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Let us . . . . .
". . . . delve into the depths of time and
Bring forth from out the ages that have rolled
A few small fragments of those wrecks sublime
Which human eye may never more behold."
Making of a Surgeon, by GATEWOOD.

Introduction

A narrative on amputations is of necessity a reiteration of surgical progress. As medical knowledge pierced the darkness of ignorance epochs were created in the progress of surgery. With this advancement the removal of an extremity because of injury, disease or deformity became a scientific procedure. After the removal of a limb, the need for a substitute became self-evident. In response to this necessity the prosthetist became closely associated with the surgeon.

Prosthesis is a Greek term meaning an addition. By definition it signifies the supplying of a lost leg, eye, tooth or other part by an artificial one. In this discussion the word is used in reference to synthetic arms or legs. The word amputation is derived from the Latin preposition *ambi* meaning around and the verb *putare* to prune. By common usage it has been accepted to signify "the cutting off of a limb or part of a limb, the breast, or other projecting part" (18). The application of the word in general surgery refers more specifically to the removal of an arm or leg, in whole or in part. Many modifying words have been used with amputation in order to describe the type of procedure. The most commonly employed terms are: transfusing, central, coat-sleeve, diclastic, oval, osteoplastic, circular, kinematic, elliptical and guillotine amputations.

The Ancient Period

Among the first duties of the ancient surgeon was the repair of broken arms and legs. His primary concern was to set bones and to bind fractures. War tremendously assisted in developing this branch of surgery. The military surgeon became essentially a bone surgeon. Whenever the arm or leg of a warrior could not be saved, it was removed. The criterion for amputation was founded upon Hippocratic precepts:

"When gangrene supervenes in a fracture, the soft parts separate quickly; as for the bones, they become detached at the limit of their exposure; but much more slowly. It is necessary to remove whatever dies first below the lesion from the healthy parts avoiding pain as far as possible, for patients die from fat embolism" (7). Thus the ancients performed amputations to remove useless members, to reduce invalidism and to save life.

The loss of limbs resulted from causes other than war: disease, accidents, cruel punishments for crime accounted for many amputations. During the Middle Ages, the loss of arms and legs was very great. This was due in part to the devastating effects of leprosy and ergotism. With the utilization of cannonshot (first used at the Battle of Crécy in 1346) and half-pound gunshot (used at Perugia in 1364) the resulting wounds were so mutilating that amputation was a necessity (4).

To replace the missing extremity the stumps were bound up in long splints. Crutches and wooden legs were used for support. It is difficult to establish an exact date as to when and where prostheses were first employed. Early references can be found in ancient literature and many pictures representing appliances are seen on antique artistic works.

Prostheses for missing extremities are mentioned in writing for the first time by the Greek historian Herodotus. "A picture on an Italian urn showed a prosthesis which consisted of a simple wooden capsule. The same type of prosthesis is depicted on an old Peruvian vessel. An artificial leg of remarkable workmanship was found

in a grave dating back to 300 B.C. It was essentially a prosthesis with side bars made of thin bronze which were fastened with bronze nails to a wooden base" (15).

"In the cathedral of Lescar (Lower Pyrenees) which according to some authorities (Longperier) belongs to the Gallo-Roman epoch, according to others (Raymond) to the twelfth century, is portrayed a negro whose left leg, lacking the foot, takes its support at the knee from the socket of a wooden pylon exactly like those in use at the present day. Rivière also describes the counter drawing of a fragment of a vase found in Paris (1862) in which is shown, among other figures, a man seated in a chair with a high back, whose right leg, amputated about the seat of election, is attached to a pylon (a temporary artificial leg) with a forked end" (16, 17).

These pictures depict rough apparatuses which the poorer classes of maimed are in the habit of making for themselves. Similar situations are portrayed more clearly in the engravings and pictures of Matsys, Bosch and Breughel than in prehistoric vases and mosaics. The frescoes in the cemetery at Pisa by Orcagna and those of Penni in the Vatican display these deformities and appliances most clearly (4, 16, 17).

One of the oldest known artificial limbs can be seen in the Royal College of Surgeons in London. "It was unearthed in an ancient tomb in what was the battle-torn city of Capua in southern Italy. It dates back to the Samnite Wars (300 B.C.) when the highway was being built and the foundation laid for the mighty Roman Empire." (6)

Literary References to Prostheses

Studies of the nonmedical literature of the past reveal interesting notations on artificial limbs. Probably one of the earliest references can be found in the comedies of Aristophanes (circa 500 B.C.). This author writes of a leg support worn by an actor in one of his plays.

