

Autumn 1957

Artificial Limbs

*A Review of
Current Developments*

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Artificial Limbs

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Throughout the 200-odd years since its inception, the surgical procedure known as disarticulation of the hip has been fraught with danger and disappointment both medically and prosthetically. On few persons has the operation been performed, and fewer still have survived for any gratifying period. Because hip disarticulation is so severe a measure, and because in recent years it has for the most part been carried out only in the attempt to forestall fatal disease, the level of medical success thus far attained has been disturbing. Because the hip-disarticulation amputee presents such a difficult problem in anatomical deficiency, his successful rehabilitation prosthetically has proved particularly evasive.

Although even in modern times postoperative mortality from residual systemic disease has remained alarmingly high, recent advances in surgical techniques and in medicine as a whole have done much to encourage hip disarticulation where it might not otherwise have been attempted. This circumstance, together with a growing tendency toward the use of radical amputation surgery as a curative measure in cases of malignancy, has been responsible for an increasing incidence of hip-disarticulation amputees. Meanwhile, the problem of providing a reasonably satisfactory substitute for a lower extremity amputated at hip level has over a long period of years continued to be most difficult for the limbmaker and most exasperating for the patient.

To satisfy functional requirements in amputations at or about the hip, the prosthetist has not only to furnish a limb with three simulated anatomical joints, all of which have to be stabilized in the stance phase of walking, but he must do so with only the torso and associated structures as a source of activation and control. In the absence of an adequate thigh stump, reliable management of an articulated lower-extremity prosthesis calls for the use of various locks, or equivalent, and for the coordinated action of pelvis, trunk, and remaining sound leg. The saving grace in this situation is that weight-bearing can still be provided on one of Nature's chosen seats of election, the ischium.

The hip-disarticulation prosthesis to which this issue of ARTIFICIAL LIMBS is devoted is the culmination of many years of practical work, later combined

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with present-day methods of organized research and the application of new materials. Canada has had much experience in the provision of orthopedic and prosthetic appliances in the aftercare of her veterans. Early in 1916, the government of the day was confronted with the matter of supply for members and ex-members of the Canadian Expeditionary Force. After thorough investigation, it was found that existing facilities were extremely limited and unable to cope with the problem. Further, although standardization of appliances was deemed essential to provide ready maintenance or renewal accessible to the veteran's place of residence over the breadth of the country, no such standardization existed throughout the Dominion. Government proprietorship was considered the best means for keeping in touch with latest developments in prosthetics from other countries and also seemed to offer the most expeditious way of initiating a domestic program of experimental work that would be productive of results in keeping with the policy of standardization.

The agency thus established, which today is known as the Prosthetic Services Branch of the Department of Veterans Affairs, now consists of some twelve operating centres and six visiting facilities situated in or adjacent to Departmental hospitals in the principal Canadian cities from coast to coast. The largest centre, located at Sunnybrook Hospital in Toronto, serves as the central manufacturing facility for the production of standard parts and stores for supply to all other centres. Here also is located a research section technically staffed for the investigation of new designs, materials, and techniques. Situated close to the medical and production facilities, and with patient personnel from the largest veteran area, this unit provides ample opportunity for field-testing and final approval for manufacture in other District facilities across the country. It was here that Colin McLaurin and James Foort were inducted into the field of prosthetics research and here also that, early in 1954, McLaurin brought into production the hip-disarticulation leg now generally known as the "Canadian type."

To produce an improved prosthesis for the hip-disarticulation case was already one of the problems confronting the design section organized in 1916. At that time, the choice of willow setups, wood or leather sockets, and heavy joints did not provide for a light limb or for good control. Later, in 1926, the Department adopted the J. E. Hanger English metal limb, which included a design known as the "tilting-table leg." This limb, although of lightweight construction and representing a decided improvement over former designs, did not eliminate locks, and, moreover, the location of the hip joint directly under the ischial seat created, when the wearer sat, a pelvic tilt that was tiresome over any lengthy period. Further design work was carried out after World War II using a lateral hip joint and folding-latch mechanism. But this device, while solving the "tilt" problem, necessitated heavy construction and gave little improvement in control. Because of this discouraging state of affairs, many hip-disarticulation and short-stump above-knee amputees had long

preferred crutch ambulation rather than bother with the best prosthesis available.

The current design of the Canadian-type hip-disarticulation prosthesis was evolved by McLaurin after some three years of work in which the scope of investigation was broadened to explore more features than the height of the joint under the seat. Included were a mechanical design of the hip joint to promote walking with a free hip, an alignment that provides stability through all phases of the walking cycle, and, finally, a new concept of a plastic socket-waistband. This all-plastic member embraces the pelvis and incorporates a rather rigid band which encircles the waist. When well fitted, it provides comfortable weight-bearing, a suspension that requires only the tightening of the front restraining strap, and a degree of control which permits the amputee to move the limb freely and confidently.

Performance on the new device by a test amputee exceeded all expectations, despite the fact that in addition to an amputation at the right hip he had suffered amputation of the right arm above the elbow. Shortly after trials, he reported his ability to walk forty city blocks with less effort than he had formerly expended in two blocks with the old-style metal limb. The ease of donning and removing the new leg with the simple yet secure suspension was impressive. Further field-testing on a larger number of hip-level amputees justified the acceptance of the design as a standard of production, and by September of 1954, through instruction and training of District fitters, it was made available on a Dominionwide basis. Some thirty-two cases have been fitted to date, and twenty-five of these have been classified as successful.

Following the results attained at Sunnybrook, the Prosthetics Research Group at the University of California at Berkeley undertook to assess the new device and to work out improved procedures for construction and fitting, and in the spring of 1956 the Committee on Prosthetics Research and Development of the Prosthetics Research Board approved the issuance of the Canadian-type hip-disarticulation prosthesis to veteran beneficiaries throughout the United States. Here, then, is a Canadian candidate for utilization by clinic teams everywhere in dealing successfully with one of the most troublesome prosthetic problems of all.

The Past and Present Medical Significance of Hip Disarticulation¹

HENRY E. LOON, M.D.²

Hip disarticulation, or amputation through the hip joint, is one of the most drastic surgical removals known to medicine. It is seldom justified as other than a last-resort, lifesaving measure and, as compared to other amputations, is seldom performed. Because of its severity, and because it has been used only for patients already on the verge of medical disaster, it has been attended by discouragingly high mortality rates throughout its 200-year history. By the same token, however, the record of the changing need for hip disarticulation is a record of medical progress against fatal disease and trauma of the lower extremity. Whereas hip disarticulation was first used extensively against gangrene or the ever-present threat of generalized infection, it is now most frequently one of the ultimate weapons against cancer. Moreover, the operation has lost much of its fearsomeness as general medical knowledge and surgical skill have increased and as the hope for prosthetic rehabilitation of these patients has become brighter.

By presenting the medical aspects of hip disarticulation in historical perspective, it is hoped to show here how the pathological conditions indicating hip disarticulation have changed as medical science has progressed, how the operative dangers of hip disarticulation have been largely overcome, and how the

surgical fashioning of the stump (within the limits imposed by injury or disease) has helped in the prosthetic rehabilitation of patients. Finally, there is appended a discussion of the recent interest paid to systemic effects that may accompany any major loss of limb.

HISTORICAL BEGINNINGS

Until the mid-eighteenth century, surgeons considered themselves helpless to treat complicated fractures or suppurative diseases of the upper part of the femur, let alone malignant growths in this region. Death from septic complications, gangrene, or, in the case of cancer, metastases, was the almost inevitable outcome of these conditions.

Surgical disarticulation of the hip was apparently first conceived by Sauveur Francois Morand, a leading French surgeon of the early eighteenth century, and was formally proposed in 1739 by two of his pupils (36). Long before the first true surgical disarticulation, however, the hip of a boy of 14 was nearly disarticulated by gangrene which resulted from his having eaten diseased rye. Observing the thigh to be connected to the trunk only by the round ligament, the sciatic nerve, and some shreds of tissue, the French surgeon Lacroix (44,65) cut these with scissors. The other leg, similarly affected, was cut from the hip in the same manner four days later, and the patient survived another 11 days. This case gave a great impetus to discussion of the matter. In 1759, the Royal Academy of Surgery offered a "double prize" for the best essay on the following subject: "Dans le cas ou l'amputation de la cuisse dans l'article paroitroit l'unique ressource pour sauver le vie a un malade, determiner si l'on doit pratiquer cette opera-

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tion, et quelle seroit la methode plus avantageuse de la faire."³ Of 44 essays submitted, 30 were in favor of performing the operation (36).

