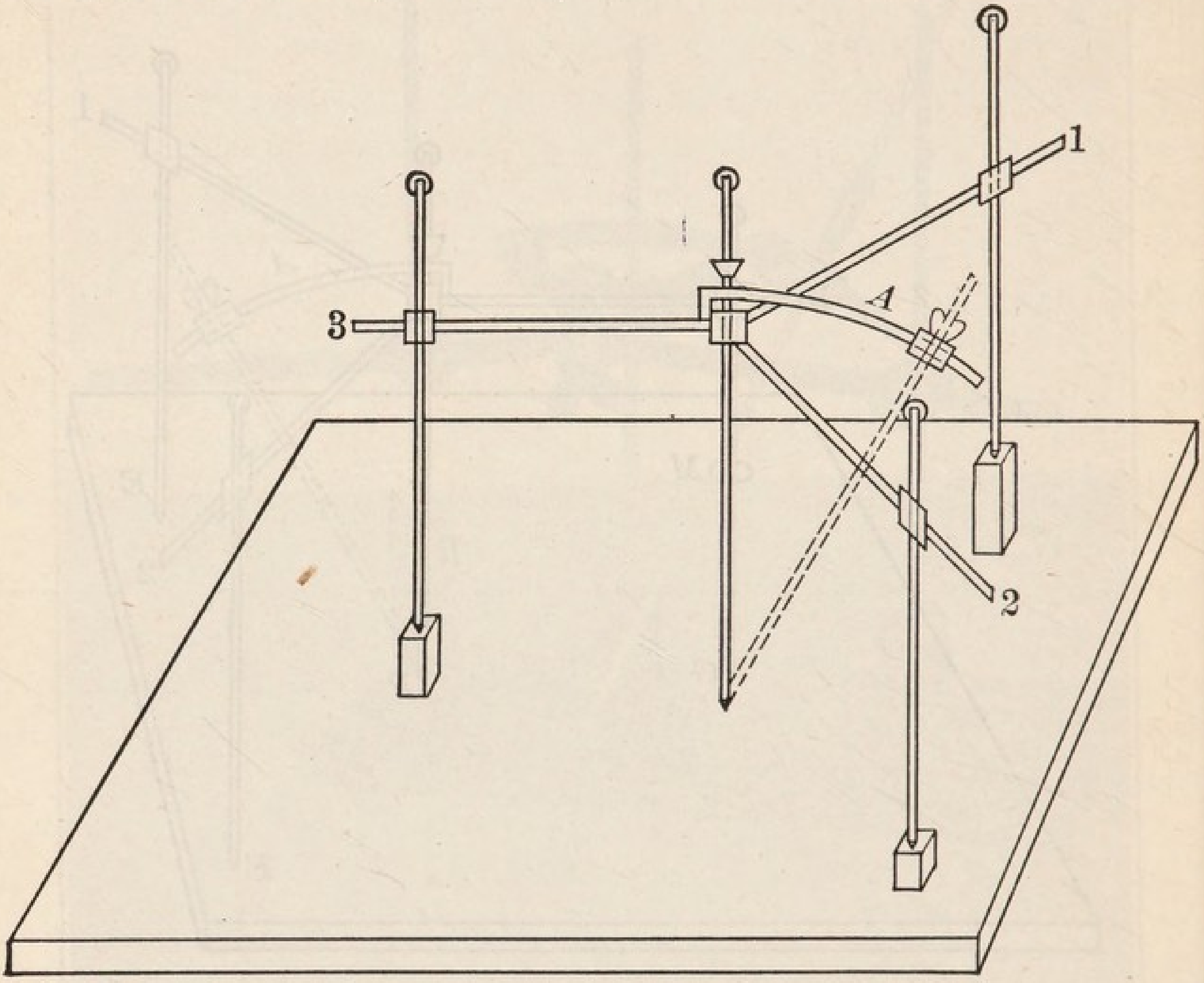


FIG. 25.—Arms and indicator of the Hirtz compass in the same position as in Fig. 24 with the legs elevated on blocks whose tops might correspond to a skin marker.

When the three legs are set at zero, quite irrespective of the position of the slider on the arms or of their angular position, and the compass stands on a plane surface, the indicating rod, passed through the slider on arc *A*, will touch the supporting plane at the center of the sphere of which *A* is a meridian arc.

A friction clip on the indicating rod may be adjusted in contact with the slider on A and the distance from the lower end of this clip to the pointed end of the indicator will be the radius of the sphere of which A is an arc.

Fig. 25 shows the compass with the legs shifted so that they no longer stand on the base plane and in fact are at quite different heights but the arc A, and the arms of the compass have *not been displaced*, so that the pointer still reaches the center point (P) in this plane.

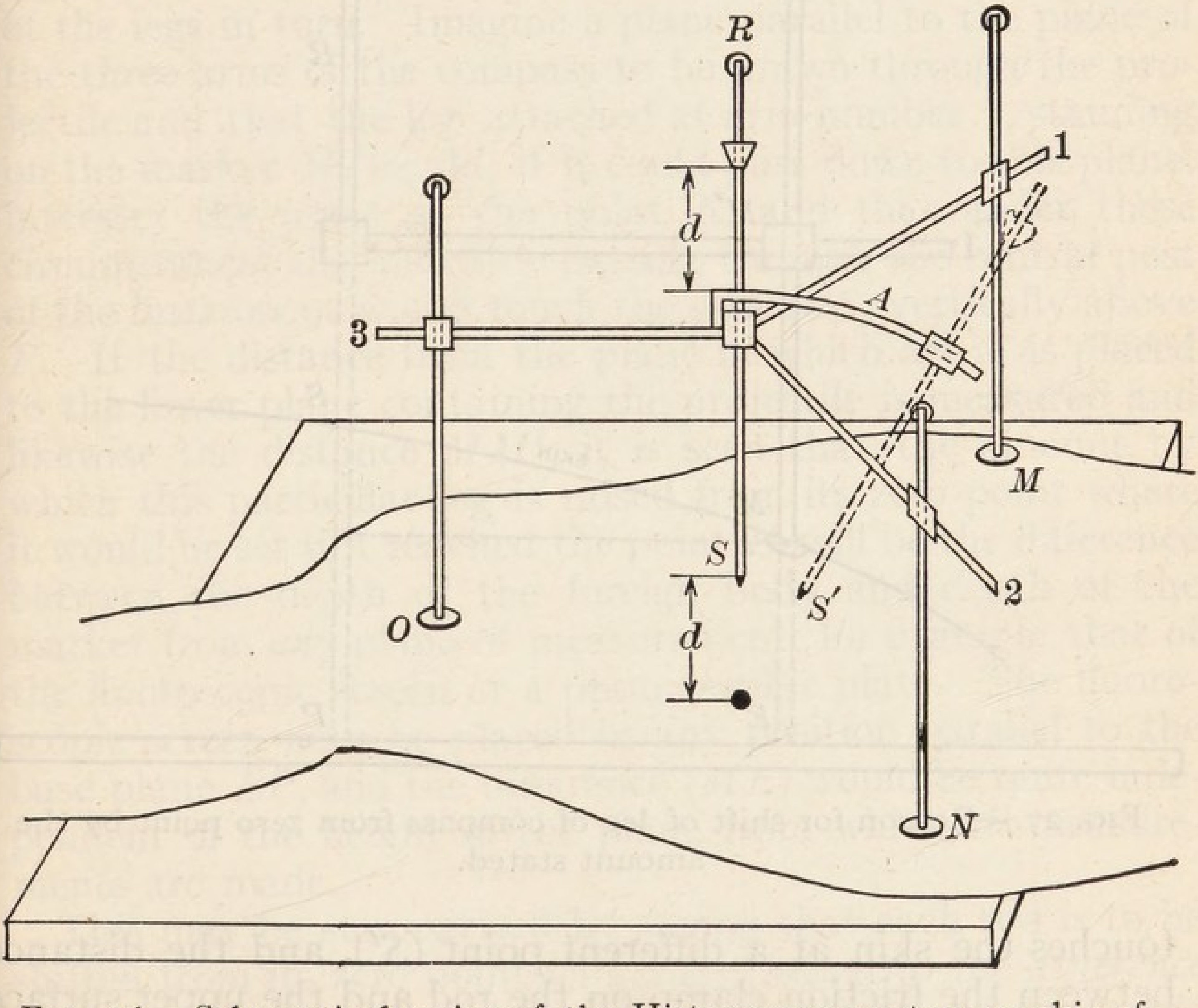


FIG. 26.—Schematic drawing of the Hirtz compass set up on skin of patient.

Fig. 26 shows the compass actually set up on the body of a patient, its legs resting on three skin marks (M, N and O), and with the indicating rod pointing toward the projectile, but failing to reach it because of contact with the skin of the patient at *S*. The depth of the projectile in this particular direction is indicated in Fig. 26 by *d*. If now the indicating rod is placed in the slider carried by the arc *A*, the rod