Herodotus (484 B.C.) tells of a native seer named Erasistratus, who was imprisoned by the Spartans and condemned to die. While in prison he cut off his foot

which chained him to the death cell. He fled thirty miles to the city of Tigea where he provided himself with a wooden leg after the wound had healed.

In the ancient religious Talmud several references are made to pylons and artificial limbs (16). The Roman writer Pliny the Younger mentions General Marcus Sergius. This Roman general lost his right hand during the second Punic War (218-201 B.C.). Subsequently he had an iron hand constructed which he used with great dexterity in battle. This Marcus Sergius was the great-grandfather of the nefarious Cataline who was scorned in public by Cicero, the distinguished orator and statesman.

The *Acta Sanctorum* and other medieval chronicles mention wooden legs and artificial supports for those who have lost an extremity. The earliest iron hand is seen in a picture of 1400 (4). The relationship between this statement by Garrison and the Alt-Ruppin hand can not be correlated. However, this artificial hand is the most ancient known: it is dated about 1400. The hand with fragments of armor were reclaimed from the Rhine mud. Gurtl published several drawings of this apparatus. It is placed in this period because an analogy exists between the forearm of the Alt-Ruppin apparatus and that of Von Berlichingen.

An illustrious German knight named Gottfried von Berlichingen achieved fame as the champion of the peasants against the nobles. In 1509 when he was twenty-three he lost his hand during the siege of Landshut in Bavaria. His exploits were the subject of one of Goethe's dramas. Herein we read that the monk Martin asked Gottfried's name and the warrior offered the monk his left hand. Martin was offended. "Why do you offer me the left hand? Am I not worthy of knightly courtesy?"

To this Gottfried replied, "Were you the emperor himself, you must be content with this. My right, though not useless in war, is insensible to the pressure of love. It is a part of my glove; you see, it is iron."

Martin courtesied and kissed the iron hand which revealed to him the name and heroism of the altruistic

captain. Later in this work Gottfried spoke thus of his iron hand: "It has rendered more service in the fight than ever did the original flesh." This warrior had several hands made which were movable in the joints, had flexible fingers capable of closure.

Several copies of the hand of von Berlichingen were made. There is one in the Museum at Vienna reported to have been constructed for Emperor Joseph II. Another can be seen at the armory of Bredow of Wagnitz (Mannheim). A third hand is in the famous Meyrik collection in Wales.

Guido Guidi (died in 1569), the Florentine surgeon, practised successfully at the court of Francis I of France. Guidi writes in his book (Book IV, Chapter 7) of a patient whose forearm was removed and replaced by an iron one. This extremity served not only as an ornament but was quite useful (16, 17).

More descriptive information on two cases is supplied by John Minadoi, a surgeon of Rovigo at the end of 1500. "As medical attendant of the Venetian consuls, he traveled widely in the Orient. He wrote a history of the war between the Prussians and Turks (1576-88). He was physician to William Gonzaga, Duke of Mantua and professor at the University of Padua. At Padua he observed two amputation cases. In one instance, after the loss of both hands, the patient by means of an iron apparatus could take off his hat, open and shut a purse as well as sign his name. The other lost his right hand and could do many acts with an improvised hand" (16, 17). Other scattered references can be found relating to the sixteenth and seventeenth centuries.

Paul Giovio relates that the Turkish corsair, Horuk, surnamed Barbarossa, lost his right hand in the battle of Bugia against the Spaniards (1517). An iron hand was made up to the elbow which he used with great ease in successful battles (16, 17).

Mention is made of an artificial hand in the French wars. There was a Huguenot general who lost his hand in the battle of Fontenoy (1570). His loss was replaced by one of metal resulting in his name "Iron

Hand." Duke Christian of Brunswick, who had lost his left hand at the battle of Fleury (1622), had an iron arm made by a Dutch workman.

In George Eliot's *Middlemarch,* an account is given of "Mr. Chessher and his irons." This refers to the surgeon Robert Chessher (1750-1831) who achieved a great reputation for his appliances for supporting fractured legs and spines. It is presupposed that he experimented with artificial limbs.