Not until 1774 was it proved that death on the operating table was not a necessary consequence of this formidable operation. In that year, the first true surgical disarticulation of the hip was performed by William Kerr (1), of Northampton, England, on an 11-year-old girl who had a tumor of the thigh and symptoms of pulmonary tuberculosis.⁴ The disarticulation had probably not greatly influenced the course of the disease, and Kerr concluded his presentation optimistically (p. 342): "With regard to the expediency of the operation, I am so much convinced of it in certain cases, that in such I shall not, for the future, hesitate to perform it when they occur."

Another disarticulation said to have been performed at about the same time by Henry Thomson at the London Hospital apparently terminated fatally (58), and the operation was not reported again for nearly 20 years. The Wars of the French Revolution and the Napoleonic Wars brought with them a new series of hip disarticulations.

SHIFTS AND CHANGES IN INDICATION OVER Two CENTURIES

Although the earliest hip disarticulations were performed for disease, in the following 100 years many more were done for gunshot wounds than for any civilian cause. Up to the end of the American Civil War, nearly two and a half times as many military as civilian operations had been reported from Europe and America, as recorded by Otis in *The Medical and Surgical History of the War of the Rebellion* (63). Since that time, the situation appears to have been reversed again owing to the decreased necessity for the operation fol-

³ "In a case in which amputation of the thigh at the articulation with the hip bone appears to be the last resort for saving the life of a sick man, to determine whether this operation should be performed, and what would be the most advantageous method of doing it."

⁴ Or possibly a metastatic cancer of the lungs. At her death, 18 days after operation, an autopsy showed them to be "almost totally reduced to matter."

lowing battle injuries and its increased use to remove malignant growths. It would be instructive to be able to compare hip disarticulations of military and of civilian origin—as to exact incidences and indications—throughout the history of the operation, but unfortunately information is incomplete and many difficulties of interpretation arise. Nevertheless, a comparison of the indications given for each group points up the necessity of considering the two categories separately.

INDICATIONS IN MILITARY SURGERY

The military surgeon has always been concerned mainly with trauma and ensuing infection, although infection plays a progressively less important role than formerly. In 1812, Dominique Jean Larrey (28), the famous French surgeon and personal physician of Napoleon, who himself (Larrey) performed seven of the early disarticulations, stated the indications for the operation in military surgery as follows:

1. A tom-off limb, or great laceration of the limb so close to the upper articulation that amputation in continuity would not be possible.
2. Fracture of the femur in the vicinity of the trochanters, accompanied by a rupture of the femoral artery or of the sciatic nerve.
3. Massive gangrene of the lower extremity extending to the vicinity of the upper articulation, as a result of extensive wounds of the soft tissues.

At the time of the American Civil War, these indications were still considered valid, and Otis (63, p. 167) repeated the first two almost verbatim. Today, however, most severe fractures, and even many comminuted fractures, of the upper end of the femur, if not associated with irreparable vascular damage, can be treated conservatively. Most of the major amputations of extremities in World War II were the result of such extensive traumatic injury that no improvement in surgical technique could hope to effect repair. According to DeBakey and Simeone (12), 69 percent of the 3177 major amputations performed in the European and Mediterranean Theaters were due to extensive trauma (by which was meant complete or nearly complete severance of the limb or part of the limb), 12 percent to infection, and 19 percent to major arterial injury.

The relatively small percentage of amputations due solely to major arterial injury could probably now be reduced still more because of new techniques of repair and grafting of blood vessels. Some successful cases were reported from the Korean War, and knowledge is further advanced today (10, p. 155).

Statistics on the specific indications for the 56 recorded cases of hip disarticulation from World War II (3) are at present not available. The implications of the records seen is that the majority were traumatic amputations. For instance, of the 154 wounds of the hip joint observed between D-Day and VE-Day at the 802nd Hospital Center, none was treated by disarticulation. Regarding the incidence of infection, there was no report of rapidly spreading hemolytic streptococcal or staphylococcal infection, such as still occurred in World War I (10, p. 239). At the 802nd Hospital Center, infection occurred in 9 of 29 injuries of the femoral head or neck. Although these were cases of persistent, long-lasting infection, leading in two cases to death, no hip disarticulation was performed. Usually this tendency toward conservatism was justified, but in looking back, the Office of the Surgeon General has modified this attitude in the following statement (10, p. 245):

1. When there has been great mechanical destruction of the bone and soft parts and when retained foreign bodies carrying fragments of clothing cannot be removed, foci of infection are maintained for indefinite periods of time.

2. A prolonged delay before amputation merely results in exhaustion of the patient, so that, when the operation is eventually performed, it often poses a serious threat to life. . . . It must be assumed that patients with large areas of mixed, penicillin-resistant infection deteriorate every day that they live and that their chances of survival after major surgery become progressively less as time passes. . . .

4. Observation of numerous instances of pyoarthrosis of the hip joint at United States Army amputation centers made it clear that when the sciatic nerve is lacerated the indication for early disarticulation of the hip is particularly strong.

Fulminating gas gangrene is still an indication for amputation, but its incidence has been tremendously reduced by the employment of prompt and thorough debridement and the administration of antibiotics. It is impossible to determine from the available statistics

whether any hip disarticulations were performed because of this infection.

To sum up, in military surgery hip disarticulations—like other major amputations—appear to be performed today primarily when the limb is completely or almost completely severed from the trunk. To these traumatic amputations must be added those cases in which disarticulation is necessitated by major injury to the blood vessels or to the main nerve trunks (particularly the sciatic) and those in which multiple foci of antibiotic-resistant infection cannot otherwise be eliminated. That the number of hip disarticulations has not been greatly reduced in comparison with former wars is testimony to the increased destructiveness of modern weapons; the type of injury which used to necessitate hip disarticulation can usually be treated conservatively today.

INDICATIONS IN CIVIL SURGERY

The civilian surgeon has also always been concerned with trauma, but disease, and especially malignant disease, has played an increasingly important role. In 1839, Velpeau (65, p. 639) stated the indications for hip disarticulation in peacetime as follows:

A comminuted fracture, a necrosis, caries, osteosarcoma, spina ventosa, or any incurable degeneration whatever, of the femur, extended above its shaft, or gangrene, or any other disease in fact which has progressed nearly as high up as the haunch, and which is of such serious character as to demand amputation, will claim disarticulation provided the cotyloid cavity and the bones of the pelvis are not affected.

The major change in indications from the nineteenth to the twentieth century is best seen from a comparison of nonmilitary hip-disarticulation cases. It may be seen from Figure 1 that, although many of the conditions listed by Velpeau might today be considered indications for hip disarticulation, they do not in practice occur very often. Cancer is *the* indication now, whereas in the early period it was one among a number of causes. The indications given by Smith (53) for his historical survey of cases fall into the following categories: malignancy, 13; severe crushing injuries, 8; suppurative diseases of the femur, 7; tuberculosis, 4 (tubercular lesions of the bones,

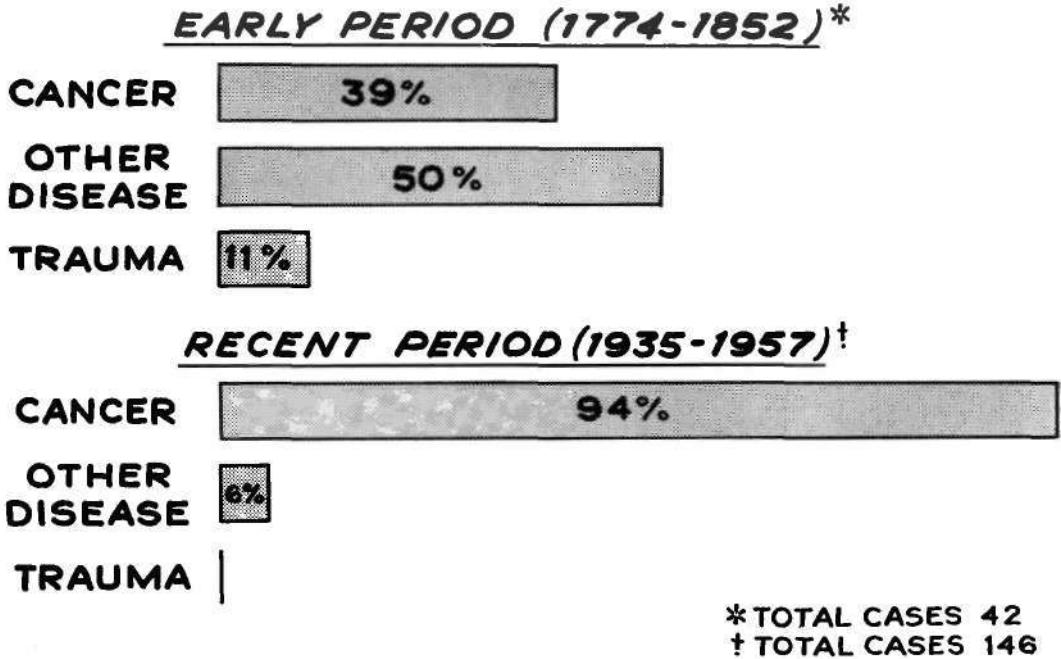


Fig. 1. Comparison of early and recent indications for hip disarticulation in peacetime. Data for the early period were taken from a compilation by Stephen Smith (53) of all known cases of hip disarticulation to 1852. Wartime operations and those for which the indication was not known were eliminated. Data for the recent period were derived from articles indexed under *Amputations* in the *Quarterly Cumulative Index Medicus* from 1935 through 1951 and in the *Current List of Medical Literature* from January 1952 through August 1957. Again, wartime operations and those for which the indication was not stated were eliminated.