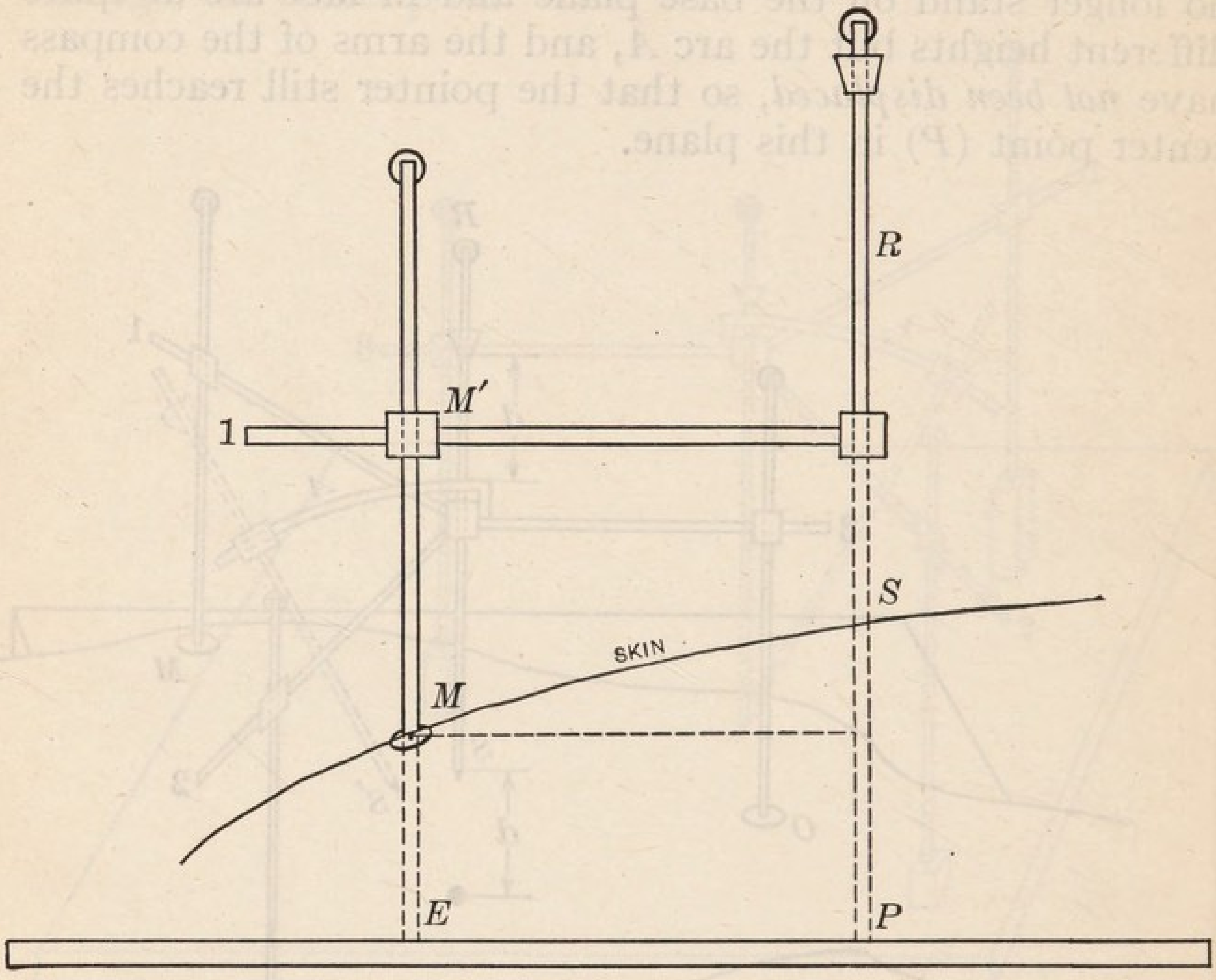


FIG. 27.—Reason for shift of leg of compass from zero point by the amount stated.

touches the skin at a different point (*S′*), and the distance between the friction clamp on the rod and the upper surface of the slider on the arc *A* will be the depth of the foreign body along the direction indicated by the dotted line. It is evident from the construction that the surgeon may place the arc *A* in any position throughout 360° and the slider at any position from the center to the extreme end of the arc and still have the indicating rod point to the foreign body and show its depth from the point of contact with the skin.

The exact amount which each leg of the compass must be shifted from its zero point in order to stand on the marker to which it belongs and yet have the indicating rod in the proper position is easiest seen in Fig. 27 in which only a single leg of the compass is shown, but the same will apply to each of the legs in turn. Imagine a plane parallel to the plane of the three arms of the compass to be drawn through the projectile and that the leg attached at arm number 1, standing on the marker *M*, would, if it could pass down to this plane, intersect the plane at the point *E*, and that under these circumstances the indicator passing through the central post of the instrument would touch the skin at *S*, vertically above *P*. If the distance from the plane in which arc *A* is placed to the lower plane containing the projectile is measured and likewise the distance *MM′*, it is seen that the amount by which this particular leg is raised from its zero point where it would be set if it reached the point *E*, will be the difference between the depth of the foreign body and depth of the marker from *any* plane of measurement; for example, that of the fluoroscopic screen or a photographic plate. The fluoroscopic screen may be placed in any position parallel to the base plane *EP*, and the difference (*ME*) would be quite independent of the height of the plane from which *all* measurements are made.

This may be summarized by saying that each rod is to be shifted from its zero point an amount equal to the *difference* between the depth of the projectile below the fluoroscopic screen, or other plane of reference, and the depth of the skin mark upon which this particular leg would stand measured for the same plane. It is absolutely essential in the use of the compass to adopt a systematic procedure so that the arm to carry the leg is identified with the depth measurement of its own skin point.

The data necessary to properly adjust the compass may now be stated by reference to Figs. 24 and 27. The indicating rod in the central position and the three legs of the compass mark out, in any plane parallel to the base plane of Fig. 24, four points of definite position in the plane. Any vertical shift of the legs will still allow them to retain their position in lines passing through the points *E*, *F*, *G* and *P*. The point *G* (Fig. 24) is then in a vertical line passing through the marker *M*, and the data necessary to set the compass must give the position, in a plane, of these four points and in addition to this must give the depth from a fixed plane, parallel to the base plane (*E*, *F* and *G*) of the three markers on the skin of the patient and of the projectile within the patient's body. Whether this data is to be found by a photographic or a fluoroscopic process is immaterial, as the steps in its use will be identical.

When a fluoroscopic method is to be used an auxiliary device may be found of considerable aid in rapidly and accurately securing the requisite data. Such a device is shown in Fig. 28*a*, and consists of three arms, each with a slider very similar to the original compass. In fact the latter may be used with rather less convenience, by removing arc *A* and allowing the indicating rod to project a short distance below the center and with the legs temporarily removed. The auxiliary compass has its arms numbered in the same way as the original Hirtz compass and has a projecting pin which fits the perforation in the screen. One of the arms is rigidly attached to a ring concentric with the axis of rotation about the pin, while the other two are movable but may be clamped by thumb-nuts to the ring. It is evident that placing the perforation in the screen in the vertical ray passing through the projectile definitely fixes the position of the center post. If, then, each marker in turn is brought into the

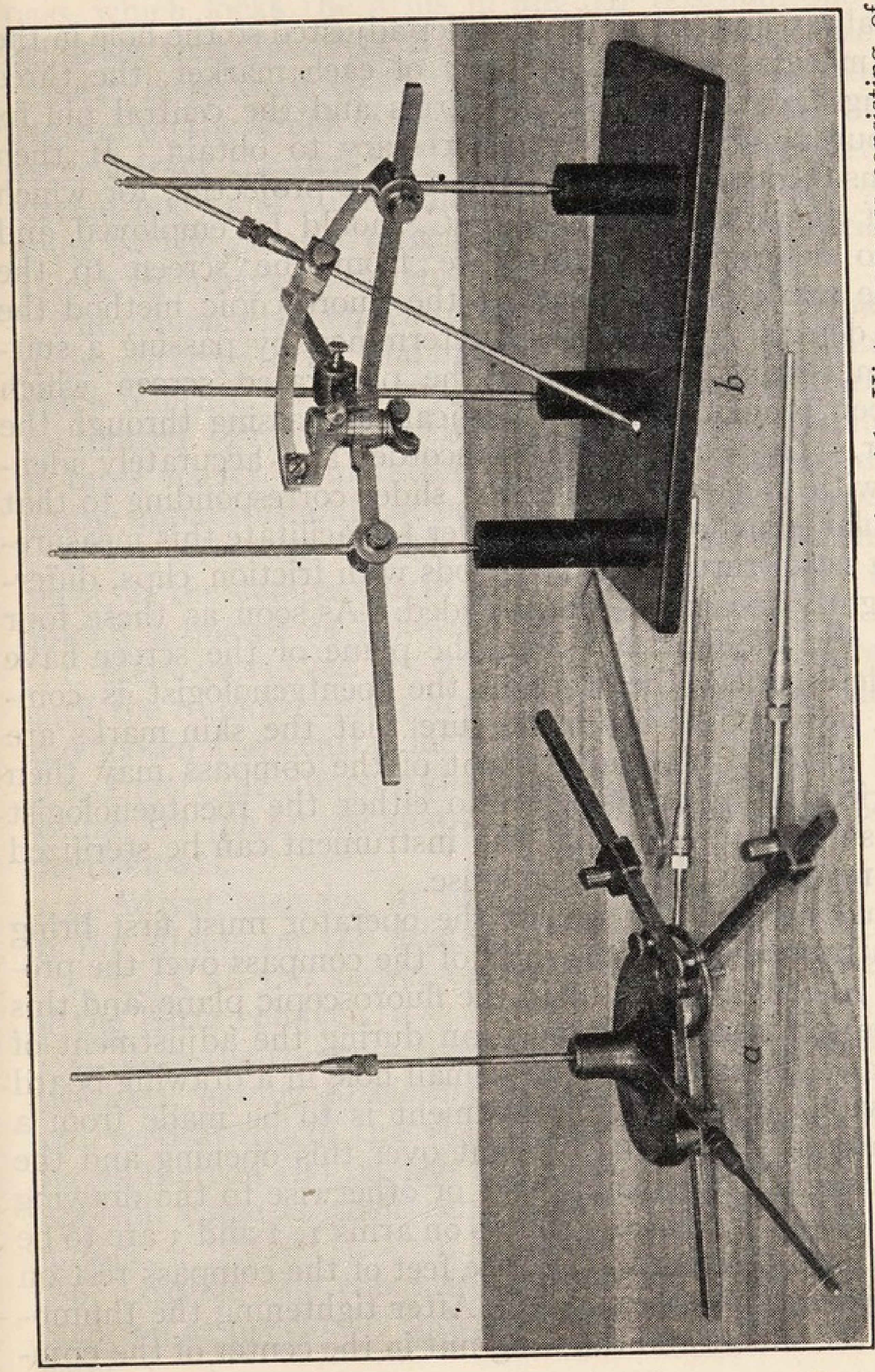


FIG. 28.—(*a*) Accessory apparatus for fluoroscopic work with Hirtz compass consisting of auxiliary compass, pedestal support and three markers with friction clips. (*b*) Hirtz compass mounted with the three legs at different levels but so that a pointer reaches white spot on the base plane below which is the center of the sphere of which the curved arc is a part.

vertical ray and the arm and slider adjusted so the hole in the slider matches such a projection of each marker, the three openings in the sliders on the arms and the central pin fix the four points which it is necessary to obtain. It then remains to determine the depth of the projectile, for which one of the methods, *A*, *B* or *C*, should be employed and also to determine the distance from the screen to the opaque markers. When using the fluoroscopic method the latter depths can be readily determined by passing a suitable measuring rod through the perforated screen which has been brought into the vertical ray passing through the marker. This depth is to be recorded and accurately identified with the arm carrying the slider corresponding to that particular skin marker. In order to facilitate this measurement a set of three measuring rods with friction clips, differing slightly in shape, are provided. As soon as these four depths and the four marks in the plane of the screen have been determined, the work of the roentgenologist is completed, provided he has made sure that the skin marks are plainly visible. The adjustment of the compass may then be carried out by an assistant to either the roentgenologist or the surgeon, after which the instrument can be sterilized and is ready for the surgeon's use.