Moby Dick is a famous American novel by Herman Melville which relates the experience of whalers. The story tells of many sailors who lost their extremities pursuing this hazardous occupation. The plot of this story concerns Captain Ahab. He was a one-legged man wearing an ivory stump to replace the missing leg. This leg was bitten off by the whale called Moby Dick. The entire plot concerns the captain's vengeance which culminates in the death of the whale.

These are some of the scattered references to artificial limbs found in the tales of long ago. Most of these apparatuses were fashioned for utility, however crude they might have been.

Fifteenth to Seventeenth Centuries

The most important occupation of the majority of people during these centuries was warfare. Much rudimentary progress in amputation and prosthesis owed its impetus to the exigencies of war.

In European museums are seen several appliances which are characteristic of these centuries. Dr. Putti, professor of orthopedics at Bologna, studied these mechanical extremities. His research took him to the Stibbert Museum in Florence and the Poldi-Pezzoli Museum in Milan.

At the former institution he described an iron prosthesis of 1330 grams. This consisted of upper arm, forearm and hand. The opening of the armpiece was furnished with a ring which allowed small movements of rotation in the apparatus. This ring had a hollow corresponding to the axilla. The fold of the elbow had an anterior protection similar to that found in armor. This arm permitted 180 degrees extension and 75

degrees flexion. Movements were controlled by a metal button projecting on the anterior surface of the forearm. Range of motion for the fingers was greatly limited. A series of holes about the edge of the armpiece were noted. Nothing was presented to show how it was suspended from the stump or shoulder (16, 17).

Another apparatus of the fifteenth century at the Stibbert Museum is made of sheet metal for the left hand. It weighs 530 grams, was designed for working and shows no attempt at beauty of design. The construction is coarse. When the fingers are closed into a fist, pressure on a button results in full extension of the fingers due to a spiral spring mechanism. The hand was attached to the forearm by four metal plates (16, 17).

A sixteenth century apparatus is exhibited at the Poldi-Pezzoli Museum. This iron prosthesis is for a right arm stump. It was attached by a strap and buckle. The upper part of the arm was embellished similar to armor of that day. Flexion of 80 degrees and extension of 160 degrees were produced by means of springs. A remarkable feature of the apparatus was that it permitted an anatomical position of the forearm.

Undoubtedly the designer was guided by the esthetic standard of armor construction. Putti concluded that the hand in supination with flexed fingers could be used only for passively holding the reins in riding. At the Imperial Museum at Berlin similar appliances can be seen. All are indicative of the same period (16, 17).

Two other hands are described in the Stibbert collection. One is so roughly formed that the only suggestion of anatomical form is a crude marking of the ulnar styloid process. Yet this hand shows signs of much usage. The second contains numerous holes arranged in artistic figures which lightened the apparatus. This hand was moved by a coiled spring (16, 17).

At the same museum a sixteenth century left lower-limb is on view. The extremity was designed primarily as an ornament. It served the purpose of concealing the mutilation of a knight on horseback. The

knee was fixed and could not be completely extended. The shortness of the thigh part would not have maintained an erect position, nor would it allow walking (16, 17).

An engineer of Bologna inherited a family legacy. Among the articles was an artificial lower leg constructed about 1616. The apparatus is called the Zucchini limb, for this is the name of the inheritor. The limb was made for the Marquis Francis Riario (1615-74), who was related by marriage to the illustrious Catherine Sforza.

Dr. Putti examined this limb but was doubtful as to the exact type of mutilation or deformity it was intended to conceal. He opened the tomb of the marquis but found not even a bone. Therefore, he drew conclusions from an examination of the limb itself. He believed it was for the right leg and theorized that it was made for a deformity, not an amputation. He decided that the most likely explanation was that it was made to compensate for a shortening. It was thought to hide the deformity of a congenital malformation, most probably an absent tibia. Genealogical investigation corroborated this contention. "The Marquis Alexander was unfortunate in his wife, who bore him three sons, the first deformed in the hands and feet, although he was able to walk and write. The other two were deformed completely" (13).

These antiques are historically interesting as indicative of a past age. Surgically they indicate a landmark in medical history. Although many of the appliances were never used, yet the artisan who constructed them had a definite objective—either functional or esthetic. Some of the hands described may well be termed working appliances which enabled the wearer to exert pressure and grasp objects; others are ornaments to hide what the wearer does not desire others to see. The soldier-knights were vain. They desired to conceal any mutilation. The scars of battle were not badges of courage but rather an indication of inferiority to the enemy. For this reason, the designer of armor would conceal the soldier's loss by

copying the armor of the lost limb or by making a metal skeleton.