3; tuberculoma of the thigh, 1); gangrene, 3; miscellaneous causes ("diseases of the femur," "coxalgia," pain, exostoses), 7.

Four of the tumors which Smith gave as indication were not classified by him as malignant. But from the description of the course of the disease they appear to have been, and they are therefore here grouped under malignancy. This is only one example of how difficult it is to determine with any certainty what the true indications for these early operations were. Another example is Kerr's case (page 5). Smith, following Kerr's own diagnosis, recorded the indication as tuberculosis; yet from the description of the case it seems conceivable that the patient had a malignant growth in the upper end of the femur and the innominate bone with metastases to the lungs.

Methods of diagnosis are greatly improved today, but it is no less difficult to obtain

reliable statistics on recent hip disarticulations. Cases that do not present striking medical or surgical aspects are no longer reported in the literature. In this country, unfortunately, no survey of the total number of amputees has ever been made, but even in countries like Germany or Great Britain, where the government has made such surveys for the larger categories of amputations, no information on the incidence of hip disarticulations, let alone the indications for them, seems to be available.

In a literature survey covering the period from January 1935 through August 1957, there were reported (Fig. 1) 146 civilian hip disarticulations for which the indications were given. Of these, 138 (94 percent) were done for malignancy {4,9,17,18,20,25,29,30,34,39,41,42,45,52,54,60}. Two were done for tuberculosis (30) and one each for osteomyelitis following an injury (24), phlegmon of thigh and general

septicemia following an injury (55), a suppurative process (etiology not stated) of the coxo-femoral articulation (7), actinomycosis (20), gangrene caused by thrombosis (34), and paralysis and contracture caused by an extradural abscess (34). It is a little surprising that, of all the reported civilian hip disarticulations, none was done primarily for trauma. I have myself seen one patient whose hip was disarticulated because of injuries in peacetime, and I am certain that there must have been a few others.

Fortunately, not all malignant growths, even in the upper part of the thigh, call for such drastic treatment as disarticulation of the hip. In some cases wide excision of the neoplasm suffices to remove it entirely. The decision as to whether or not to disarticulate depends upon the site and the type of the neoplasm. The indications upon which modern surgeons agree are well stated by Pack and Ehrlich (40, pp. 966-969), and the reader interested in these details is referred to that excellent paper.

INCIDENCE RELATIVE TO ALL LEG AMPUTATIONS

Comparison of the number of hip disarticulations with total numbers of lower-extremity amputations shows still more clearly how seldom hip disarticulation is performed. It has now become much rarer in military than in civilian practice. During the American Civil War (63, pp. 870-871) 86,413 wounds of the lower extremities were recorded. In 12,605 of these cases (less than 15 percent), the wounds resulted in major lower-extremity amputations. Of these, 66, or 0.5 percent of the amputations, were hip disarticulations (Fig. 2). In World War II (3, pp. 193-194), 248,000 wounds of the lower extremities were recorded. Of these, 12,612 (5 percent) are estimated to have resulted in major amputation. Fifty-six, or 0.4 percent, of the amputations are estimated to have been hip disarticulations. Thus the percentage of hip disarticulations in relation to total lower-extremity amputations has changed very little; it has remained small. Both the number of hip disarticulations and the number of lower-extremity amputations have, however, de-

creased greatly relative to the number of wounded.

In civilian cases the ratio of the number of hip disarticulations to all major lower-extremity amputations is probably somewhat higher but still less than 2 percent. Thus, of 70 lower-extremity amputees who underwent amputation or were treated at the University of California Medical Center from 1941 to 1955, only one had had a hip disarticulation (26). Of 663 patients with major lower-extremity amputations who have passed through the Veterans Administration Hospital in Oakland since the end of World War II, eight have had hip disarticulations (26). Even the records of an institution treating predominantly cancer patients show a very small number of hip disarticulations. The Bone Tumor Service of the Memorial Center for Cancer and Allied Diseases in New York City reported only 15 hip disarticulations from 1930 to 1946 (11), a fact which suggests that even today this operation is done only to forestall certain death.

THE LONG STRUGGLE TO REDUCE MORTALITY

There was good reason why hip disarticulation was not attempted, or even conceived, until the eighteenth century. The surgical skills which had been developed up to that time were still grossly inadequate for an operation attended by so much danger of hemorrhage and shock.

OPERATIVE MORTALITY

When we consider that the operation had to be done as fast as possible, without benefit of anesthesia or knowledge of asepsis, it is surprising how many of the earliest patients survived even a few days or weeks. Larrey (28), who was probably one of the most skilled surgeons of his time, has recounted cases in which, after ligating the femoral vessels together, he completed the procedure in 14 to 15 seconds. To achieve this speed, he used only four knife strokes. He drove a blade perpendicularly between the base of the femoral neck and the tendinous attachments of the lesser trochanter until it emerged posteriorly and, with an oblique downward stroke, cut the medial flap; raised the flap proximally to expose

the articulation and with a stroke of the bistoury cut the articular capsule; abducted the thigh (nearly dislocating the head of the femur) and in a stroke cut the interarticular ligament; and with a downward and outward stroke of a small straight knife cut the lateral flap. The remaining arteries were then ligated. Larrey did not consider it necessary to suture

the muscles. If there was no "irritation," the subcutaneous tissues and the skin were approximated with a few retention sutures. The edges of the wound were further drawn together by compresses dampened with red wine, and a large bandage was applied.

Larrey reported that his first patient survived the operation well but a few hours later



Fig. 2. One of the few survivors of disarticulation of the hip during the American Civil War. Note the large amount of soft tissue in the stump. From Otis (62).

had to follow the army in a 24-hour forced march in winter, so that he died presumably of cold and exposure. His second patient also seemed well on the road to recovery when, six days postoperative, a soldier with the plague was bedded on the same straw mat with him. Larrey's patient became infected and died within 24 hours.

The fate of these patients, who died not as a result of the operation itself, shows how difficult it is to establish the date of the first "successful" hip disarticulation. These two, together with others in which death occurred within a year after operation, were in early mortality statistics classed as fatalities.⁶ On the other hand, there are no verifiable records of several of the early hip disarticulations claimed by later authors to have been successful. Otis on whose two works (62,63) the early figures given here are based, pointed to other frequent sources of fallacies in surgical statistics. He said (62, p. 6):

The desire for distinction of ambitious operators sometimes tempts them to report successful results prematurely, and to fail to record unfortunate cases. Feverish partizans of particular operative procedures, in accumulating statistics, not unfrequently evince an unpardonable disregard for the fundamental rules of evidence, and admit testimony abounding in transparent fallacies. Some writers, in their zeal to gather together numerous observations, group those that are very dissimilar, and deduce inferences from the collection that are pertinent only to particular cases.

He stated that in his own report the authenticity of cases was scrutinized and that doubtful cases were rigidly excluded (62, p. 7). Insofar as the records of earlier operations Otis recorded have been checked, he was indeed conscientious; yet in evaluating his figures it is essential to bear in mind all the limitations of this early material.

According to Otis (62, p. 18), 111 known civilian cases of hip disarticulation were reported from Europe and America to the end of the American Civil War. Of these, 46 were considered successful and 65, or 59 percent, terminated fatally. In military surgery (63, pp. 127, 163), 254 authenticated hip disarticulations were reported, with 28 recoveries,

⁶ Thus the figures that follow are not statistics of operative or even hospital deaths alone.