In making this adjustment the operator must first bring the central opening in the shaft of the compass over the projection P_0 of the projectile in the fluoroscopic plane, and this must be retained in that position during the adjustment of the arms. It is advised that a small hole in a drawing board be provided in case the adjustment is to be made from a diagram and that P_0 be brought over this opening and the paper attached by thumb tacks or otherwise to the drawing board. Then each of the sliders on arms 1, 2 and 3 are to be brought into position so that the feet of the compass rest on the projections of the markers. After tightening the thumb-nuts on the sliders and the wing-nut in the center of the compass, which locks the arms in angular position, one should again see that these feet are adjusted to the proper points.

Next, bring each leg so that its zero point coincides with the top of the slider by which it is carried. Then for each leg, subtract the depth of the skin marker from that of the foreign body and adjust the corresponding leg from its zero point by the number of centimeters so obtained, being sure to lock each leg in position.

The compass is then ready for use by the simple attachment of the curved arc and the indicator, provided the skin marks which indicate its proper position are not, in the meantime, obliterated. Probably the best way to insure the permanence of these marks is to tattoo them, which may be done by simple apparatus and not be undesirably conspicuous.

When using the special adapter provided with the army outfit, if the compass is to be used at once it may be very quickly adjusted as follows:

1. Remove curved arc and indicating rod, lower each leg until the rounded end is about a centimeter from the slider, and loosen the central lock.

2. Invert the compass and place upon the inverted adapter so that the pin on the adapter engages the central opening of the compass.

3. Adjust each leg in turn to engage the small opening in the sliders on the adapter.

4. Lock all the sliders on the arms and the central lock of the Hirtz compass.

5. Turn the compass right side up and put it on the stand provided, having *previously* firmly *adjusted* the sliding clip and vertical rod of this stand, so that when the compass is placed thereon and the legs loosened in their holders, all three legs will come to their zero, if the base stands on a plane surface.

6. Leaving the compass supported by the stand, adjust each rod as previously indicated, *always starting from its zero point.*

When the operation is to take place a considerable period after an x-ray examination is made, a suitable form of record must be entered as a part of the temporary record of the patient and care must be taken that it is accurately labelled so as to be identified with certainty at the time of operation.

When using the Hirtz compass radiographically two exposures are necessary, either made upon a single plate which remains in a fixed position relative to the patient while the tube is shifted, or else two plates may be used with proper markings; one being exposed with the tube in the first position, the other in a second position. The use of the two plates is recommended, and in order to superimpose them for the purpose of measurement a small piece of celluloid, which may be attached to the tunnel-plate changer, is used and carries two small metal wires forming a cross; when these crosses are made to coincide on superimposing the negatives the proper measurements may be made.

In order to explain the procedure necessary in this case reference is made to Fig. 29 in which is shown the position of the tube for two successive exposures with reference to the plate and the formation of the shadows of one of the skin markers. It should be noted that each skin marker and the foreign body will be projected in the same way, only the displacement of their shadows in the two exposures will differ according to their distance from the plate.

In the method approved the distance CX from the central position of the tube to the plate in the vertical direction is to be 60 cm. and the tube shift F_1F_2 is to be 6 cm.; that is, from a point 3 cm. to the left of C, to a point 3 cm. to the right of C. For this arrangement a table is supplied which gives the height of a point above the plane of the plate corresponding to any probable shift of image measured on the completed negative, that is, Fig. 29, for a measured M_1M_2 there is given the height MM_0.

The reason for the procedure given with reference to measurements on the negative may be shown as follows:

Let X be the cross wire marker at the center of the plate; CX a perpendicular to the plate at X and C the level of the tube focus. If M is one of the markers on the skin, it is required to determine M_0 the foot of the perpendicular, dropped from M to the plate, and the height M_0M.

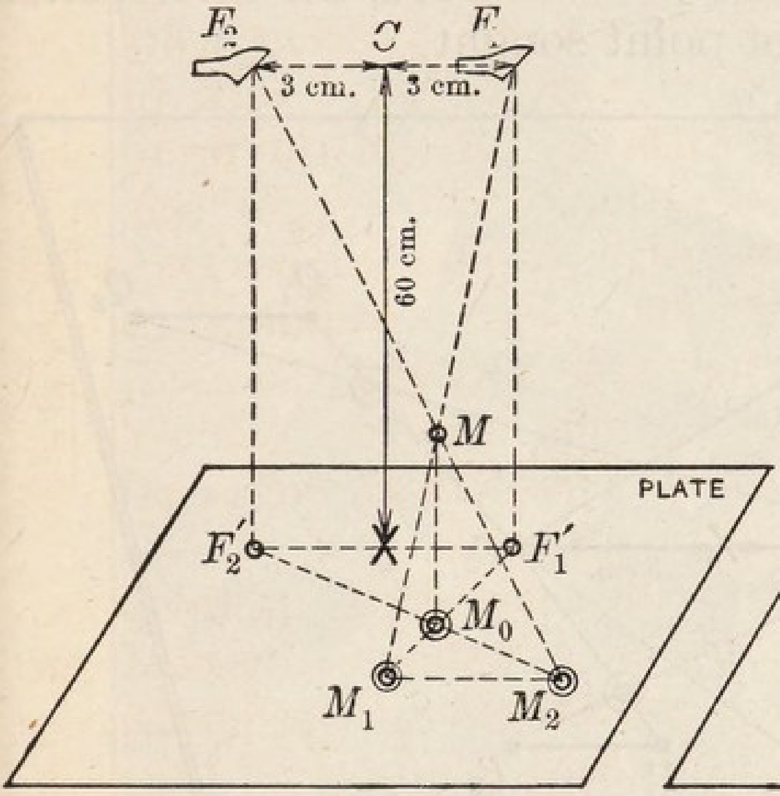


FIG. 29

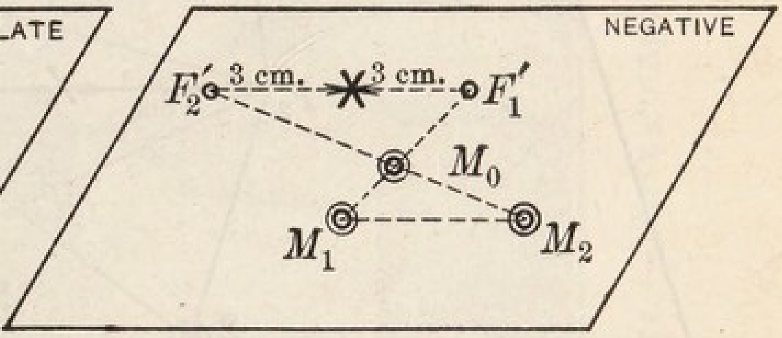


FIG. 30

FIG. 29.—Schematic representation of plate, cross wire marker and tube focus positions for radiographic use of the Hirtz compass.

FIG. 30.—Construction for finding one of the foot points M from the shadows of a corresponding marker as shown at M and M and the shadow cross marker X.

According to instructions the exposures are made with the focus at F_1 and F_2 where $F_2C = F_1C$. The shadow M_1 is cast by M when the focus is at F_1. If we draw F_1F_1' perpendicular to the plate, the plane $F_1M_1F_1'$ is perpendicular to the plate and passes through M. The same is true of $F_2M_2F_2'$. From this it follows that the line of intersection of these two planes (MM_0) is also perpendicular to the plate.

But $F_2'F_1'$ is parallel to F_2F_1 and of equal length. Also M_1M_2 is parallel to F_2F_1 and therefore to $F_2'F_1'$. This at once gives the construction of Fig. 30. There appears on the negative the shadow of the marker X and the two shadows of M, M_1 and M_2. Hence, join M_1 and M_2 and draw a line through X parallel to M_1M_2. Mark one-half of the tube shift on each side of X on the line so drawn as F_2' and F_1'. Join M_1 and F_1' also M_2 and F_2'. Then M_0, the intersection of these two lines, is the foot point sought.