The fabricators of artificial limbs in the fifteenth and sixteenth centuries were makers of cuirasses, arquebuses and swords. Their products reflect the influence of an art of the period which had reached great perfection in Italy and Germany. "How can one help recognizing the style, decorations and mechanism of armor in the apparatus depicted in the works of von Gerensdorff, Riff and Fabricivs of Acquapendente (1537-1619)" (16, 17).

From the fifteenth to the seventeenth centuries the purpose of the limb-maker was to restore to casualties of war the limb lost on the battlefield. The warrior desired primarily a workable hand for holding his lance or sword. When this was not possible he was anxious to hide his loss. Deformities of the leg were in this category especially when the knight was mounted on a horse. Prostheses, secondarily, were constructed in an effort to help the manual laborer and to improve the appearance of the non-warring maimed. In many of these crude appliances can be seen the architectural principle upon which our modern prosthetic art is founded.

Ambroise Paré (1510-90)

An artificial limb is a natural supplement to a surgical amputation. The surgical procedure should not kill the patient because of hemorrhage, but should produce a useful stump. This could be obtained only after some method of checking loss of blood from the vessels was discovered. Before this discovery, amputations could result only in the destruction of segments of a limb by crushing. The resulting stump was not suited to any type of prosthesis.

Herein lies the fame of Paré. When Francis I fought Charles V, Paré accompanied Marshall Monte-Jean as his army surgeon. During the campaign he had occasion to use his surgical skill in preventing hemorrhage. When he did not have any boiling oil he ligated the arteries and found that this treatment resulted in more rapid healing. With this discovery he announced

that he had found a new method. At that time he was nineteen years of age. "Paré thus made amputation what it is today by reintroducing the ligature, which had almost fallen into abeyance since the time of Celsus" (4). He is credited with performing the first exarticulation of the elbow-joint (1536). He introduced massage, artificial eyes (of gold and silver) and perfected artificial limbs.

An artificial hand depicted and described by Paré was constructed in Paris (1550). It is called "le petit Lorrain." The dorsum of this hand has the form of a steel gauntlet. "The thumb is rigid and the fingers are kept extended by four springs fixed in the palm. Paré also portrays another upper limb in which the mechanism controlling flexion and extension of the elbow is clearly shown and easy to understand" (16, 17). An artificial leg, illustrated in this same volume on surgery, was made of sheet metal plate. This resembled an armor which was hiding a peg leg for high amputation. It had a joint at the knee so that the warrior could sit on a horse (19).

For the first time in the history of amputation a scientific approach is noted. In 1564 Paré made the first known attempt in choosing sites of election for amputations. Many of his drawings and descriptions are not unlike some of those in common usage today. For this reason he is rightfully called the founder of cinematic amputation.

The Nineteenth, The Greatest Century

The crowning achievement of this century was the birth of antiseptic surgery. Before the days of aseptic surgery healing following amputation was by granulation with excessive scar formation in the stump. Infection was a great barrier to proper healing. After the advent of clean surgery infection diminished remarkably. From this period modern surgery finds its greatest inspiration. Prior to considering this era mention should be made of other notable contributions to surgical science during the nineteenth century.

Napoleon's surgeon-in-chief was Dominique Larrey (1766-1842). He was one of the first to amputate at

the hip-joint with success (1803). As chief surgeon to the Grande Armée he became a master at amputation. It is said that at the battle of Borodino he performed as many as two hundred amputations in one day (4).

The outstanding English military surgeon of the time was George Guthrie (1785-1856) of London. He served in America and in the Napoleonic wars. At Waterloo Guthrie successfully amputated the hip-joint (1815). His most important work is his *Treatise on Gunshot Wounds of the Extremities requiring Amputation* (1815) (4).

Many isolated operations and surgical procedures were described. Of these mention is made of the interscapular-thoracic amputation (excision of arm, scapula and clavicle) which was performed by Ralph Cuming of the Royal Navy (1808). In England excision of the femoral head was described for the first time by Anthony White (1822). Jacques Lisfranc of France devised many new operations for the partial amputation of the foot (1815) and described methods of disarticulating the shoulder joint (4).

