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# THE SURGICAL ASPECTS OF THE MODERN SMALL-BORE PROJECTILE.

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# THE SURGICAL ASPECTS OF THE MODERN SMALL-BORE PROJECTILE.[1]

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WITH the introduction of the Lebel rifle by France, in 1886, a new epoch was created in modern warfare and military surgery. The French example was soon imitated by other powers, until to-day every advanced nation has practically the same character of rifle.

Although thirteen years have elapsed since that date, and wars of more or less consequence have occurred, we are still short of sufficient data to enable us to reach complete and uniform conclusions as to the influence and effect which this new rifle is capable of creating.

With the improvement of the rifle, and the corresponding improvement of the projectile and explosive, we are able to drive a missile with more energy, more accuracy, and greater velocity; furthermore, the combatant enters the conflict with a greater number of cartridges, which can be fired with greater accuracy and rapidity than formerly. Under such circumstances, engagements were expected to occur at longer ranges. Dressing stations and hospitals to be removed to greater distances or to protected positions, greater number of wounded, and greater difficulties in the removal of not only a larger number of wounded, but removal under more difficult conditions.

Much has been promised for and much is expected of the small-bore projectile, but as to how thoroughly it will fulfil the expectations and demands yet remains to be determined.

[1] A paper read before the Mississippi Valley Medical Association, October 5, 1899.

The experimental efforts have been both numerous and various, but their conclusions lack the desired uniformity, at least, as regards certain specific features. This lack of uniformity in the experiments of Beck, Bruns, Reger, Delorme, Chavasse, Chauvel, and others, has prompted the Prussian War Office to undertake an elaborate series of experiments, with the view of reaching accurate conclusions as regards the new projectile. Practical results justify one in doubting as to whether the new projectile is a step forward or backward, when broadly considered from a humane as well as fighting stand-point. Here the attending circumstances must be considered. It largely depends upon whether the contending forces represent an advanced civilized nation or not. In the latter instance the new projectile has fallen short of the expectations. Certainly no stronger proof of this insufficiency could be desired than that furnished by the English government. The creation of the "Dum Dum" bullet is a positive confession that the new projectile does not fulfil the practical demands.

In the Chitral expedition, the English, armed with the "Lee-Metford" rifles, were clearly unable to stop the rush that was made upon them. Soldiers have been known to continue fighting after a half-dozen Lee-Metford bullets had passed through them. This experience resulted in the invention, by Captain Bertie Clay, R.A., of a soft-nose bullet known as the "Dum Dum."

The experience of the Italians in Abyssinia armed with the Carcano rifle was not different; not only were they easily defeated, but the Abyssinians indulged in humorous criticisms, such as "Les fusées d'enfants" and "Qui ne tuent pas," regarding the new weapon. A similar result attended the use of the Murata rifle by the Japanese during the Chinese-Japanese war. "The Chinese, wounded by two or more small-bore bullets, had no difficulty in getting away, while the real execution was done by the heavier bullets, which were still being used by the bulk of the Japanese troops."

General Howe (*loc. cit.*, Annals of Surgery, Vol. xxv, p. 48), who commanded the leading column in the Chitral campaign, is quoted by the *Washington Post* as saying, "Often prisoners were brought in with two or three bullet-holes through them that seemed to cause the wounded men but little inconvenience, for they had been marched six or seven miles before they reached our bivouac. These prisoners accounted for the extraordinary absence of the dead enemy on the field by saying that unless a man was shot in the head or bowels he did not die, and nothing but a wound in the joints of the lower extremities disabled him. I am clearly of the opinion that for fighting savages the old forty-five (45) calibre arm should be used. The Chitrals had a forty-five (45) calibre rifle, and they disabled or killed a man whenever they hit."

From this it is evident that the practical results have not been sufficient to enable us as yet to reach a uniform conclusion as to the precise merits and demerits of the new projectile. That it has advantages it is useless to repeat; that there are certain shortcomings the practical results have already demonstrated. At present, the interesting feature of the new projectile is to determine the conditions under which the greatest advantages are to be gained. The circumstances under which it behaves as a humane invention and when it does just the reverse.