225 deaths, and one result unknown—a mortality rate of 89 percent. Of the 187 patients who underwent hip disarticulation prior to the American Civil War, 17 survived, giving a mortality rate of 91 percent. In the 67 cases occurring during the Civil War, 11 of the patients recovered—a mortality rate of 84 percent.

In spite of this extremely high mortality rate, disarticulation gave better results than did more conservative methods of treatment for complicated fractures of the upper end of the femur. Of 252 patients with intracapsular shot fractures who were treated conservatively during the American Civil War, three recovered, giving a mortality rate of 99 percent (63). Fifty-five excisions of the femoral head resulted in a mortality rate of 91 percent (63).

The mortality rate did not improve materially until well after the general introduction of asepsis in the 1880's. In 1878, Farabeuf (14), when presenting his method of disarticulation to the Societe de Chirurgie in Paris, cited a still-persisting death rate of 75 percent. The American surgeon Wyeth (67), writing in 1890, mentioned "the terrible death-rate after hip-joint amputation."

Improvements in Surgical Technique

After deaths from complications of infectious processes had been somewhat brought under control by the general introduction of aseptic surgical procedures, surgical shock still accounted for a large number of the operative deaths. A main contributing factor was hemorrhage.

Reduction of Hemorrhagic Shock. The arteries to the upper part of the thigh and the gluteal region branch out from several main trunks (Fig. 3), so that it is much more difficult to control the flow of blood for a hip disarticulation than for a thigh or leg amputation. Methods attempted for control ranged from a high tourniquet placed about the upper end of the thigh to compression of the aorta.

An ordinary touniquet is difficult to apply satisfactorily for a hip disarticulation. Placed about the thigh at the groin, it not only does not control bleeding from a number of the main vessels but it also slips out of place easily after enucleation of the proximal end of

the femur. For this reason, there were developed various devices for holding a tourniquet in place, the best known being Trendelenburg's (61) and Wyeth's (67) systems of pins. In both procedures, long steel pins were driven through the soft tissues to prevent slippage of rubber tubing used to constrict the tissues.

Of the more radical methods for compression of the parent trunks, some, such as a Davy's lever introduced through the rectum for the compression of the aorta, were dangerous, and they were not always reliable (49). Other authors recommended making an abdominal incision and temporarily compressing (32) or lifting (17) or even permanently ligating (6,22) the common iliac artery. The latter procedure has been recommended as recently as 1954 (18), but it is not commonly used today. Many surgeons hesitate to add to the system an additional shock by making an incision into the abdominal cavity.

In general, more conservative measures are and have been advocated. Although initial ligation of the femoral vessels does not provide a completely bloodless field (because of the many anastomoses from the obturator and gluteal arteries), it has usually been considered the most satisfactory method. As we have seen, Larrey in his early operations recommended preliminary ligation of the femoral artery and vein, and regardless of the type of incision this has been common practice to the present day. Farabeuf (15), whose procedure is still widely used, especially in Latin American countries, recommended an anterior racquet incision. The stem of the inverted Y should be over the point at which the femoral vessels pass under the inguinal ligament, and the artery and vein are sectioned and ligated before proceeding with the operation. Farabeuf claimed that other arteries could satisfactorily be cut and compressed by assistants as they

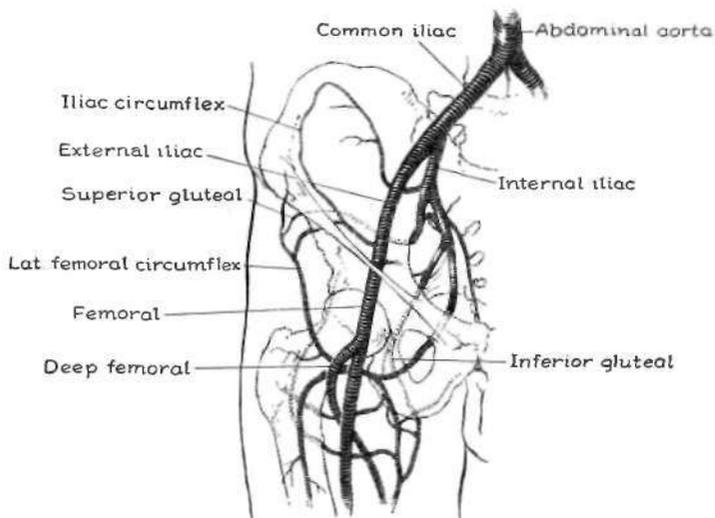


Fig. 3. Arterial system in the hip and upper part of the thigh. Redrawn, by permission, from *Gray's Anatomy*, 26th ed., Lea & Febiger, Philadelphia, 1954. The original appeared in Eycleshymer and Jones' *Hand Atlas of Clinical Anatomy*, Lea & Febiger, Philadelphia, 1925.

were encountered and then ligated before closing the wound. Marquardt (33) in a recent book stated that in Germany it is considered best to follow Angerer's two-stage procedure (2), in which ligation of the femoral artery and vein is done through an incision in Scarpa's triangle one or two days before the proposed hip disarticulation. This expedient allows the vessels to become thrombosed so that there is little loss of blood during the disarticulation itself.

Finally, blood may be conserved if, after ligation of the artery, the leg is elevated for several minutes to allow maximal drainage to the trunk before ligation of the vein (11,19,25,27,40).

In addition to careful hemostasis, it is helpful to section the muscles, wherever possible, in the avascular areas close to the tendinous origins or insertions rather than through the muscle bellies. This principle, proclaimed by Callander (8) in 1935 for his amputation just above the knee, has been applied to hip disarticulations by Leriche (30), Boyd (5), Slocum (51), and Piquinela (42). In the days when speed of operation was the primary consideration, the principle was necessarily violated.

If guillotine operations are excluded, it is hard to imagine a faster method than Larrey's, but cutting each flap with a single stroke, as Larrey did, meant sectioning the muscles through the richly vascularized bellies, thus contributing greatly to hemorrhage and shock. He was, of course, caught on the horns of a dilemma for those times, because speed, too, was essential to lessen shock.

Other Techniques for Avoiding Shock. Even in cases in which there has been no infection or excessive hemorrhage, shock often occurs. Bustos (7) gave this as reason for believing that conditions which could cause pain played the major role in causing shock. Gentle handling is considered essential by most modern surgeons. Layer-by-layer dissection, using a scalpel, was recommended by Petrovskii (41). Caprio (9) recommended the use of an electric scalpel, with which he claimed that he could carry out the whole operation without even turning the patient over, as is usually done.

Many surgeons have taken precautions to avoid shock that might result from overstimulation of the sciatic nerve. Since this large nerve trunk runs through the posterior portion of the thigh, it is ordinarily not sectioned until the latter part of the operation and is in the meantime subjected to a variety of tensions, particularly after the dislocation of the femoral head, when the half-severed limb hangs from the trunk, connected only by this nerve and associated soft tissue. Various methods for overcoming this problem have been suggested—proper support of the limb throughout surgery to avoid these tensions (54); injection of the nerve with procaine before sectioning it (5,7,9,11,20,30,34,37,40,41,51); and even, in a debilitated case, section of the sciatic nerve (after injection with procaine) almost at the start of the operation (7). In 1917, Morris (37), using spinal anesthesia, began his operation by injecting the sciatic nerve with procaine through a small posterior incision and then proceeded through anterior incision with what is usually the first part of the operation. He stated that no shock was observed during the ensuing disarticulation.

Recently, the use of spinal anesthesia has

been questioned (40) on the grounds that hypotension results, which could be dangerous in view of the seriousness of hip disarticulation. However, hypotension does not occur routinely when the level of spinal anesthesia is so low that the splanchnic nerves are not anesthetized (43). Injecting the sciatic nerve may appear superfluous if spinal block has been performed prior to the operation. It seems to be done as an additional precaution and as a means of blocking any afferent fibers that, traveling via the sympathetic chain, may enter the cord above the level of spinal anesthesia.

A two-stage operation is sometimes advisable for patients who are in very poor condition. We have already mentioned Angerer's procedure of ligating the femoral vessels one or two days before the disarticulation, a method which aids in avoiding shock by reducing blood loss. Even a three-stage procedure has been recommended (23). In most cases today, however, the operation is performed in one stage only.

Improvements in Adjunct Therapy

In the first quarter of the twentieth century, great progress in several fields decreased the risks of serious operations such as hip disarticulation. More careful debridement of wounds was supplemented by chemotherapy and the use of tetanus antitoxin. By the end of World War I, shock occurring in American Army soldiers was treated by fluid replacement and whole-blood transfusion (64).