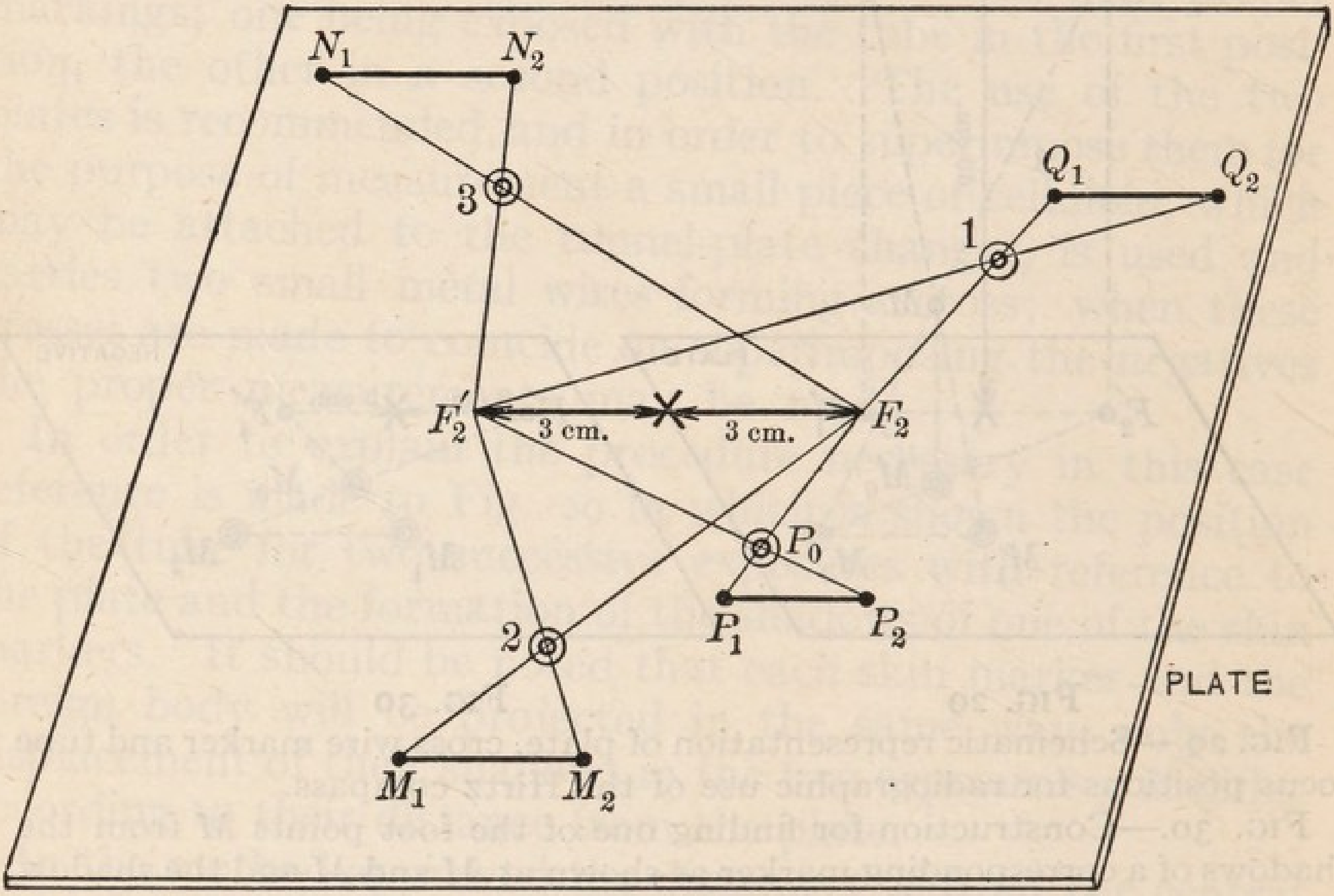


FIG. 31.—Complete chart for setting feet of the Hirtz compass.

Measure M_1M_2 in centimeters and fractions thereof and find this length in column marked displacement in the table for this setting and opposite this number read the height of marker or projectile above the plate. Fig. 31 shows the complete construction on the plate.

The only difference between the plate method and the fluoroscopic is that in the former the reference plane is below the patient and in the latter it is above. The method of setting the compass is the same in each case.

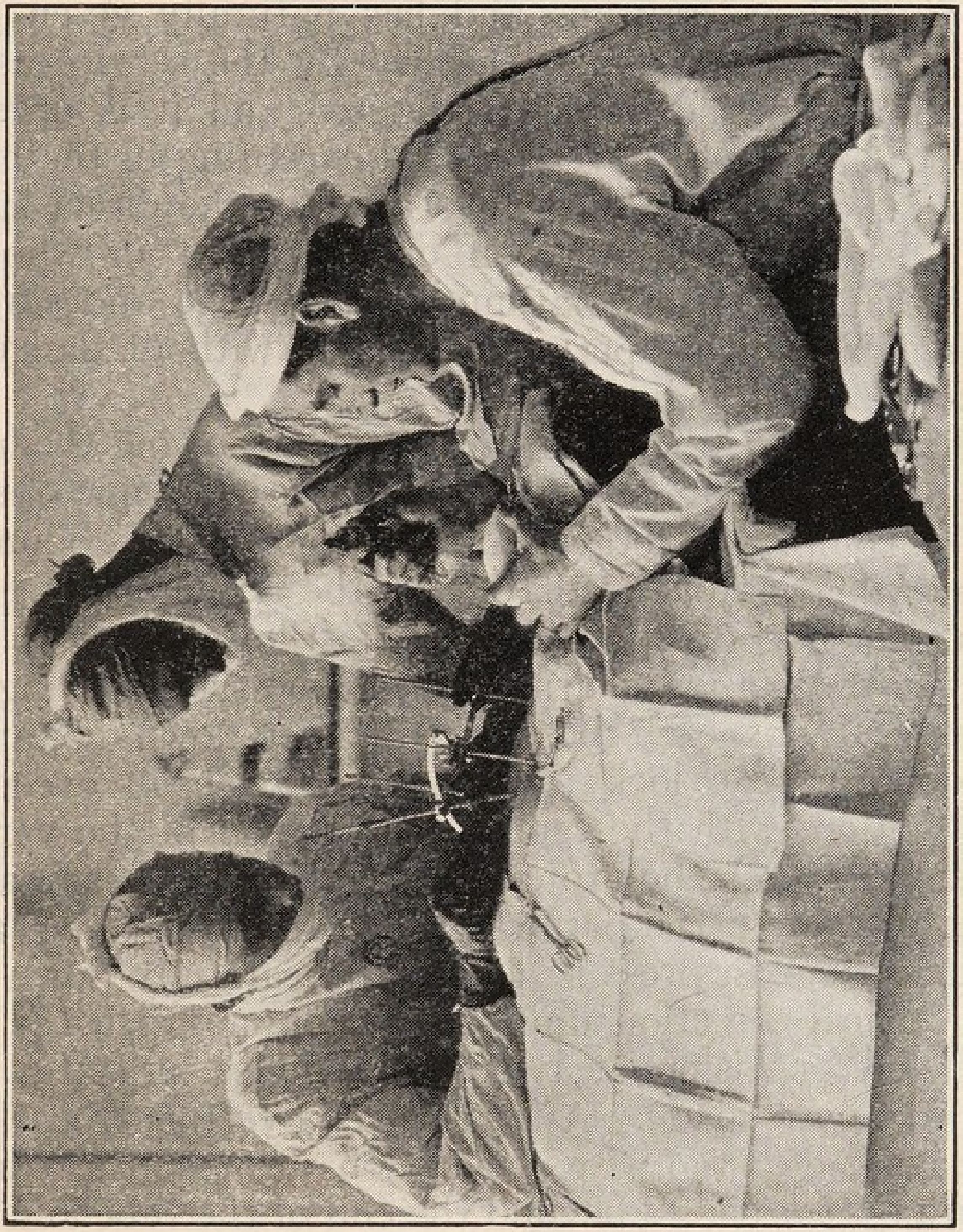


FIG. 32.—Hirtz compass in position.

Fig. 32 shows the compass in position on the patient at operation.

Method F.—Method F is one that has been known under various designations and attributed to a variety of authors.

It may be described as the method of direct approach through the skin and tissue to the foreign body, under fluoroscopic guidance, or, according to the apparatus used, as the method of canula and trocar. While the method has been advocated by some excellent surgeons and has naturally given good results in many cases, it is regarded by the service as the least desirable of the methods adopted and it is urgently advised that it should never be used excepting in the hands of an operator who will either work under the direct supervision of a competent surgeon or anatomist or who has acquired that degree of anatomical knowledge and surgical judgment which would permit of its use without danger to the patient.

The illustrations in various publications showing the introduction of the instruments at an *angle* with the line of sight should be completely forgotten, as this method is bound to result in a considerable mutilation of the tissue before one is likely to come in contact with the projectile.

In using the standard army outfit, one should bring the target vertically beneath the projectile, stop down diaphragm to a moderate size, lock the screen against all excepting vertical motion, with the central perforation in the vertical ray passing through the projectile. Then insert the canula and trocar through the perforation in the screen and after puncturing the skin press it slowly and carefully down in a strictly vertical direction until either contact with the projectile is felt or vision at two slight angles indicates that contact has been made. After this remove the trocar and pass the hooked piano wire or harpoon through the canula, being sure that it passes beyond the end of the tube and that it is not withdrawn on removal of the canula. While inserting the canula it will best be held by use of a strong pair of forceps as provided. These may lie flat upon the fluoroscopic screen and in this way keeping of the canula in a vertical position will be somewhat easier. The wire which has been inserted