The war of 1812 revived the interest in artificial limbs. During this period a famous appliance came into prominence. This is called the Anglesea leg. It belonged to the Marquis of Anglesea who having lost his leg had a false one constructed by James Potts of London. This appliance is considered to be the forerunner of the type which is termed the American leg. Among these socalled American legs are a ball-and-socket joint apparatus by Dr. Bey and the Mark's leg (19).

The renowned William Beaumont describes a scene following a battle near Plattsburg (War of 1812) in which innumerable amputations were performed. "A most distressing scene ensues in the hospital—nothing but the groans of the wounded and agonies of the dying are to be heard. The surgeons wading in blood, cutting off arms, legs and trepanning heads to rescue their fellow creatures from untimely deaths. To hear the poor creatures crying, 'Oh, my God! Do, Doctor, Doctor! Do cut off my leg, my arm, my head to relieve me from misery! I can't live, I can't live!' would have rent the heart of steel, and shocked the insensibility of

the most hardened assassin and the cruelest savage. It awoke my liveliest sympathy, and I cut and slashed for forty-eight hours without food or sleep. Who can think of the shocking scene when his fellow creatures lie mashed and mangled in every part with a leg, an arm, a head or a body ground in pieces" (1, 12). No mention is made of postoperative care or the use of prosthesis. The crudeness of amputation is clearly depicted during this period. As Beaumont states it was a "slashing" procedure.

Little real improvement occurred up until the United States Civil War. At that time several American limbmakers obtained patents to protect their products. During this period the wars in the Crimea and in Italy produced many limbless soldiers. A well-known leg has been mentioned by Steindler called the Beaufort limb. This was described in Paris and is remarkable because it had an automatic knee lock (1867).

The unsanitary conditions in military hospitals resulting from the Crimean War (1854-56) were conducive to terrible infections. Uncleanliness in the war zone produced infections causing the loss of many arms and legs. This war gave birth to the modern idea of nursing.

Florence Nightingale, a woman of talent and vision, set out for the battlefield with a staff of trained nurses to care for the sick and wounded. So it was that the principles of hygiene were applied to hospital administration. Where formerly there was chaos and sorrow, she brought orderliness and happiness. Although her work in the Crimea was accomplished several decades before Lister's revolution in surgery, nevertheless, her principles were based on the Listerian concept of scientific cleanliness.

In the *Lancet* (1867), Joseph Lister (1827-1912), later Lord Lister, published his observations which profoundly altered the history of amputation. With Lister's asepsis modern amputation commenced to ascend scientifically with a resultant benefit to the patient. His work was the beginning of antiseptic technique. Prior to Lister's time, because of infection, hospitals were considered to be houses of death. Into the dark infected

operating room Lister brought the light which dispelled the blackness and eradicated the stigmata of disrepute which had branded the septic surgeon. With the advent of aseptic surgery less infection and sloughing of the soft parts of amputated stumps followed.

The Listerian principles were adopted by the American military surgeon. In 1877, Captain Gerard, U.S.A., returned from England thoroughly convinced of the value of Lister's antiseptic method. His report to the surgeon general contained a full description of this method. Thereafter Weir's antiseptic spray apparatus was issued as standard equipment to the United States Army medical department.

Colonel William Arthur, U.S.A., who was on active duty during 1870 and 1880 recounted the following reminiscence: "At this post, Fort Washakie, a cavalry soldier was accidentally shot in the right thigh. The bullet passed across the limb in front of the femur, but tore through the femoral artery. It was necessary to tie the external iliac just below Poupart's ligament. This operation was done in the ward on a mess table borrowed from the troop barracks, for our three attendants ate in the kitchen and we had no operating table. Collateral circulation was not established and soon it was evident that gangrene of the foot and leg was inevitable. While waiting for a line of 'demarcation' to form between dead and viable tissues, I was called to the hospital one night to find that secondary hemorrhage had set in. The only chance it seemed to me of saving the man's life was amputation at the hip-joint."

"At night, by the light of a few candles, the operation was done. The anesthetic was given by the hospital cook, a private of cavalry. The hospital steward, recently appointed, fainted at the first stab of the knife, was shoved under a bed and left to come to in his own good time. A patient in the ward, a cavalry private, crawled out of bed, told me he had worked in a drug store before enlisting and offered to help, he did very well, and the disarticulation was soon completed. The patient died before daybreak."