Knowledge of the physiology and technique of blood transfusion was greatly advanced in the second quarter of the century. Methods of preserving whole blood and plasma were developed, although such problems as the occurrence of homologous-serum hepatitis virus in stored plasma remained unsolved and caused considerable damage. Surgical knowledge of the repair of fractures and of replacement of hopelessly damaged parts of bones by grafts of various types made conservative treatment possible in many more cases than before. The use of sulfa drugs and antibiotics greatly reduced the incidence of infection after severe wounds. Finally, psychotherapeutic measures to prevent psychic trauma and to facilitate re-

covery became an important adjunct to surgical care.

Operative death has become rare (39), but the extent of shock and the resulting damage to the system continue to deserve study.

MORTALITY FROM CANCER

Another mortality rate is, however, a matter of much greater concern today. As we have seen, most modern civilian hip disarticulations are performed for cancer. Since at the present time hip disarticulation is commonly not resorted to until other measures (radiation, wide excision) have failed, it often has only a palliative effect. The mortality, if studied for the 5-year-cure rate, is extremely high. Of a series of 52 patients operated upon at the Memorial Cancer Center in New York from 1926 to 1948, 44 (85 percent) died of cancer within five years (39).

Pack (39) and others (11,25,29) have emphasized that, if disarticulation is resorted to only at this late stage, the mortality rate in such cases will continue to be high. In a recent study of patients with malignant disease who underwent hemipelvectomy (an operation comparable to hip disarticulation for the purpose here), Lewis and Bickel (31) observed:

Twelve of the 18 patients who had had symptoms less than six months at the time of operation are still living (two with metastases), and 4 of the 6 who had had symptoms for six months to one year are still living (one with metastases), while only 8 of the 25 patients who had had symptoms for more than one year have survived the present follow-up periods, and one of these has evidence of metastases.

Although there is sometimes justification for disarticulation as a palliative measure, it would be much more desirable to employ it as a cure. Disarticulation as a curative measure will, however, be possible only when surgeon and patient alike are willing to take this radical step at an early stage of the disease.

To what extent will hip disarticulation be replaced by the even more drastic operation of hemipelvectomy? Hemipelvectomy is indicated if malignancy (or, for that matter, a severe crushing injury or a suppurative process such as that mentioned on page 8) has involved the tissues proximal to the coxofemoral joint. Leriche (30) went beyond this in 1937 when he

predicted that hemipelvectomy would one day be considered the operation of choice for malignant growths of the upper part of the thigh. Lee and Alt (29) in 1953 compared hip-joint disarticulation with hemipelvectomy from the point of view of anatomy and surgical technique, extent of postoperative disability and use of prosthesis, and therapeutic effectiveness. They found that under modern conditions there was no great difference between the two operations so far as surgery or postoperative disability are concerned, whereas hemipelvectomy definitely offered better hope of a cure. They therefore considered hemipelvectomy the procedure of choice for high-grade soft-tissue or osteogenic malignant tumors of the upper thigh as well as of the pelvis.

Not all modern surgeons go so far as this. Coley (11) has emphasized that it is essential to discriminate between cases, the decision depending upon the site and grade of malignancy of the tumor. Osteosarcomas and chondrosarcomas of the lower fourth of the femur do not call for hip disarticulation and are better treated by high thigh amputation, since then considerably less disability results.

In sum, allowing a wider margin between the tumor and the incision is now generally recognized to be necessary to ensure elimination of all malignant cells. This means that the level of amputation has tended to move in a proximal direction. While some hip disarticulations have been replaced by hemipelvectomy, high thigh amputations have also been replaced by hip disarticulation, so that no appreciable decrease in the number of hip disarticulations is to be expected as a result of this trend.

SURGICAL FASHIONING OF STUMPS

The surgical techniques of hip disarticulation practiced today have evolved as a result of this many-faceted experience. Throughout the history of the operation, the sequence of procedures has been dictated primarily by cumulative experience in combating hemorrhage and shock. The shape of the resulting stump has been affected primarily by the change in indication for the operation from predominantly traumatic to predominantly malignant cases. To a lesser degree, the shape

has been affected by considerations of healing and subsequent fitting with a prosthesis.

THE LARGE SOFT-TISSUE STUMP

The large soft-tissue stump popular during the early history of hip disarticulation (Fig. 2) may originally have been developed through association with a high-thigh stump. Surgeons first experimenting with the dangerous operation of hip disarticulation may well have been loath to cut away too much soft tissue. But many of the early operations were actually done by first performing a circular high thigh amputation and then disarticulating the head of the femur through a lateral incision (21,49,61).

During the latter half of the nineteenth century, many experiments were carried out with various kinds of subperiosteal amputations, in which a cuff of periosteum was left overlapping the end of the bone stump. Difficult as it was to perform, a subperiosteal hip disarticulation was done several times. Originally devised by Oilier of Lyons in 1859, it was carried out by James Shuter (50) of London in 1881. A circular amputation was first performed at the junction of the middle and upper thirds of the thigh. The vessels were ligated, and through a longitudinal incision on the lateral aspect of the thigh the remaining portion of the femur was dissected out, leaving the periosteum (peeled off up to the intertrochanteric line) in the flaps.

The advantage of this method, according to Shuter and others who observed the patient over a year after operation, was that the residual periosteum provided a point of attachment for the muscles and caused a growth of what Shuter termed "new bone" but which other observers described as "a firm resisting cord" (50, p. 89), cartilaginous rather than bony in character. Observers testified that this "cord" provided such a good attachment for the muscles that they were "in a high state of nutrition" and that the patient not only could flex, extend, adduct, and abduct the stump powerfully but also could communicate all these movements to the artificial limb. Durand (13) of Lyons had a woman patient who, more than four years after a similar operation, had a regenerative process resembling a tough

fibrous stalk, which also provided an excellent attachment for the muscles. She was able, he stated, to lift a weight of 15 kg. with her flexed stump.

In a modern case (24) the patient, although apparently not operated upon subperiosteally, was said to have had a stump with many of the characteristics claimed for the subperiosteal stumps. Disarticulation was done for osteomyelitis of the femoral shaft, trochanter, and neck, a sequel to extensive injuries of the thigh. The femur was carefully dissected out from the surrounding tissues, leaving a soft-tissue stump measuring 6 in. when relaxed. It was reported that "The muscles had become attached to each other by scar tissue, so that there was active flexion and extension of the stump if one grasped the muscles with his hands." The patient was able to wear a suction-socket prosthesis, which he could flex and extend at the hip joint "because of the fixation of the skin and muscles to the side of the socket by the suction exerted upon the distal end of the stump." This method of activating the prosthesis was compared to that used by crustaceans in activating their exoskeletons, and a point was made of the importance in this case of designing the socket so that, upon weight-bearing, the contracted muscle mass would be properly positioned on the ischial seat beneath the ischial tuberosity.⁶

About the turn of the century, subperiosteal amputations were gradually abandoned, mainly because of the frequency of undesirable growths of new bone emanating from the periosteal cuff. Apparently only a few subperiosteal hip disarticulations were performed. In addition to the uncontrollability of new bone growth, other, even more important, reasons prevented the operation from becoming popular. One was the difficulty of stripping the periosteum from a healthy bone. Shuter's subperiosteal operation was done for a suppurative process of the femur, in the course of which the periosteum had already achieved a considerable degree of natural separation from the bone. Durand did not mention a similar condition in his patient, but his operation was done

⁶ Cf. discussion of very short thigh stumps, page 15.

for tuberculosis, and possibly a suppurative process was present. Another reason, much more significant today, was that the retention of the periosteum made the procedure unsuited for any disarticulation done because of a malignant neoplasm.

THE COMPACT STUMP

After disarticulation for malignancy, the hip stump commonly fashioned today is compact, with the soft tissues reduced to a minimum. When involvement of the inguinal nodes is proved, or, in certain disease, even suspected, a radical groin dissection is also done, thus removing even more tissue from the body.

Most incisions today, whether of the anterior racquet or semioval type, start just below the inguinal ligament and thus provide immediate access to the femoral vessels and nerve in Scarpa's triangle. These incisions create a long posterior flap and leave an anterior scar that is well removed from terminal and lateral pressure areas and from any possibility of fecal contamination before wound-healing is complete. The semioval incision has the advantage of eliminating the "handle" of the racquet, which, if carried too far, may easily invade a pressure area under the pelvic corset of the prosthesis. For this reason, it would seem to be the incision of choice for the use of the Canadian-type hip-disarticulation prosthesis, as may be seen from Figure 11, page 37. This prosthesis is, however, very adaptable and can easily be modified to accommodate a larger or smaller amount of soft tissues (even dog-ears). Bony prominences are not necessary to anchor it. If the wound has healed by first intention, it is no longer critical whether the scar lies under a pressure area.