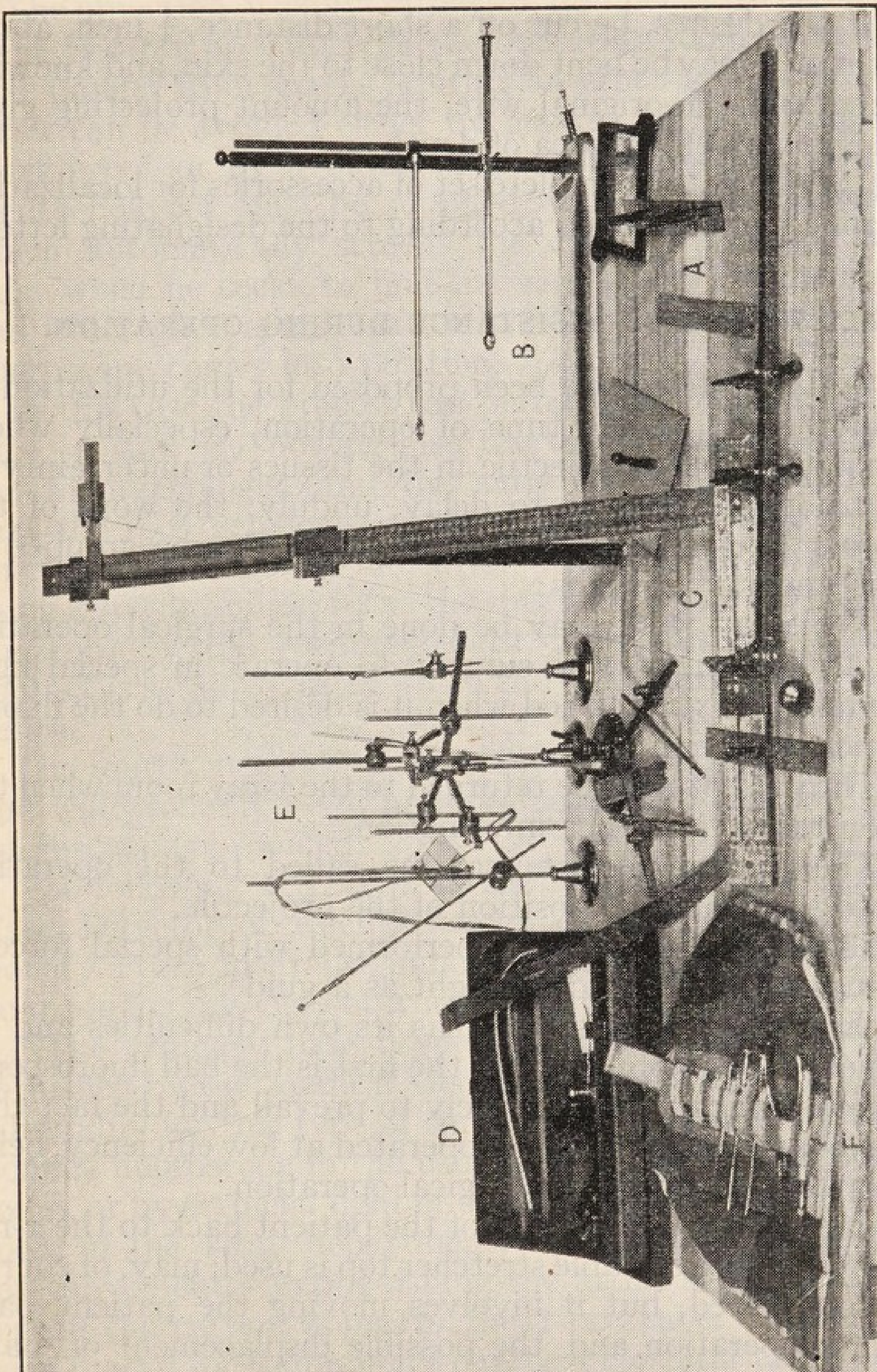


FIG. 33.—Set of localization accessories supplied in the regular outfit.

may, if one desires, be cut off a short distance, $\frac{1}{4}$ inch, above the skin or it may be bent down close to the skin, and knowing the length of the original wire, the amount projecting gives the surgeon a definite idea of depth.

Fig. 33 shows the complete set of accessories for localization as supplied, and grouped according to the designating letters.

FLUOROSCOPIC ASSISTANCE DURING OPERATION.

Several methods have been proposed for the utilization of the fluoroscope at the time of operation, especially where the mobility of the projectile in the tissues or uncertainty of its position are such as to delay, unduly, the work of the surgeon. The methods so far proposed may be grouped as follows under four heads:

1. The *x*-ray work may be done in the surgical operating room, thus requiring the surgeon to operate in special light which may be extinguished when it is desired to do the fluoroscopic examination.
2. The patient may be returned to the *x*-ray room when the surgeon requires further information.
3. The roentgenologist may be called to the operating room to point out the position of the projectile.
4. The operation may be performed with special forceps while using the fluoroscopic light as a guide.

Each of these propositions has its own difficulties and its own merits. The objection to the first is the bad fluoroscopic conditions which would be likely to prevail and the fact that the *x*-ray apparatus would be operated at low efficiency, being necessarily delayed by the surgical operation.

In the second, the transfer of the patient back to the *x*-ray room, provided a suitable stretcher top is used, may, of course, be accomplished, but it involves moving the patient back again for operation and the possible displacement of parts during the transfer.

The objection usually raised to number 3 is the requirement of *x*-ray apparatus in the operating room and the possible danger from sparks igniting an ether-air mixture. The latter can be avoided either by making the *x*-ray apparatus spark-proof or by avoiding these fumes in the room. The roentgenologist must be supplied with a bonnet fluoroscope which automatically screens the eyes by suitable colored glass when he seeks to find his way about a lighted room, and which glass is automatically lifted or removed when the fluoroscope comes into position.

In this case the process can perhaps be illustrated best by Figs. 34 and 35, showing also the type of indicator used by the roentgenologist and the surgeon; it being understood that the roentgenologist working *above* the sterile sheet can give an approximate indication after which the surgeon, using a sterile pointer *below* the sheet, may, under fluoroscopic guidance by the roentgenologist insert his indicator until contact is attained, after which the operation may proceed as before.

The fourth method is essentially one for the surgeon alone and will probably be of more value when a practical stereo-fluoroscope is provided.

The following extract from the report of Major James T. Case, Director of Roentgenology of the American Expeditionary Force in France indicates the preparation which will be made for this class of work.

"The ordinary base hospital or portable table regularly furnished by the Medical Department of the Army will serve admirably for this type of surgery, either operating with the bonnet fluoroscope in the usual bright light of the operating room, or by artificial light of suitable color in the fluoroscopic room of the *x*-ray department, with suitable arrangements for conveniently extinguishing the artificial light, and turning on the current going to the *x*-ray tube. An order has been placed for a hundred extra base hospital tables without the screen support, to be issued to operating rooms for this very purpose, our anticipation being that the bonnet method will be far more popular than the open screen method. We

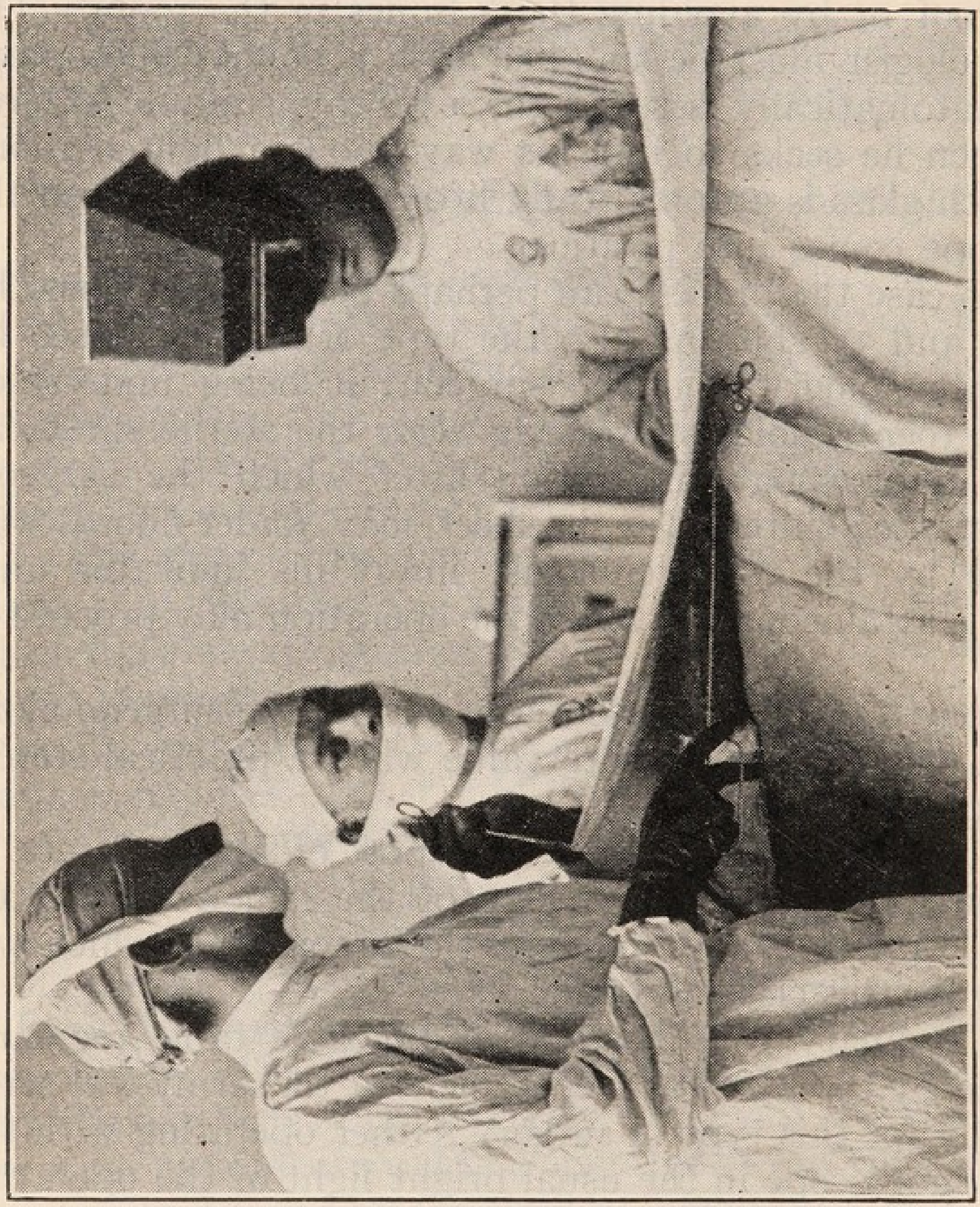


FIG. 34.—Intermittent control. Roentgenologist with fluoroscope raised ready to lower it and proceed with examination.

have acquired in France a small supply of collapsible operating tables with aluminum tops, also designed for this special type of roentgenosurgical work. Lacking any of these tables, the roentgenologist will be able to improvise a suitable equipment by combining the bedside outfit with an ordinary stretcher resting on the regular stretcher supports which will be available in the field.