"During my two years at Fort Washakie, I did quite a little surgery, especially amputations for frost-bites,

and to my surprise the operative wound healed uniformerly by first intention. I believe this was due to the fact that no pathogenic organisms had been introduced and that though I was surgically dirty, I couldn't infect my cases. I do not remember ever having seen any pus all the time I was at that station" (1). The Spanish-American War contributed nothing to the advancement of prosthesis or amputation.

Toward the end of the nineteenth century a new term was used—cineplastic. "A cineplastic amputation is one in which a stump is created, and in addition the muscle power of a certain individual muscle, or muscles, in the stump is made use of independent of the general movements of the stump itself" (11). This individual muscle power is used to inactivate especially constructed prostheses for the upper extremity.

The idea of cineplasty was conceived by the surgeon Vanghetti following his experiences in the Italian-Abyssinian War (1897-8). During this conflict the Abyssinians cut off the left hand at the wrist of Italians suspected of treason. Vanghetti observed that the muscles of the forearm remained intact and functioned. He then studied the possibility of employing these muscles as the motivating force for a prosthesis. After much experimental surgery on animals, especially chickens, he attempted to apply his results to human beings. The first human operation was performed by Ceci of Pisa, surgeon and friend of Vanghetti (1900). Other continental European surgeons carried on this work. Among these were Sauerbrück in Germany and De Francesco and Galleozzi in Italy.

Twentieth Century

The new century was to place the problem of amputation and prosthesis in a new perspective. Functional value of stumps was to be considered with much concern. Prior to this century the sites of election were poorly chosen. In many instances nature did the choosing by forming a line of demarcation. Methods were found which demonstrated that better stumps resulted when less soft parts are left in the stump. Better pro-

cedures for treating the bone end and its periosteum were devised.

The prosthetic artisan excelled the surgeon in finished technique by his service to the amputee. The surgeon was satisfied with the healing of the stump and discharging the patient. When this was done the surgeon complimented himself on his success. The patient waited until the stump diminished in size and then went to an artificial leg-fitter. Little or no personal contact occurred between the surgeon who removed an injured extremity and the prosthetist who applied an artificial limb. Today the prosthetist dictates to the surgeon. He recommends for consideration the amputation sites. Very often they are superior to the recommendations in surgical text-books.

The war years of 1914-18 showed that the European nations were behind America in the development of appropriate false limbs (6). Wounds of bones and joints were very numerous and severe. The number of amputations in the A.E.F. were 4,403 (1); the British forces suffered 42,000; the total amputations in all the armies of Europe approximated 100,000 (6). The majority of these men were restored to functional usefulness. This was one of the greatest surgical contributions of the war. Amputations were necessary primarily because of infections, particularly gas gangrene.

Entering the war late, the United States profited by the orthopedic experience of France and England. In this way the fitting of prostheses came under expert guidance. Soldiers who had had amputations were grouped in designated military hospitals. Here specialists gave excellent surgical care and postoperative treatment of the stump. Prosthetic fitting and instructions for its use were carried out under the supervision of the surgeon. For the first time a consulting relationship occurred between the surgeon and the prosthetist. These efforts hastened the return of the patient to society where he could resume activity in the world at peace.

Cineplastic amputation was not generally accepted before the World War. Since those years it has been revived. Major Baer and Captain Wilson of the United

States Army intensively studied this subject in Italy (1917-18) for the surgeon general. Cineplastic surgery brought about great advances and improvements in artificial arms from a technical aspect. Many of these contrivances have become very complicated.

The most commonly used artificial mechanical arm is the Carne's arm. Steindler agrees with the belief that the usefulness of a simple nonmovable appliance is much better than complex ones. "Plain hooks, split hooks, claw hooks, spade and shovel grips and tool holders of various designs are much more useful for manual labor than any mechanical hand" (19). By employing these types of appliances a functional upper extremity results which is of assistance in performing gainful manual labor.

The Present Era

Modern industry, the automobile, and the airplane in America cause more annual amputations than our soldiers suffered in the war. An estimation of the number of persons in the United States wearing artificial extremities approaches three-fourths million (6). To this number is added several thousands each year. With so many people concerned, the necessity for serious consideration of this topic is obvious. Studies of this matter have demonstrated a decided difference between antiquated and modern conceptions of prosthesis.

In previous years, prosthesis merely implied the supplying of an artificial leg or arm. Today it demands the applying of a limb in order to return the patient to a useful social and economic life. The amputee is no longer discharged when his wound has healed. The doctor and limb-maker are concerned with assisting each other in securing functional efficiency from an artificial limb for the greatest benefit to the patient. Thus an individual, who, in past years, was considered a social liability, can now find his proper place in the maze of life.