For further information on the modern technique of hip disarticulation, the reader is referred to Slocum's procedure, which is detailed on pages 242-244 of his work, *An Atlas of Amputations* (51). The muscles are sectioned in the avascular areas close to their tendinous origins or insertions. Some additional precautions against shock, as already discussed, may be found desirable in certain cases. For cases in which involvement or suspected involvement of the inguinal nodes necessitates radical groin dissection, Pack and Ehrlich's

standard method (40) can be followed. A racquet incision, with the handle of the inverted *Y* extending proximally, is recommended for this procedure, which is carried out before the hip disarticulation. The only problem here is that the large skin flaps, denuded of all underlying subcutaneous fat, lymphatic tissue, and fascia, are susceptible to necrosis and sloughing along their edges. Not much can be done about this, since in order to be effective the procedure has to be thorough. Since the wound does not ordinarily heal by first intention, the scar, extending as it does well above the line of the inguinal ligament, may present problems in the fitting of the Canadian-type hip-disarticulation prosthesis.

POSSIBILITY OF SHORT THIGH STUMP

Most cases of malignancy, as we have seen, require radical removal not only of the bone but also of as much soft tissue as possible. When the amputation follows trauma or disease other than cancer, however, the question may arise as to whether to disarticulate or to leave a very short thigh stump. The improvement of artificial limbs, as well as of surgical techniques, has made it possible to fit above-knee amputees of higher and higher amputation level with thigh prostheses rather than with hip-disarticulation prostheses. In 1930, Verrall (66) stated that any stump measuring less than 5 in. below the greater trochanter had to be fitted with a tilting-table (hip-disarticulation) prosthesis. In 1949, Slocum stated (51, p. 402) that "When amputation approaches the level of the lesser trochanter, the function of this [hip] joint is nullified ..." and that therefore a patient with an amputation at this level or higher had to be fitted with some type of hip-disarticulation prosthesis. The possibility of fitting a suction socket depends, however, not only on the length of the residual bone but also on the volume of the soft tissues which provide the seal for holding suction. Indeed, in the case of the man with a completely boneless stump (cf. p. 14), the soft tissues alone enabled him to wear a suction-socket prosthesis.

The leverage provided by even a small segment of the femur is, of course, a great advantage in activating a prosthesis. Tikhonov

(59) reported interesting experiments to lengthen a short residual femur by bone grafts. He said that it was not possible to give an absolute measurement for the shortest thigh stump which could activate a thigh prosthesis, since this length depended also on the volume of soft tissues, which varied from stump to stump. Instead, he gave a formula based on the relation of length to circumference. He also noted that except for extreme cases a stump should measure somewhere between 8.5 and 13.5 cm. (3.3 and 5.3 in.) from the perineum in order to allow for piston action of 2 to 3 cm. (about an inch) yet still permit the prosthesis to be moved in any direction. For the patient with other handicaps in addition to the very short thigh stump (such as amputation of the contralateral extremity or an upper-extremity amputation), Tikhonov and his co-workers recommended that surgical lengthening of the short stump be considered as a means of increasing the patient's ability to get about.

Tikhonov reported on the lengthening of three short thigh stumps by from 3 to 6 cm. (1.2 to 2.4 in.). A homoplastic graft, taken from the diaphysis of the fibula, was inserted into the medullary canal of the femur. After a maximum period of observation of 10 months, he reported that bony union had already been achieved in two of the lengthened stumps and that these were providing satisfactory additional leverage for activating a prosthesis.

POSSIBLE SYSTEMIC EFFECTS OF MAJOR LOSS OF LIMB

As more patients have survived these drastic operations and have become subjects for rehabilitation, increasing attention has been paid to the possible medical consequences of the loss of so large a part of the body. The entire limb can now be removed without great risk of operative death, the patient can be fitted successfully with a prosthesis, and appropriate attention can be given to his psychological and vocational readjustment. Then this question arises: What is the *medical* outlook for such a patient? The same kind of question has been raised in regard to many diseases and disabilities to which corrective measures have been applied. Frequently, all of the medical

consequences of a selected course of therapy cannot be foreseen. The physician asks himself: Am I doing the right thing? Will the radiation therapy that appears so beneficial now give rise to untold medical harm later?

In the recent literature of several European countries, there have been raised questions about possible systemic aftereffects of major amputation which could hold much significance for the rehabilitation of amputees. The answers have proved difficult. Many of the opinions expressed have been supported only by clinical impressions or by studies lacking in desirable controls. Many have been accompanied by enthusiastic but untested hypotheses. It appears that, before this mass of information can be evaluated properly and before definitive answers can be obtained, the questions may need to be rephrased and made the subject of carefully controlled studies.

In their examinations of amputees, many physicians have observed signs and symptoms and have obtained in clinical tests results which have led them to suspect that amputation is followed by an increased incidence of systemic disease. The review of published observations made by Schulze in Germany in 1942 shows that major limb amputations had at that time already been thought capable of leading to a rather startling list of disorders, including obesity, abnormally increased perspiration, arteriosclerosis, enlargement of the heart, damage to the heart muscle, hypertension, pulmonary tuberculosis, aggravation of bronchial asthma, various disturbances of the digestive system, kidney disease, deformities of the healthy leg and foot, joint deformities, and worsening of varicose veins (48, pp. 72-73). Some of these conditions are more likely to occur after major amputation than are others. Aside from further changes in the musculoskeletal system, the most frequently claimed effects have been cardiovascular disease—especially hypertension—and changes in the regulation of body heat—in particular, excessive perspiration. German authors have advanced hypotheses to explain the development of these clinically observed phenomena.

Sturm appears to have been interested in these problems since 1940 and has published recently, with two colleagues (57), a report of

detailed clinical studies on 150 amputees. Of these patients, 130 were at Bad Nenndorf for a "cure." Medical histories were elicited from them by means of a questionnaire and were amended through interview and examination. In addition, various tests of cardiovascular function were made, with amputees appropriately grouped, in order to show that the incidence of cardiovascular abnormalities increases with the length of time since amputation. In an earlier paper, Sturm (56) described a syndrome characteristic of a few patients with long-standing amputations of the thigh and with a history of severe suppuration of the stump. Examination of such a patient showed a pale angiospastic face, a definite lability of pulse rate and blood pressure, marked dermographism, increased reflex activity, fine tremor of the hands, moist skin, and increased luster of the sclera. Most of Sturm's observations were offered in support of his hypothesis that "vegetative regulatory disturbances" in amputees result from chronic hypothalamic irritation, which in turn arises (by a stated neurophysiological mechanism) from prolonged infection, pain, and vasoconstriction of vessels of the stump.

Schneider (46), who observed an increase of systolic pressure to over 140 mm. Hg in 20 percent, and of diastolic pressure to over 100 mm. Hg in 5 percent, of 67 amputees, developed Sturm's thesis further. He hypothesized that pain (triggered by a neuroma, long-lasting suppuration, deep-tissue scars, or even the pressure of the prosthesis) could, in constitutionally predisposed patients, excite the central sympathetic area of the hypothalamus and eventually create a central lesion with resulting hypertonia. Schneider also pointed out that the role of psychosomatic factors should not be underestimated. The frustration and resulting emotional conflicts experienced by amputees who were attempting to compete with normal individuals could contribute to an early development of essential hypertension.

Another hypothesis concerns the heat-regulating mechanism of the body and the changes which result in it from the loss of a leg. Excessive perspiration in high-thigh and hip-disarticulation amputees has been frequently observed on a clinical basis. Schroder (47) com-

mented on the role played by the extremities in the cooling system of the body in providing arteriovenous shunts to direct the flow of blood into deep or superficial vessels as needed and in providing a large surface area for evaporation. To him, the loss of a whole lower extremity would appear to mean the loss of a valuable part of the cooling system at the same time that extra demands on energy are being made, with resulting excessive production of heat. Such phenomena would indicate an unusual burden on the circulatory system.

These views have excited interest and aroused controversy. Although clinicians may observe in amputees pathological conditions which strongly suggest themselves to be the aftereffects of amputation, analyses of government health records, and clinical studies based on them, have failed thus far to confirm these observations in amputees as compared with equivalent nonamputee populations.