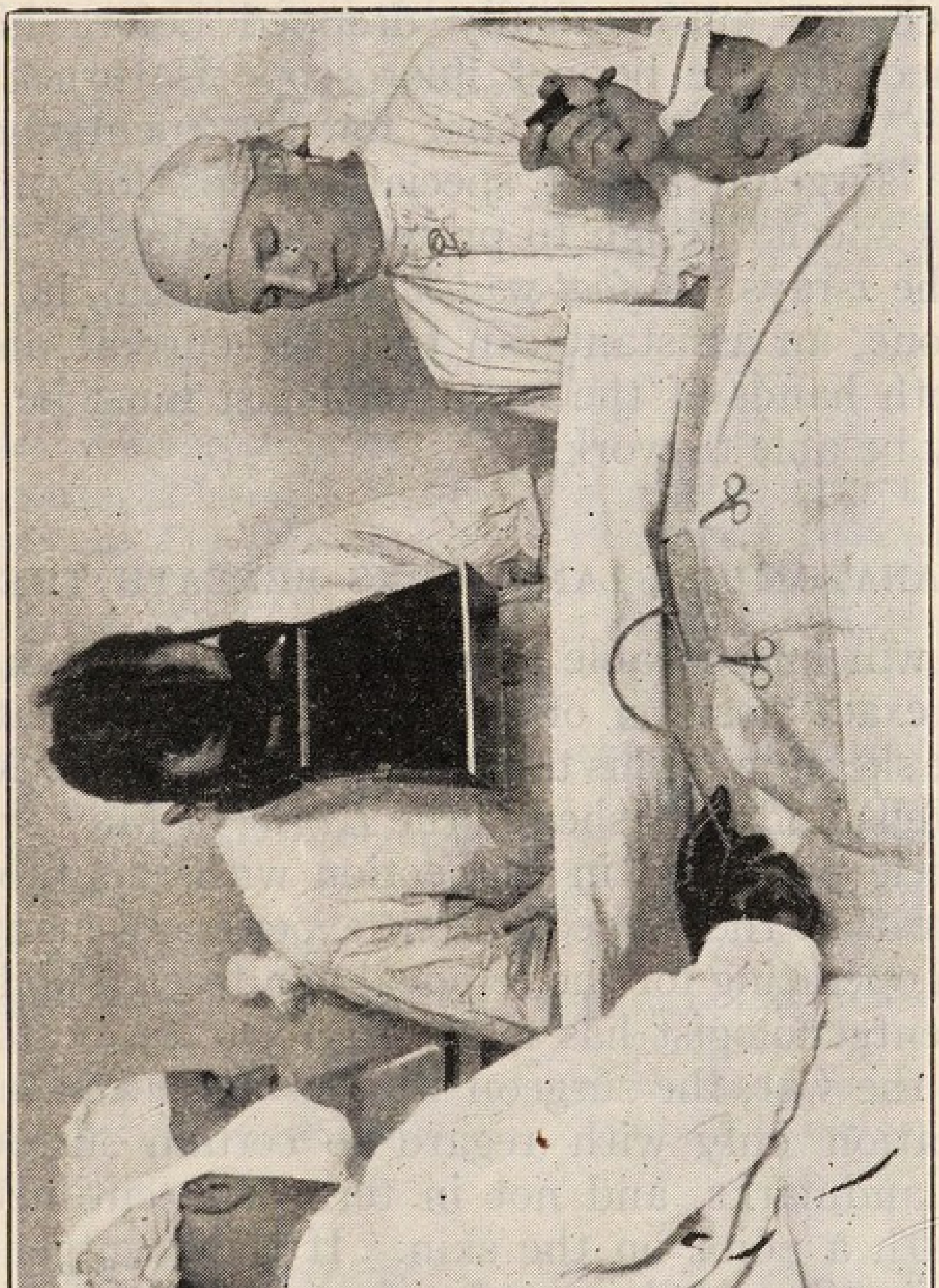


FIG. 35.—Intermittent control. Surgeon and roentgenologist working simultaneously.

"It is anticipated that the usual arrangement will be a base hospital table (without screen support) with overhead wire connections from the neighboring *x*-ray room, or there may be provided a special bedside unit.

"For operations in the usual light of the operating room, there will be needed a bonnet fluoroscope so arranged that when the roentgenologist is not actually working with the *x*-ray, his visual acuity will be preserved by means of dark glasses which are automatically dropped before his eyes when the hood of the bonnet fluoroscope is turned up; a special *metal pointer* (indicateur) for the roentgenologist, one for the surgeon, and a special forceps for projectile extracting of special design to protect the hands of the surgeon from the *x*-rays. A *foot switch* will be a help, but in the absence of one, an assistant can turn the current on or off at will. Both hands of the roentgenologist must be free so that he may be able to work."

DEPTH OF ANATOMICAL LANDMARKS BENEATH THE SKIN.

Surgeons will find a table given below of value in determining the exact position of a foreign body in relation to points on the skeleton. This table was prepared by T. Metcalf and Keys-Wells and published in the *Lancet* of May 27, 1916. In their article published in connection with this table, the authors state that the surgeon often experiences many difficulties when operating for the removal of a foreign body even after the roentgenologist has made an accurate localization. Previous to the war, the surgeon studied the ultimate depth of his operation only with regard to certain surrounding anatomical landmarks, and not in terms of centimeters or inches beneath a point on the skin. If the roentgenologist reports a projectile as being 4.5 cm. from a point on the skin of the back overlying the transverse process of the twelfth dorsal vertebra, the surgeon has little knowledge as to where this depth will lead him. If, however, the surgeon knows that the average depth of this structure is less than 4 cm. from the skin he appreciates the fact that the projectile must lie in or just anterior to the transverse process. The objection is, of course, that individuals vary greatly in thickness of various parts, but the authors call attention to the fact that the soldier is selected after rigid examination and as a result the extremely thin and extremely obese are not present.

Incision.	*Depth of Anatomical Position.*
Head: Laterally.	
Just above zygoma.	1 inch to sphenosquamosal suture.
Just below zygoma.	1½ inches to sphenoidal bone.
To coronoid process or condyle of mandible.	1 inch.
Neck: Anteroposteriorly.	
Through center of larynx.	2 inches to body of vertebra.
1¼ inches to side of center of larynx.	1½ inches to transverse process of cervical vertebra.
1¼ inches to side of center of larynx.	3 inches total depth of neck.
Through middle line of trachea just below cricoid.	1½ inches to body of vertebra.
1¼ inches to side of center of trachea.	1½ inches to transverse process of vertebra.
From center of suprasternal notch.	1¼ inches to posterior border of manubrium.
Neck: Laterally.	
From center of middle of neck.	1½ inches to transverse process of vertebra.
From center of middle of neck.	2¼ inches to body of vertebra.
From just below tip of mastoid process.	2¼ inches to body of first cervical.
Chest: Superiorly.	
From a point midway between root of neck and tip of acromion.	2 inches to apex of pleura, downward.
From a point midway between internal and external extremities and just behind posterior border of the clavicle.	2 inches to apex of pleura, downward.

Chest: Anteriorly.	*Depth of Anatomical Position.*
From center of lower border of clavicle backward to subscapular fossa just clear of ribs.	3 inches.
From a point just over tip of coracoid to subscapular fossa backward.	3 inches.
From a point 1 inch external to sternoclavicular joint just below clavicle.	$1\frac{1}{3}$ inches to first rib
From a point 1 inch external to sternoclavicular joint just below clavicle.	$\frac{3}{4}$ inch to pleura.
From a point 2 inches external to sternoclavicular joint just below clavicle backward.	$1\frac{1}{4}$ inches to first rib.
From a point 2 inches external to sternoclavicular joint just below clavicle backward.	$1\frac{3}{4}$ inches to pleura.
From a point 2 inches below center of clavicle.	2 inches to pleura.

Chest: Posteriorly.	
To supraspinous fossa.	1 inch.
To intraspinous fossa.	$\frac{3}{4}$ inch.
To transverse process of seventh cervical vertebra.	$1\frac{1}{2}$ inches.
To pleura level of seventh cervical vertebra.	2 inches.
To anterior level of body of seventh cervical.	3 inches.
To transverse process of twelfth dorsal vertebra.	$1\frac{1}{3}$ inches.
To pleura level of twelfth dorsal vertebra.	2 inches.
To anterior level of body of twelfth dorsal vertebra.	$3\frac{1}{3}$ inches.

Abdomen: Thickness of Wall from Front.	*Depth of Anatomical Position.*
$\frac{1}{2}$ inch to either side of middle line just above umbilicus.	1 inch.
$\frac{1}{2}$ inch to either side of middle line just below umbilicus.	$1\frac{1}{5}$ inches.
Just internal to anterior superior spine to iliac fossa.	3 inches.
Midway between anterior superior spine and pubic crest to front of acetabulum.	2 inches.

Abdomen: Thickness of Wall from Side.

On level of tip of twelfth rib in line upward from anterior superior spine.	1 inch.

Abdomen: Thickness of Wall from Back.

To transverse process third lumbar.	$1\frac{3}{4}$ inches.
To anterior level of body of third lumbar.	$4\frac{1}{4}$ inches.
To anterior level of psoas muscle.	5 inches.

Hip and Thigh from Front.

3 inches below anterior superior spine to head of femur.	$2\frac{1}{4}$ inches.
3 inches below anterior superior spine to neck of femur.	$2–2\frac{3}{4}$ inches.
6 inches below anterior superior spine (level of lesser trochanter) to front of femur.	$1\frac{1}{2}$ inches.
To great trochanter	$4\frac{1}{4}$ inches.
To lesser trochanter.	$3\frac{1}{2}$ inches.
Brim of pelvis 1 inch in front of sacro-iliac synchondrosis.	$3\frac{3}{4}$ inches.
To anterior inferior spine.	$1\frac{1}{4}$ inches.
To spine of ischium.	5 inches.
To ischial tuberosity.	$5\frac{1}{4}$ inches.
To anterior surface of line of junction of ascending ramus of ischium and descending of pubis.	$2\frac{3}{4}$ inches.

Hip and Thigh from Back.	*Depth of Anatomical Position.*
To ischial tuberosity.	$2\frac{1}{4}$ inches.
To spine of sacrum on level of posterior superior spines of ilia.	$1\frac{1}{4}$ inches.
To sacral groove.	2 inches.
To head of femur.	2 inches.
To great trochanter.	$3\frac{3}{5}$ inches.
To lesser trochanter.	3 inches.
To brim of pelvis 1 inch in front of sacro-iliac synchondrosis.	4 inches.
To anterior inferior spine.	6 inches.
To spine of ischium.	2 inches.
To posterior surface of junction of ascending ramus of ischium and descending ramus of pubis.	$4\frac{1}{2}$ inches.

RELATION BETWEEN THE ROENTGENOLOGIST AND THE SURGEON.

In considering the great responsibility that must be assumed by the medical profession in this serious world conflict, every effort should be made to secure that degree of fair-minded consideration of the different subdivisions which is necessary to carry on this work expeditiously and in a satisfactory manner. This is no time for the exploitation of personal prestige or for any propaganda in reference to any department or specialty in medicine.