To the patient who has had a limb amputated, the surgeon has an added responsibility. Life itself may be the price for indifference. The adequacy of the prosthesis can alter the mental outlook as well as the phys-

ical well-being of the patient. Either the patient will consider himself a useless cripple or feel he can be adjusted to fit into the pattern of society. The prosthetist concerns himself not only with the making and fitting of the artificial appliance, but suggests the amputation site. He is interested in all phases of the task with the objective of making the stump as nearly perfect as possible. For it is known that without a proper stump, no appliance can function properly.

Through the passing decades surgeons have studied this question. Their desire was to find the most suitable amputation site for the most efficient prosthesis. In France, Chopart (1710-1881) and Lisfranc (1790-1847) investigated this aspect with much enthusiasm. Other contributions to this topic were made by the Russian Pirogoff (1810-1881) and the Italian Gritti (1828-1920). The latter's findings were substantiated by the American Stokes (1804-1878). Carden (died in 1872) and Syme (1799-1890) of England published valuable data based on their amputation results. All were eager to find the ideal site which would enable them to formulate some general principles of amputation.

General Principles

Studies, experiments, success and failure have evolved in some measure certain fundamental principles. In amputation of the lower extremity the surgical theory had been to save all possible length. "This has been disproved since many resulting stumps are difficult to fit, uncomfortable, unwieldly to use, and unsightly in appearance. Too often such stumps necessitate reamputation before a prosthesis can be successfully worn, or else the patient is compelled to go through life without the benefits of modern prosthesis (6). "The site of preference for amputating the lower extremity is through the middle third. Gritti's amputation is a very useful arthroplastic method" (19). Haddan believes that extra long stumps, disarticulations of knee and ankle, and the majority, if not all, of partial foot amputations should be avoided. Most sur-

geons agree that amputation of the lower third of the leg is never recommended.

Important factors have been learned on the mobility and weight-bearing ability of the stump. The former concerns its excursion as well as its active strength. The latter depends essentially upon a large surface, hardening of the skin, bursæ at the point of contact and the integrity of nerve and blood supply (19). At one time it was considered correct to shorten nerve ends and to inject them with alcohol. The injection practice may lead to an alcoholic neuritis and hence is not advocated.

Through judicious management of the patient and the satisfactory application of prosthetic legs, a good substitute for the real one can be made for ordinary walking. The reason is that the required movements are few, not too complicated, and can be copied quite efficiently by a modern artificial leg.

When considering the upper extremity no functional substitute can be found for the natural arm. Here, too, the amputation site is the major factor for adequate functional and cosmetic proficiency. Partial amputations of the hand are not favored because of unsightliness plus the inadequate fitting of an artificial appliance. When a thumb and index finger are lost, the hand is practically functionless. If such a hand is fitted with a prosthesis it can possess only esthetic value since it is functionally impotent. Wrist disarticulations are unsatisfactory because of insufficient soft tissue, poor circulation and difficulty associated with fitting an artificial hand.

A general statement on amputation of the forearm is that the junction of the lower and middle third is the ideal location. An amputation just above the condyles of the humerus offers the best site for upper arm amputation. Prostheses can be fitted to shoulder disarticulations but their value is largely cosmetic (6, 19). Briefly it may be said that the use of a prosthesis for the upper extremity has not been as satisfactory as lower limbs. Successful wearing of a prosthesis depends upon the character of the stump, the attitude of the individual and the nature of the prosthesis.

One of the most popular cosmetic appliances is a

mechanical arm without any hand function. The hand may be rubber which can be placed in various positions by the normal hand. The most common type of mechanical arm is one in which the hand mechanism is activated by a cord attached to the opposite shoulder. Where an individual has to do heavy work, the arm may be of heavier construction. Some of these appliances are fitted with removable hooks such as the Bowler or Dorrance hook (9). "In the cineplastic amputation the remaining muscles in the stump are utilized to activate the prosthesis. By means of pegs passed through canals in the muscles and attached to levers operating the artificial hand mechanism, the physiological action of the stump muscles is restored" (9).