In a contribution to the *Revista de Ciencias Medicas*, of Havana (*loc. cit.*, *London Lancet*, June 6, 1896), Dr. Enrique Pedrassa, a Spanish military surgeon, remarks, "that the benign results he had expected to see do occur, but only when the enemy is 150 yards or more distant. When the patient is shot at from ten to seventy yards, the destruction of the tissues is very great, and it is this that has given rise to the suspicion that explosive bullets were being used, especially as the orifices of outlet and entrance are so small that they can hardly be seen. If the fighting should never occur at less than 200 yards, the Mauser would be the most humane weapon."

To appreciate the small-bore projectile, it is well to consider some of the conditions governing the behavior of the projectiles in general.

Whenever a projectile strikes a body we are at once confronted by two opposing forces, the one in the main an onward force inherent in the projectile, and the other a resistant force inherent in the object. Each of these forces is capable of wide variation under modifying conditions. On the side of the projectile the effect is dependent upon the character of the weapon, the explosive, and the projectile itself.

The rifling of the bore of the modern weapon has given to the projectile a rotatory movement in addition to its purely penetrative one. This rotatory motion imparts accuracy to its flight and an independent lateral action on meeting an object. This has been thoroughly brought out by the experiments of the German War Office and others, that even after the penetrative action of the projectile ceases, the rotatory action may continue.

The substitution of practically smokeless for the ordinary powder has increased the missile's energy and velocity, not to speak of the other advantages which the smokeless explosive has over the common gunpowder.

Hand in hand with the rifling and other improvements in the weapon, and the improvement in the propulsive agent, came the change in the projectile. For a soft, wide, and heavy projectile we substitute a hard (non-deforming), narrow (diminished frontage), and lighter, the latter enabling the combatant to carry a greater number. The change from a soft to a hard projectile overcame its tendency towards alteration in its form, and upon the preservation of its form largely depended its degree of penetration, as well as the character of the wound it was capable of creating. The humane nature, whenever the wound partakes of this character, is due more to the non-deforming character than any other element. For this reason the English introduced the soft-nose or "Dum Dum" bullets in their colonial wars. These projectiles produced gruesome wounds, and exposed England to the criticism from other powers that the use of this bullet was contrary to the convention made with European powers in 1868. Lately, the "Dum Dum" bullet has been replaced by another projectile, known as the hollow-tip bullet. The following is extracted from an abstract of an article by Professor Bruns, *Beiträge zur klinischen Chirurgie*, Band xxiii, Heft 1, in ANNALS OF SURGERY, Vol. xxix, page 651:

"This bullet is the same diameter, 303, the same length, one and one-fifth inch, and the same weight, 215 grains, as the Lee-Metford bullet. The case is of nickel, the base only being filled with lead. The conical end is left empty, and when it strikes the enemy bursts open backward and lodges in the body, penetration being lessened and shock increased. The new bullet is spoken of as the man-killing instead of the man-penetrating bullet. It is propelled with cordite, and has as much energy as the Martini-Henry bullet of 410 grains with the best gunpowder; whilst it is half the weight, it is more easily deformed than the ordinary jacketed projectile, but not as easily deformed as the 'Dum Dum.' At short range, all injuries are more severe than the jacketed. Wounds of hollow viscera containing fluid are of tremendous severity, as the missile explodes with great force. In penetrating, it compares favorably with the ordinary; so long as no alteration in its shape is produced the greater the resistance of the target the more unfavorable the comparison. The following examples are instructive:

"Distance twenty-five metres, dry deal block, 'full mantle,' no change, 100–110 centimetres penetration; hollow tip, slightly altered, eighty-four centimetres penetration; lead tip, markedly altered, twenty centimetres penetration. Same distance, dry beachwood, 'full mantle,' no change, fifty-four centimetres penetration; hollow tip, markedly altered, fourteen centimetres penetration; lead tip, markedly altered, twelve centimetres penetration."