Considered as an end in itself no *x*-ray examination, no matter how well carried out, or accurately reported, or how much is spent in equipment, will be of any value whatever unless it gives such information to the surgeon and the physician as will expedite and facilitate their work. In saying this the writer has no intention of minimizing the importance of the *x*-ray service. Consultation with eminent surgeons who have had actual experience has indicated that roentgenology may be of the very highest importance, but it is especially desired to call attention of both the roentgenologist and the surgeon to the fact that the full realization of the ends to be attained can only be accomplished by mutual coöperation.

If either party is destructively critical of the work of the other, if either declines to give the information in a usable form or with sufficient accuracy for practical use, or is generally incompetent, it should not be assumed by the surgeon that all roentgenologists are to be condemned, or by the roentgenologist that all surgeons are wrong or arbitrary. Each may be expected to assist the other in a tactful and effective manner in order that they may jointly realize ways in which the work may be improved.

When time permits it would be extremely desirable for the surgeon to attend a considerable number of cases during the *x*-ray examination and to allow the roentgenologist to be present at the operation of these cases. In this way a better realization of the specific difficulties, generally unavoidable, which beset the work of each specialist will be mutually appreciated.

This does not mean that the surgeon should be an expert roentgenologist, or the reverse. Each has a field sufficient for all his abilities and efforts, and division of labor is essential to its rapid performance and to the highest development of the art. But both parties should be jointly responsible for a most important and valuable work in which neither can attain the full measure of success without the assistance of the other.

CHAPTER XXVIII.

THE TREATMENT OF INFECTED WOUNDS BY THE CARREL-DAKIN TECHNIC.

1. General Considerations.—Neither Carrel nor Dakin claim to have made a new discovery. Their statement is that the systematization of known processes has produced new results. Their method of sterilization of infected wounds consists in applying a certain antiseptic in a precise manner under a definite control.

2. Results Claimed by Use of the Solution.

(*a*) It destroys bacteria in the presence of bloody serum and pus.

(*b*) It acts neutrally on living tissues.

(*c*) It dissolves necrotic tissues.

(*d*) It requires components easily obtained in war-time in large quantities.

3. Nature of the Solution; Its Preparation.

Definition.—Dakin's hypochlorite solution[1] is a solution of sodium hypochlorite (NaOCl) which contains not less than 0.4 per cent. nor more than 0.5 per cent. sodium hypochlorite; and which is not alkaline to powdered phenolphthalein but is alkaline to alcoholic solution of phenolphthalein. If the percentage of sodium hypochlorite is less than 0.4 per cent. the antiseptic power of the solution is too low; if greater than 0.5 per cent. the solution is irritating. If the solution is alkaline to powdered phenolphthalein, the solution is irritating; if the solution is acid to alcoholic solution of phenolphthalein the solution is unstable.

[1] Dakin, H. D.: British Med. Jour., Aug. 28, 1915, p. 318.

The Titration of Dakin's Solution.—Measure 10 c.c. of Dakin's solution. Add 5 c.c. of a 10 per cent. potassium (or sodium) iodide solution and 2 c.c. of glacial acetic acid. Then run decinormal thiosulphate solution into the flask from a burette to decolorization.

The number of cubic centimeters decinormal thiosulphate required, multiplied by 0.03723, gives the percentage of sodium hypochlorite.

Tests for Alkalinity.—Test with powdered phenolphthalein: A few crystals of powdered phenolphthalein are dropped on the surface of about 5 c.c. of the solution to be tested and the solution vigorously shaken. Dakin's solution should remain entirely colorless. If there is any red color the solution is too alkaline and must either be discarded or the excess alkalinity neutralized.

Test with alcoholic solution of phenolphthalein:

About half a cubic centimeter of alcoholic solution of phenolphthalein (1 per cent.) is squirted from a dropper into about 5 c.c. of the solution to be tested in a test-tube. The solution should show a red color which will soon disappear. If there is not at least a momentary flash of red color the solution has so low an alkalinity that its hypochlorite content will rapidly diminish.

Preparation.—Dakin's solution may be satisfactorily prepared: by the electrolysis of a sodium chloride solution; by the action of chlorine on sodium carbonate; by the double decomposition of calcium hypochlorite and sodium carbonate.

Preparation from Chlorine and Sodium Carbonate.[1]—A solution is prepared containing 14.1 grams of dry sodium carbonate per liter (= 16.6 grams monohydrate or 38 grams washing soda), a measured quantity, 4.8 grams per liter (or about 1600 c.c.) of chlorine gas is allowed to run into the solution. Chlorine may be obtained in liquid form in steel

[1] G. E. Cullen and H. H. Austin, Proc. Soc. Exp. Biol. and Med., December 19, 1917.

cylinders and is easily measured by a chlorine meter manufactured for the purpose. This is a stable, economical and convenient source of chlorine. Ten cubic centimeters of the solution is then titrated. If the solution is too strong it should be diluted to 0.5 per cent. NaOCl with 1.4 per cent. sodium carbonate solution, which serves to correct the unduly diminished alkalinity caused by the excess of chlorine introduced into the solution. However, the designated amount of carbonate is planned to give, at a concentration of 0.5 per cent. NaOCl, the minimum degree of alkalinity consistent with stability, and if chlorine has been introduced in such excess that the titer exceeds the desired by more than 3 c.c. of $\frac{N}{10}$ thiosulphate or if the solution fails to give a momentary flash of color with *alcoholic solution of phenolphthalein* it should be discarded. The solution should be titrated for hypochlorite concentration every twenty-four or forty-eight hours.

Preparation from Bleaching Powder.—Bleaching powders vary so greatly in their composition that it is necessary to determine the percentage of available chlorine. They contain such variable amounts of free alkali that it is impossible to prepare from different bleaches hypochlorite solutions of the same alkalinity by adding a fixed amount of acid. For this reason the following method of Dakin's is preferable to his alternative method or to Dufresne's modification, in that the solution is adjusted *by titration* to a definite alkalinity *i. e.*, the point where powdered phenolphthalein no longer gives color.

Titration of Bleaching Powder.—Exactly 10 grams of bleaching powder made up of small samples from different parts of the jar are well stirred up in a liter of water. After several hours the solution is filtered and a 10 c.c. sample of the filtrate is titrated in exactly the same manner as in the titration of Dakin's solution. In this case the number of cubic centimeters of decinormal thiosulphate required to decolorize, multiplied by the factor 3.55 gives the percentage of *active chlorine* in the bleaching powder.

Dakin's Method.[1]—A strong "solution of hypochlorite may be prepared by decomposing bleaching powder with dry sodium carbonate in the proportion of 150 gm. (bleaching powder) to 105 gm. (sodium carbonate) dissolved in 1 liter of water. The mixture is filtered and a measured portion of it (20 c.c.) rapidly titrated with boric acid solution of known strength (31 gm. per liter, $\frac{1}{2}$ normal), using phenolphthalein suspended in water as indicator (the usual alcoholic solution of phenolphthalein will not serve because the alcohol is at once attacked) in order to determine the amount of boric acid to be added to the rest of the filtrate. (Each cubic centimeter of $\frac{N}{2}$ boric acid calls for 3 gm. boric acid to be added.) An excess of boric acid should be avoided, as it favors the liberation of hypochlorous acid and renders the solution less stable. It is best to add slightly less than the calculated amount. The concentrated solution thus prepared contains about 4 per cent. of sodium hypochlorite and should be mixed with 7 parts of water before use. It can be kept for a month without serious decomposition."

Preparation of a Less Alkaline Dakin's Solution.[2]—A further reduction of the hypochlorite solution, *i. e.*, to the minimum degree of alkalinity consistent with stability (hydrogen ion concentration of about 10^{-9}) is permissible. This is accomplished by adding a fixed amount of sodium bicarbonate after the solution has been neutralized to powdered phenolphthalein. It should be noted that this somewhat decreases the solvent action and in cases where great solvent action is required even at the expense of greater irritation it may be desirable to use the solution at the more alkaline reaction. In most cases, however, the modified solution is preferable. The method is as follows:

[1] Quoted from Dakin and Dunham's Handbook of Antiseptics, p. 25.

[2] G. E. Cullen and J. H. Austin: Loc. cit.

Mix well with 5 liters of tap water the amount of bleaching powder, indicated in the appended table, in accordance with the titration of the bleaching powder.

TABLE FOR APPROXIMATELY 40 LITERS OF DAKIN'S SOLUTION.

Active chlorin in bleaching powder, per cent.	Bleaching powder in 5 liters of water, grams.	Sodium carbonate in 5 liters of water anhydrous grams.	monohydrated grams.	crystalline. grams.
20 to 26	800	600	700	1600
28 to 34	600	420	490	1300
36 to 42	500	335	390	900

Dissolve the designated amounts of sodium carbonate in another 5 liters of tap water. Pour the solution of sodium carbonate into the bottle containing the bleaching powder which has stood several hours, shake well, and allow the precipitated calcium carbonate to settle.

Siphon off the supernatant liquid through a filter, neutralize to powdered phenolphthalein with dilute hydrochloric or boric acid and add 62.5 grams sodium bicarbonate per liter of filtrate. Test for alkalinity, titrate and dilute to the desired volume.

The following formula simplifies the calculation of the dilution:

1. $\dfrac{\text{Present Strength (or Titer)}}{\text{Desired Strength (or Titer).}} \times$ Present Volume = Desired Volume.
2. Desired Volume − Present Volume = Volume water to add.

4. TECHNIC OF APPLICATION.—The results of treatment depend almost entirely upon the manner in which the antiseptic is applied. The following conditions must be considered:

(1) The contact of the antiseptic with the bacteria.
(2) The concentration of the solution.
(3) The length of time the antiseptic should be applied.
(4) The action of the hypochlorite solution on tissues.

(1) Sterilization cannot be effected when the character of the wound, presence of necrotic tissue, blood-clots or compress prevent the germicide from reaching the walls of the wound.

In fresh wounds, prepared mechanically by such incisions as permit all surfaces to come in contact with the antiseptic, sterilization is promptly effected; but when the wound reaches the stage of suppuration, it becomes more difficult to establish contact between bacteria and antiseptic.