Care of Stumps

Orthopedists agree that the success of an amputation and prosthesis depends upon the postoperative care and the proper preparation of the stump for prosthesis. Experience has brought to light several facts in reference to treatment. The care of amputation stumps has for its purpose the improvement of local blood circulation and the prevention of faulty positions and ankylosis of neighboring joints.

To prevent malposition and ankyloses, movements of the stump should be started a few days after amputation. Faulty positions are abolished by active exercises of the stump, and by passive stretching. Early gymnastics of the stump prevent contracture as well as atrophy of the muscles which are necessary for the appropriate use of a prosthesis. When muscles weaken and become flabby, bones become atrophic. Flexion and ankylosis are then more likely to occur. When edema occurs massage, elastic compression and bandaging are found useful.

All artificial limb-makers agree in their warning against wearing any temporary prosthesis for a long time since it affects the gait, and furthermore, does not teach the patient to walk properly. The use of wooden legs tends to fix contractures which may be present in the hip or knee joint while prostheses will tend to mobilize them. The orthopedists have concluded that im-

provised prostheses are generally justified only in time of war, when adequate appliances can not be obtained in sufficient quantities in the time demanded. In peacetime makeshift prostheses should not be used as they are not much better than crutches. Moreover, the patient should learn from the beginning to walk as normally as possible with his prosthesis (8).

Prosthetic Construction Material

Plaster of paris bandages were introduced by Anthony Mathijsen (1805-78), of Holland, in 1852 (4). This material was one of the first employed in constructing peg legs. It was soon learned that most amputation stumps with ample soft tissue were capable of bearing weight in buckets formed of plaster of paris. The only prerequisite was accurate molding of the plaster to the surface of the stump to avoid friction.

Addison introduced wood in the construction of artificial limbs. Any type of wood is suitable, preference is given to those which are light and durable. Thus hickory, walnut, linden and willow are desirable. Cork was used but discarded because of brittleness. Wooden receptacles for the stump are heavy, therefore leather has been preferred. The outstanding proponent for wood in prosthesis is Hermann of Prague (19).

Hard rubber was first employed by Joseph Leiter of Vienna. This is characterized by greater resistance, durability, and facility of molding a form to fit the limb.

Leather is used for permanent limbs. Closed cuffs, which can be regulated by lacing, fit the shape of the stump as it changes. This is especially true of the thigh cuff which is used for artificial limbs (19).

In addition to leather and wood, sheet metal, fiber and cellon have been utilized. Cellon in the form of a fiber leg was employed during the first World War. Lacking durability it was abandoned. "Paper, combinations of celluloid, shellac, water, glass, glue, etc., have been used. For the metal legs are recommended the new silver, aluminum and bronze. Over the stump are placed stockings or stockettes of firm material. In order to alleviate pressure, other auxiliary means are used, such as cushions of rubber and sponges. Many have

called attention to the fact that it is expedient to set the stump in a ring in the bucket, so that the stump may be free without any pressure" (19). In the construction of sockets for artificial arms, block leather, metal or certalamid are preferred. With these basic materials an external form is created by the artisan in an attempt to approximate in appearance the missing limb.

Conclusion

The day has passed when the surgeon's duty terminates at the bedside of the amputated patient. The application of an artificial limb is the concern of the surgeon, although the making of a limb is the specific task of a limb-fitter. Their close relationship results from a common interest in perfecting the efficiency of an amputation stump. Every amputation should be done with the thought in mind of constructing a stump that is most suitable for a prosthesis. Where possible there should be adequate cooperation between the surgeon and the artisan: one aiming at providing an ideal stump, the other at employing his ingenuity to fit an appliance as functionally perfect as possible. Thus there has been created a new meticulous art devoting itself to returning to the cripple that body which is his rightful heritage.

The amputation and prosthetic problems remain among our most creative surgical topics, pre-eminent from a combined medical, social and economic viewpoint. In no other instance can the socioeconomic trend in modern medicine be visualized with more clarity than in cases of amputation. Today the vision of medicine is panoramic. The age is gone when the man of medicine concerns himself solely with the treatment and cure of his patient. The modern doctor is not only a healer, but a psychologist, a sociologist and an economic adviser on many occasions. A person with a missing extremity is a typical example. The leg has been removed to save the patient's life, and with great diplomacy the surgeon must inform the patient of his loss. Then he must assist the prosthetist in arranging for an artificial limb. The doctor's encouragement and

understanding guides the patient as he is assisted in rehabilitating himself into the society he must face with courage and confidence.

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