The difficulties of assessing the aftereffects of amputation are well reflected in the reports, annotated in *Lancet* (16,38), of the committee of the Ministry of Pensions in England which in 1950 was asked to find whether amputation of a limb, and subsequent wearing of a prosthesis, could initiate or aggravate cardiovascular disorder and whether such amputation reduces the expectation of life. The interim report of this committee in 1951, termed "somewhat inconclusive," revealed in living amputee pensioners a slight elevation of the mean blood pressure but no abnormal incidence of cardiovascular disease. A more detailed study of death certificates suggested, although not to the point of statistical significance, that patients with leg amputations died earlier, and more commonly from cardiovascular disease, than comparable pensioners with leg wounds not requiring amputation. The majority report of the committee in 1953 introduced a new factor—calling for further committee investigation—by suggesting that men who have suffered major sepsis, with or without amputation, have a higher late incidence of cardiovascular disease and an earlier average death. The committee then arranged for the medical examination of 5500 pensioners, of whom 4500 were to be amputees and 1000 were to be controls, but unfortunately so many of this sample

"failed to attend" that no firm conclusions could be drawn. In 1955, however, the committee, after reviewing all of its evidence, made the following statement (38):

Limb amputations, and the subsequent wearing of a prosthesis do not, in time, produce effects on the body as a whole which may initiate, or aggravate, cardiovascular disorders to any significant extent. There is no material difference between the mortality rates of amputees, by reason of amputation, and that of the corresponding rates for pensioners who have suffered wounds not leading to amputation. Such excess as there is in both classes over that in the general population is quite small.

For the German regional government of Schleswig-Holstein, Meyeringh and Stefani (35) sought to determine the incidence of hypertension in 794 above-knee amputees. They found a resting systolic blood pressure of over 150 mm. Hg in 9 percent, which they compared with an incidence of over 10 percent in the "average German population."

In reviewing the articles pertinent to this controversy, one begins to suspect that a single careful distinction might do much to resolve it. This distinction would be between (a) asserting that systemic disease does occur in amputees and is due at least in part to the fact of amputation and (b) asserting that systemic disease occurs more frequently in amputees than in other persons. Conceivably, the same person who develops high blood pressure owing to physiological stresses imposed by amputation could also have developed high blood pressure for different reasons of physiological stress had he retained his leg. Whereas this explanation would seem too simple, it is not too difficult to imagine a complex of factors at work that could mask from certain types of statistical examination a true relation between amputation and subsequent disease.

It would seem a pity should too much energy be expended in statistical quibble. The question of relative incidence of systemic disease in amputees and in normals is an important question for practical reasons—such as life insurance, pensions, and the allotment of research funds. Of more moment, however, to researcher, practitioner, and amputee alike, is the question of how and why systemic disease develops in amputees and whether it can be

averted in rehabilitation. Furthermore, far from being dispensable, statistical analyses of data obtained from groups of amputees and from appropriate control groups would be a tool valuable to this elucidation.

Many factors offering clues to the situation have been taken into consideration to a greater or lesser extent by individual authors—pre-disposition to hypertension, prolonged sup-puration associated with amputation, difference in level of amputation or amount of body mass lost, age at amputation, and obesity. Owing to the differences—or obscurities—regarding the selection of subjects, the use of controls, and the criteria for systemic disease, the results of these authors cannot be compared satisfactorily or generalized. The possible importance of activity or inactivity, the wearing of a prosthesis, and the stresses attached to home and work environments has hardly begun to be considered from the medical viewpoint of systemic disease! Investigation into the systemic effects of amputation could lead to conclusions beneficial not only to amputees with hip disarticulations and high thigh amputations but also to amputees with less serious disabilities and even to persons suffering from other disorders.

SUMMARY

Hip disarticulation is a drastic amputation used almost exclusively as a last-resort or life-saving measure. A review of the medical history of the operation during the last 200 years shows a number of changes. The one with the most far-reaching implications has been the major shift from operations indicated by injury or by disease other than cancer to operations indicated by malignant growth. Better methods for controlling hemorrhage and shock, together with progress in adjunct therapy, have reduced operative deaths from as high as 91 percent in pre-Civil War military cases to none in a recent American series done for malignancies. But the postoperative mortality in cancer cases continues to be extremely high (in the aforementioned recent series, 85 percent within five years of operation). For this reason some hip disarticulations, when indicated at all for cancer, may well be indicated much earlier in the course of the disease

if the operation is to be therapeutic rather than merely palliative.

The shift in indication has also influenced the surgical shaping of the stump to the extent that today, in contrast to earlier methods, a maximal removal of soft tissues as well as bone is considered essential in cases of malignancy. In the rarer cases in which the indication for operation is trauma or some other type of disease, it is advantageous to leave, whenever possible, a small segment of the femur and additional soft tissues in the stump, thus making possible the use of an above-knee rather than a hip-disarticulation prosthesis. With the Canadian-type hip-disarticulation prosthesis, the shape of the stump is not critical, because this device can readily accommodate any irregularities of body form.

Whether disturbances of cardiovascular function, or of other functions such as thermoregulation, occur as a result of the loss of so large a part of the body is today a controversial subject. Although systemic disease has been noted frequently in amputees with major loss of limb, no controlled studies have demonstrated convincingly that the incidence of systemic disease is greater in amputees than in comparable nonamputees. Similarly, hypotheses that have been advanced to explain how systemic disease develops as a result of amputation are interesting but still without substantial verification physiologically. This area should be an attractive one for further research.

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LITERATURE CITED

1. *An account of the operation of amputating the thigh at the upper articulation, lately performed by Mr. William Kerr, Surgeon to the Royal Regiment of Horse-Guards Blue, and to the Hospital in Northampton.* Communicated to Dr. Duncan, by Dr. Toll, Surgeon to the Fourth Regiment of Dragoons, M. & Philos. Commentaries, 6:337 (1779).
2. Angerer, H., *Ein einfaches Vorgehen zur Verringerung der Operationsgefahr bei Exartikulationen im Hüft- und Schullergelenk*, Zentralbl. Chir., 69:1647 (1942).
3. Beebe, Gilbert W., and Michael E. DeBakey, *Battle casualties: incidence, mortality, and logistic considerations*, Thomas, Springfield, Ill., 1952.
4. Bolot, F., and P. Merz, *Disarticulation de la hanche pour un osteosarcome du fémur ayant envahi les parties molles et provoque une hémorragie grave*, Maroc. med., 31:560 (1952). (Only title seen.)
5. Boyd, Harold B., *Anatomic disarticulation of the hip*, Surg., Gyn., & Obstet., 84:346 (1947).
6. Brooks, Barney, *Exarticulation of the hip joint; with preliminary ligation of the common iliac artery*, J.A.M.A., 76:94 (1921).
7. Bustos, Fernando M., *Desarticulacion coxofemoral (profilaxis del shock por seccidn primaria del cidtico)*, Bol. y trab. Acad. argent. cir., 32:195 (1948).
8. Callander, C. Latimer, *A new amputation in the lower third of the thigh*, J.A.M.A., 105:1746 (1935).
9. Caprio, Gerardo, *Grandes desarticulaciones en la raiz de los miembros*, Bol. Soc. cir. Uruguay, 22:518 (1951).
10. Coates, John Boyd, ed., *Orthopedic surgery in the European Theater of Operations*, Office of the Surgeon General, Dept. of the Army, Washington, D. C., 1956.
11. Coley, Bradley L., *Neoplasms of bone*, Hoeber, New York, 1949.
12. DeBakey, Michael E., and Fiorindo A. Simeone, *Battle injuries of the arteries in World War II*, Ann. Surg., 123:534 (1946).
13. Durand, M., *De la disarticulation sous-periostee de la hanche et de ses avantages sur la methode ordinaire*, Rev. chir., Paris, 17:646 (1897).
14. Farabeuf, [L. H.], *Communication orale sur la disarticulation coxo-femorale*, Bull. et mem. Soc. de chir., 4:180(1878).
15. Farabeuf, L. H., *Precis de manuel operatoire*, 4th ed., Masson, Paris, 1893-1895. pp. 648-678.
16. *The fate of the amputee* (Annotation), Lancet, 1:633 (1953).
17. Ghitzesco, C. I., *La disarticulation de la hanche sous l'hémotase provisoire de l'artere iliaque primitive ou de l'hypogastrique correspondante*, Presse meU, 43:243 (1935).
18. Giles, Roscoe C., and William T. Keig, *The control of bleeding in disarticulation of the hip by ligation of the common iliac artery and vein*, Illinois Med. J., 106:209 (1954).
19. GULis, Leon, *Amputations*, Heinemann, London, 1954.
20. Grey, Jorge de Moraes, *Actinomicose do membro inferior e desarticulacao da coxa. Consideracoes clinicas e technicas em torno de duas desarticulacoes da coxa*, Rev. brasil. cir., 11:159 (1942).