Reduction in calibre means a reduction in the resistance offered, not alone by the object but also by the atmosphere. The accuracy of the projectile's flight depends largely upon its weight, for the lighter the missile the more rapid must be its rotation to secure accuracy, and the lighter the missile the easier will its rotation become irregular.

According to Köhler, a five-millimetre projectile must rotate about 7000 times per second to secure its accuracy. We may sum up that energy, velocity, weight, frontage, and the likelihood of deformation are the factors on the side of the projectile, which determine its effect upon striking an object.

In speaking of the ballistic qualities of the new projectile, different writers have compared its action with that of a spinning-top. When the top begins to spin, it is a rotatory motion accompanied by more or less lateral wabble, soon the lateral wabble disappears, and we have a pure rotatory motion, towards the close it again assumes the lateral wabble, which increases with the decrease of the rotatory motion until the spinning comes to a close.

Largely upon this behavior occurred the division of the new projectile's flight into three zones. The first or explosive zone, owing to explosive appearance, which wounds created in this zone commonly present; the second or penetrative zone, owing to a purely penetrative nature, which represents the behavior in this portion of the missile's flight, and the third or contusing zone. By explosive effect we mean the destruction created outside of the projectile's passage.

In the first zone, the projectile's flight represents a high degree of energy, velocity, rotation, and lateral sway.

In the second zone, a gradually diminishing energy, velocity, and rotation, with very slight lateral sway, which makes its effect practically a purely penetrative one.

In the last, the energy, velocity, and rotation are diminished, and the lateral sway again occurring and increasing with the decreasing penetrative action.

The German War Office does not favor such a classification, owing to the difficulty of determining a division in the projectile's flight.

The elements inherent in the object or target which determine the effect of the projectile are various, prominent among which are two forces, elasticity and cohesion. To these may be added the physical properties peculiar to the body, such as specific gravity, homogeneity, etc.

Before a body will break or tear it will bend and stretch in proportion to the amount of elasticity it possesses. The assertion of the elastic force is largely dependent upon the velocity of the projectile, for the greater the velocity the more the object behaves as an inelastic body, and the less favorable is the condition for the exhibition of the elastic force. The influence of cohesion applies as strongly to the projectile as it does to the object, for if the cohesive force in the target is greater than that of the projectile, there occurs a destruction of the projectile rather than that of the target.

Köhler divides the resistance which a body offers into active and passive. The active is that which is appreciated in a gross way, and the passive that which is considered in a molecular sense. Both, however, are molecular in their character, for to overcome the resistance is to overcome the molecular inertia or destroy its cohesive force. This has been shown in a classical way by Kocher, by firing into a tin box filled with marbles and observing the impressions that the exterior of the box presented as the result of the internal impact (*loc. cit*, Köhler, "Die Moderne Kriegswaffen," p. 152).

Specific gravity is another factor, modifying the momentum of the projectile as much as it modifies the resistance of the target. The heavier the projectile, the greater the momentum; the heavier the target, the greater the resistance, other things being equal.

Homogeneity modifies the effect, in that the more homogeneous the body is, the more perfectly is force transmitted. Here, again, experimenters have made the can serve a useful purpose. When filled with water and fired into, a perfect explosive action is obtained. The experiments of Reger, "Neue Beobachtungen über Gewehrschusswunden" (*Deutsche Militär Aerztliche Zeitschrift*, 1887, Heft 4, Taf. i–iv), have demonstrated the influence which distance plays upon the development of explosive action. Cans filled with fluid and fired upon at a short range showed perfect explosive action, whereas, when fired upon at a long range were simply attended with an opening of entrance and exit. Furthermore, he recognized the *rôle* which the deformation of the missile played in the production of the wound, and suggested in an address, "Die Aufforderungen der Humanität," *loc. cit.*, Lühe, "Vorlesungen über Kriegschirurgie," the substitution of hard for soft missiles; a suggestion which later met with adoption, but for purely technical reasons. Since the amount of moisture which a tissue possesses determines the explosive effect as much as the distance, and owing to the difficulty of determining the limit of the respective zones, the German War Office proposed, in lieu of the division into zones, a classification into "Nähschüsse," short range, and "Fernschüsse," or long range.