Hemostasis must be carried out so that no clot remains to harbor the bacteria, because hypochlorite dissolves bacteria slowly.

The antiseptic solution must be applied in conformity with such physical laws and hydraulic practice as are necessary to bring it in direct contact with every part of the actual wall of the wound.

(2) When the antiseptic comes in contact with the wound, it is destroyed, also it is diluted by the secretions from the wound, with the result that in a very short time (fifteen to twenty minutes) no active substance remains. Proper concentration of the solution in the wound is maintained by small rubber tubes introduced into every part of the wound and by frequent flushings.

(3) The aim of the treatment is not to effect an absolute asepsis but to obtain a degree of sterilization that will permit the secondary closure of the wound with primary union.

(4) The action of the hypochlorite solution on tissues of wounds under therapeutic conditions is almost neutral.

The results of continuous hypochlorite instillation are borne well by the skin, but its surface should be protected by vaseline to prevent maceration.

The hypochlorite dissolves necrotic tissue.

The rate of wound cicatrization is more rapid in wounds when treated by hypochlorite solution than by vaseline or salt solution.

The normal rate of cicatrization of aseptic wounds is not modified by the action of the hypochlorite.

5. MATERIALS REQUIRED.—(1) A solution of neutral hypochlorite of soda of the required concentration.

(2) Glass vessel holding 500 to 1000 c.c. An ordinary laboratory "wash bottle" with a cork perforated by a long and a short glass tube, best answers the purpose.

(3) Irrigating rubber tube connected to the short glass tube which passes only through the cork, the bottle, inverted delivers its contents freely into the rubber tube.

(4) A soft-rubber tube 2 meters long.

(5) A spring clamp for closing the tube (rubber protected artery forceps will do just as well).

(6) Small rubber tubes in ample supply, 4 mm. internal diameter and 30 to 40 cm. in length, closed at one end by a ligature and perforated laterally with 1 mm. hole 5 or 10 cm. from the closed end.

Some of these tubes have their perforated part covered with a layer of Turkish towelling for use on superficial and in through-and-through wounds.

(7) Similar tubes which are not ligated and which have a small lateral opening near one end are used in cup-like wounds.

(8) Glass "manifolds" to connect supply tube with dressing tubes.

(9) Dressings, made up in the form of gauze pads, 3 cm. thick, and large enough to enclose completely wounds of various sizes. These pads are formed of a layer of common cotton, with a layer of absorbent cotton on the outside, the whole being covered by one piece of gauze.

6. METHOD OF OPERATION.—On general principles, every wound should be treated as soon as possible within the first twelve hours, or at the latest within twenty-four hours, to prevent deep infections, or to secure the earliest resolution of slighter infections.

The treatment consists of four stages:

(1) Surgical treatment.
(2) Chemical sterilization.
(3) Bacteriological control.
(4) Closure.

(1) *Surgical treatment* must be carried out with the technic demanded by any major operation and with the best surgical judgment available. The wound must be widely laid open. All corners and ramifications opened and cleansed so as to permit the dressing tube to deliver the antiseptic solution to all of the surfaces of the wound.

Every part of the wound should be seen by the eye. A complete excision of the contused and necrotic tissue must be made by careful dissection. Shell fragments, pieces of clothing, every particle of foreign matter must be extracted. Free bone splinters are removed, but all fragments adherent to the periosteum are preserved.

Blood-clots are carefully removed and hemostasis thoroughly made (plain catgut) because bacteria remain located in the blood-clots and the hypochlorite cannot rapidly dissolve them.

The treatment of old suppurating wounds is different: In this class of cases, a surgical operation should not be attempted until at least ten days after the infection has been diminished by chemical sterilization. The suppurating wound is first treated by chemical means and when the infection is reduced as much as possible, the necessary surgical cleansing is performed. It is then followed by a new and thorough chemical cleansing.

(2) *Intermittent instillations* maintain constant contact and concentration of the antiseptic fluid with all parts of the wound. It is necessary to know how much fluid is required in a given time. This amount varies according to the size of the wound and the number of the instillating tubes. This is best determined after the tubes are in place and the dressing

is ready to be closed. Then, in the presence of the nurse, the surgeon opens the stop-cock for the predetermined time. The height of the bottle should vary from 40 cm. to one meter above the patient's bed. It should be regulated according to the number of tubes, particular needs of the wound and sensitiveness of the patient. Intermittent instillation must be given every two hours day and night, and continued until chemical and bacteriological evidence shows the wound to be sterilized.

The dressings must be simple, easy to renew, afford sufficient protection and permit easy connection between the supply and the dressing tubes.

This end is accomplished by using pads which are held in place by safety-pins without bandages.

(3) *Bacteriological Control* (see Fig. 36).—Every second day a smear, taken from each wound, is stained and examined microscopically to count the number of organisms in a single microscopic field.

It is important to know, not the average bacterial count, but the condition of the more badly infected part of the wound, because it does not matter if nine-tenths of a wound be sterile, if one-tenth remains still infected.

The simple determination of the number of organisms in a microscopic field indicates the increase or decrease of infection. A nurse or orderly can readily be trained to do this work. One dozen microscopic fields from the same smear are examined, the total numbers counted, and an average recorded on the microbic chart.

Where there are multiple wounds, a chart is kept for each wound or the microbic counts for each wound may be recorded on the same chart in different colors, arranged in accordance with the key of colors to indicate the wound to which the particular color pertains.

Each number on the chart indicates the average count of twelve microscopic fields in a smear. If more than sixty organisms are averaged, the case is thoroughly septic and is reckoned as infinity.

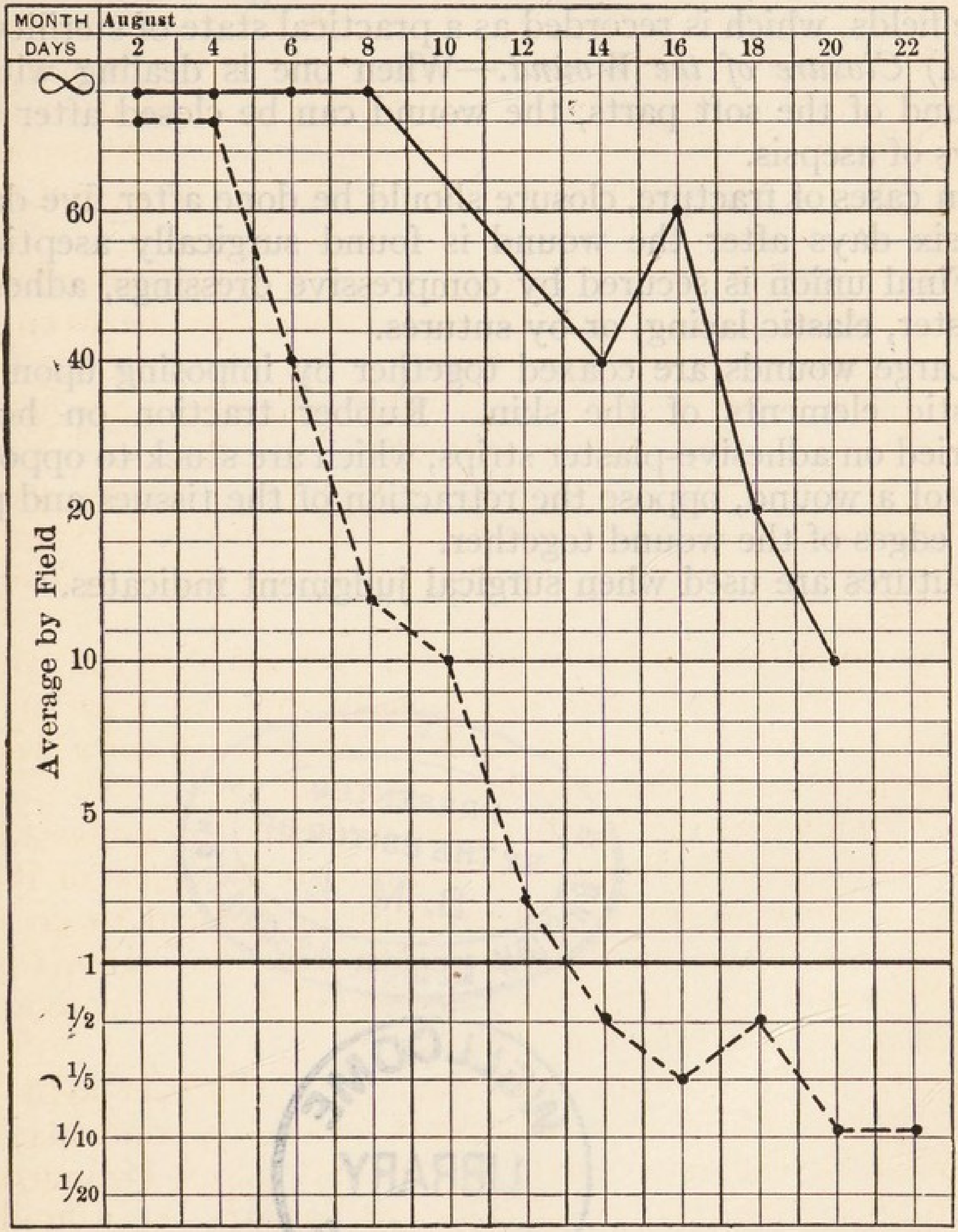


FIG. 36.—Bacteriological control: ——— compound fracture of the right tibia; - - - - - - wound of the lumbar region.

The fractions indicate one organism to two fields, etc. The wound is not considered as sterile enough to close until the bacterial count is reduced to one organism in at least five fields, which is recorded as a practical state of sterility.

(4) *Closure of the Wound.*—When one is dealing with a wound of the soft parts, the wound can be closed after two days of asepsis.

In cases of fracture, closure should be done after five days, or six days after the wound is found surgically aseptic.

Final union is secured by compressive dressings, adhesive plaster, elastic lacing, or by sutures.

Large wounds are coaxed together by imposing upon the elastic elements of the skin. Rubber traction on hooks carried on adhesive-plaster strips, which are stuck to opposite lips of a wound, oppose the retraction of the tissues and pull the edges of the wound together.

Sutures are used when surgical judgment indicates.