The explanation of the explosive effect that commonly attends wounds of viscera filled with or rich in fluid lack a noticeable degree of unanimity. According to Busch, it is due to hydraulic pressure, and is encountered in wounds of the skull and shafts of long bones. Von Beck, Vogel, and the German commission consider it to be due to a hydrodynamic rather than a hydraulic force. Sir William McCormac (*London Lancet,* August 3, 1895) believes "that the explosive effect is due to the rapid arrest of the flight of the bullet on piercing fluid matter and its motion being transferred to the parts immediately surrounding it, and these again transmitting it to parts further removed, somewhat as wave-circles are produced by a stone dropped into smooth water. He objects to the hydraulic idea, because the pressure is not equally exerted in all directions, but chiefly in the direction of the flight of the projectile, and it occurs in almost an equal degree in both closed or entirely open vessels filled with fluid or jelly." According to Köhler, page 174, it is due more to the projectile acting as a wedge which, moving with a high degree of velocity, produces an impression that is suddenly and perfectly transmitted in every direction throughout the entire mass. The same author points out that the velocity makes it impossible for the water to separate with the necessary rapidity, and being incompressible and homogeneous, it not only behaves as a solid body, but in the most sudden and perfect manner transmits force in all directions. In considering this, two factors must be borne in mind; the degree of increase in volume and the rapidity of this increase. Water has indeed an extraordinary influence on the projectile's flight, as Sir William McCormac has pointed out, that a projectile capable of travelling 4000 yards in air will be arrested after travelling three or four yards in water. Summing up, we may repeat the epigrammatic expression of Köhler,—diminished velocity and increased mass, increased velocity and diminished mass, destroy in a like manner the opposing object. Movement and mass, on the one hand, and time and space, on the other, are the elementary factors in the behavior of the projectile and target.

Coming more directly to the effect of the projectile on the human body, we again refer to the division of its flight into zones, this at least being a convenient way of analyzing the character of wounds it is capable of creating.

The first zone comprises the first 500 yards of the projectile's flight, and has been termed, by Habert, the explosive zone, and by Bruns, the zone of greatest energy. The second zone comprises a distance of from 500 to 1200 yards, and the third zone, a distance of from 1000 or 1200 to 2000 yards, *loc cit.*, Dr. Eschweiler, " Die Schussverletzungen durch das kleinkalibrüge Gewehr."

Wounds of bones that have been inflicted in the first zone are characterized by extensive crushing and splintering, while in the second zone we have a clearly perforated wound, such as might be made by a punch, and that has by many been referred to as typical of the new projectile. In the third zone, we have an extensive injury to the bone different from that created in the second zone, but resembling again somewhat that created in the first zone. These conclusions have received the indorsement of the French experimenters.

The prognosis, where the bone is splintered, depends largely upon the degree of comminution.. Where the fragments are large, with the periosteum intact, the fragments may yet receive sufficient nutrition to preserve their integrity, and determine a successful reunion. Where there is great comminution with a separation from the periosteum, they are not only lost, but play the harmful *rôle* of foreign bodies. The degree of splintering and comminution is not alone dependent upon the distance, but also upon the portion of the bone that is involved. A wound involving the shaft is attended with a fracture into larger fragments, and less real comminution than that which attends a wound of the extremities of the bone. These large fragments, with their intact periosteum, give to these wounds a more favorable nature.

Reviewing the experiments of Bruns, Sir William McCormac (*loc. cit., London Lancet,* August 3, 1895) notes that Bruns found intense explosive effects up to 400 yards. These attained their maximum in the skull, and upon semifluid organs, like liver, spleen, a full stomach, or intestine. In the elastic lung tissue, however, or upon empty viscera no effects of this kind followed. When the bone was implicated, the track as far as the bone was usually no larger than the ball, but the tissues beyond were always intensively damaged, and the exit wound was very large. At a distance of 400 to 800 yards explosive effects were only witnessed in the skull. Soft parts were traversed by a narrow channel no larger than the bullet itself, with but little damage to the surrounding tissue. At the range of 800 to 1200 yards explosive effects were only occasionally produced in the skull, and in a much diminished degree. The 900 experiments made by the German War Office do not harmonize with Bruns's classification of injuries into groups according to range. As the range increases there is a gradual diminution in the velocity and energy of the projectile, and a corresponding diminution was observed in the extent of the injury. The bullet, in nearly every case, was found to go straight through the part struck, and the old-fashioned contour shot was never met with. The human body is traversed with ease at 2000 yards, and the skull, thorax, and abdomen will suffer alike. At less than half this distance the old bullet has lost most of its momentum, and becomes flattened out or impacted when it strikes a bone without penetrating deeply. In wounds of the abdomen, the liver showed the largest amount of damage, and, in some cases of suicide, large portions of it were reduced to pulp. Up to 1200 yards the entrance wound was usually large and stellate, and the exit track funnel-shaped, with lateral rents extending from it.

Gunshot fractures of the long bones vary according to which bone or part of the bone is struck. The effect upon the spongy extremities and upon the compact tissue is very different. From 100 to 200 yards the shaft of the femur is broken up into small pieces, for an extent of from three to five inches, and the humerus from two to six inches. At the entrance wound in the bone the fragments remain in part attached to the soft parts, but at the wound of exit they are completely filled with bone *débris* and detached fragments of bone, the muscles and tendons are torn, and the exit wound in the soft parts is large and ragged.

In the spongy bones and spongy extremities of the long bones the crushing and fissuring at short range are also great, but the fissures are often concealed by untorn periosteum, and there is less damage to the soft parts at the wound of exit. At the range of 600 yards there are occasionally key-hole shots, with radiating fissures in the spongy tissue, and at 800 yards the key-hole channels become frequent, but even up to 1600 yards the compact tissue is extensively fractured. At 1200 yards the fragments of bone, as a rule, are no longer driven into the soft parts beyond; but this happens occasionally even up to 2000 yards.

According to McCormac, the conclusion to be drawn from the German experiments is "that the damage to the shaft of a long bone is very extensive for all ranges up to 2000 yards, the main difference being that at short ranges, of 200 to 300 yards, for example, the fragments are more numerous, smaller, and more stripped of periosteum, while the converse obtains at longer ranges. Cases where a large artery is wounded generally die before help arrives; and it is interesting to know that, in the late war in China, the Japanese surgeons had such perfect arrangements that in two cases, one a wound of the brachial and the other of the femoral artery, the vessels were tied and the patients saved in the fighting line itself."

## Conclusions.

(1) All advanced nations have *practically* the same character of rifle and projectile, and the remarks applying to one apply *practically* with equal force to all.

(2) That the modern small-bore projectile is capable of producing wounds of both a humane and gruesome nature.

(3) The nature of the wound produced by the small-bore projectile is either dependent upon the intervening distance or the character of the structure wounded, or both.

(4) The precise manner in which the explosive action is developed in structures filled with or rich in fluid is still *sub judice*.

(5) The weight of the evidence and the majority of authors favor the hydrodynamic rather than the hydraulic theory.

(6) The new projectile is propelled with greater energy, velocity, and accuracy; it is lighter, has a smaller frontage, and is less liable to deformation on striking an object.

(7) The new projectile has less "disabling capacity," and on the whole produces wounds of a more humane character than the old leaden bullets.

(8) By explosive action is meant the damage created in structures outside of the projectile's passage.

(9) The explosive action depends upon the deformation of the projectile, the range, and the character of the tissue.

(10) The shorter the range within the first 400 to 600 yards of the projectile's flight the more pronounced the explosive action.

(11) At 800 or 1000 yards explosive action is occasionally met with, and then only in the skull or in other parts of the body filled with or rich in moisture.

(12) At a distance of 800 to 1200 yards the new projectile, as a rule, creates wounds with small orifices of entrance and exit, and little or no explosive action.

(13) That the rotatory action of the projectile may continue after its penetrative movement ceases, and that the character of the wound is partially dependent upon this rotation.