21. Gross, S. D., *Report of the committee on surgery*, Trans. Kentucky State Med. Soc., 2:99 (1853).
22. Halsted, W. S., *The effect of ligation of the common iliac artery on the circulation and function of the lower extremity. Report of a cure of ilio-femoral aneurism by the application of an aluminum band to that vessel*, Bull. Johns Hopkins Hosp., 23:191 (1912).
23. Huard, P., *Etudes sur les amputations et disarticulations des membres*, Masson, Paris, 1940.
24. Hutter, Charles G., *Suction-socket prosthesis for a hip-disarticulation amputee*, J. Bone & Joint Surg., 35A:230 (1953).
25. James, Arthur G., and Wesley Furste, *Radical surgery for cancer of the extremities*, Am. J. Surg., 85:503 (1953).
26. Katz, Elias, Private communication.
27. Kirk, Norman T., and Leonard T. Peterson, *Amputations*, Chapter 10 in *Lewis' Practice of surgery*, Prior, Hagerstown, Md., 1944. Vol. 3, pp. 84-87.
28. Larrey, Dominique Jean, *Memoires de chirurgie militaire, et campagnes*, J. Smith, Paris, 1812. Vol. 2, pp. 180-195. Vol. 3, p. 350.
29. Lee, C. Marshall, Jr., and Lewis P. Alt, *Hemipelvectomy and hip disarticulation for malignant tumors of the pelvis and lower extremity*, Ann. Surg., 137:704 (1953).
30. Leriche, Rene, *A propos de 13 cas de disarticulation de la hanche*, Mem. Acad. chir., 63:1435 (1937).
31. Lewis, Royce C., and William H. Bickel, *Hemipelvectomy for malignant disease*, J.A.M.A., 165:8 (1957).
32. McBurney, Charles, *Direct intra-abdominal finger-compression of the common iliac artery during amputation at the hip-joint*, Ann. Surg., 25:610 (1897).
33. Marquardt, Wolfgang, *Gliedmassenamputationen und Gliederersatz*, Wissenschaft. Verlagsges., Stuttgart, 1950. pp. 82-85.
34. Maynard, R. L., *Hip-joint disarticulations*, Trans. New England Surg. Soc., 24:248 (1941).
35. Meyeringh, H., and H. Stefani, *Besteht nach einer Amputation des Oberschenkels eine Neigung zur Adipositas und zur Hypertension?*, Deutsche med. Wchnschr., 81:10 (1956).
36. Morand, Sauveur Francois, *Opuscules de chirurgie*, Desprez, Paris, 1768. Vol. 1, pp. 176-228.
37. Morris, Robert T., *Hip joint amputation, ventral hernia, appendicitis, salpingitis, a clinic at the New York Post Graduate Medical School April 18, 1917*, West. M. Times, 37:1 (1917).
38. *Outlook for the amputee* (Annotation), Lancet, 1:89 (1955).
39. Pack, George T., *Major exarticulations for malignant neoplasms of the extremities: interscapulothoracic amputation, hip-joint disarticulation and interilioabdominal amputation*, J. Bone & Joint Surg., 38A:249 (1956).
40. Pack, George T., and Harry E. Ehrlich, *Exarticulations of the lower extremities for malignant tumors: hip joint disarticulation (with and without deep iliac dissection) and sacro-iliac disarticulation (hemipelvectomy)*, Ann. Surg., 123:965 (1946). Parts I & II.
41. Petrovskii, B. V., *Method of disarticulation of the hip*, Vestnik khir., 72:50 (1952). In Russian.
42. Piquinela, Jose A., *Desarticulacion de cadera.—Su tecnica de acuerdo con los principios del metodo de Callander*, Arch. urug. med., 48:191 (1956).
43. Pitkin, George P., *Conduction anesthesia*, 2nd ed., James L. Southworth, Robert A. Hingson, and Winifred M. Pitkin, eds., Lippincott, Philadelphia, 1953.
44. Richerand, cited in 60, p. 8.
45. Saltzstein, Harry C., *Osteogenic sarcoma of upper third of femur; well ten years after disarticulation at the hip joint*, J. Michigan Med. Soc., 43:145 (1944).
46. Schneider, K. W., *Zur Frage der Plethora und Hypertonie bei Amputierten*, Klin. Wchnschr., 31:697 (1953).
47. Schroder, Joachim, *Zur Frage einer besonderen Kreislaufbelastung bei Gliedmassenamputierten infolge einer Mehrbeanspruchung ihrer Warmeregulation*, Deutsche med. Wchnschr., 81:1620 (1956).
48. Schulze, Karl, *Über den Einfluss grosser Amputationen auf den Gesamtorganismus; eine Studie zur Frage der Spatschaden bei Oberschenkelamputierten*, Arbeit u. Gesundh., No. 41:69 (1942).
49. [Shuter, James], *Subperiosteal amputation at the hip-joint*, Report of Clinical Society of London, Brit. Med. J., 1:314 (1883).
50. Shuter, James, *Subperiosteal amputation at the hip-joint: formation of new bone in the stump: moveable stump: patient wearing an artificial limb*, Trans. Clin. Soc. London, 16:86 (1883).
51. Slocum, Donald B., *An atlas of amputations*, Mosby, St. Louis, 1949. pp. 239-247, 402-410.
52. Smith, Beverly Chew, *Disarticulation of the hip for endothelioma (Ewing's tumor): 31-year follow-up*, Ann. Surg., 115:318 (1942).
53. Smith, S., *Statistics of the operation of amputation at the hip-joint*, New York J. Med., 9:184 (1852).
54. Stajano, C., *El mecanismo del "choc" en la desarticulacion de la cadera*, Arch. urug. med., 10:642 (1937).
55. Strauss, Kurt, *Exarticulatio coxae bei Schwangerschaft und allgemeiner Sepsis*, Miinchen. med. Wchnschr., 86:1751 (1939).
56. Sturm, Alexander, *Hochdruck nach Oberschenkelamputation*, Med. Klin., 48:197 (1953).
57. Sturm, A., W. Frisch, and H. W. Grünwald, *Interne Auswirkungen von Beinamputationen; Ergebnis einer Reihenuntersuchung*, Medizinische, No. 35:1132 (1954).
58. Thomson, John, *Report of observations made in the British military hospitals in Belgium after the Battle of Waterloo*, Blackwood, Edinburgh, 1816. pp. 259-279.
59. Tikhonov, V. M., *Short thigh stump in children, its lengthening and preparation for prosthesis*, Tr.

- Tsentr. Nauchnoissledov. inst. protez. Moskva, 72:258 (1949). In Russian.
60. Tixier and Arnulf, *Auto-transfusion au cours d'une desarticulation de la hanche, en utilisant le sang du membre enleee. Disarticulation pour epithelioma developpt sur une ancienne brulure de la cuisse et de la /esse jusqu'd Vanus; anus de Pollosson (derivation totale) prealable*, Lyon chir., 32:443 (1935).
 61. Trendelenburg, F., *Ueber Exarticulation des Oberschenkels*, Arch. klin. Chir., 26:858 (1881).
 62. U. S. Surgeon General's Office, *Circular No. 7: a report on amputations at the hip-joint in military surgery* [By G. A. Otis], U. S. Gov't. Print. Off., Washington, D. C., 1867.
 63. U. S. Surgeon General's Office, *The medical and surgical history of the War of the Rebellion (1861-1865)*, U. S. Gov't. Print. Off., Washington, D. C., 1870-88. Part 3, vol. 2: *Surgical history*. pp. 88, 89, 127-168.
 64. U. S. Surgeon General's Office, *The Medical Department of the U. S. Army in the World War*, U. S. Gov't. Print. Off., Washington, D. C., 1921-1929. Vol. II, *Surgery*, Part 1 (*General surgery, orthopedic surgery, neurosurgery*).
 65. Velpeau, Alf. A. L. M., *New elements of operative surgery*, 1st American ed., from last [2nd] Paris ed. [1839], translated by P. S. Townsend, under supervision of Valentine Mott, S. S. & W. Wood, New York, 1847. Vol. 2, pp. 637-653.
 66. Verrall, P. Jenner, *Some amputation problems*, Proc. Roy. Soc. Med., 24:183 (1930).
 67. Wyeth, John A., *Bloodless amputation at the hip joint*, New York Med. J., 61:528 (1890).

The Evolution of the Canadian-Type Hip-Disarticulation Prosthesis

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Not many people are amputees. Still fewer people are prosthetists. Not many amputees are hip-disarticulation cases. Hence, not many prosthetists are interested in hip-disarticulation prostheses except when occasion demands. That just about sums up the history of hip-disarticulation prosthetics.

A more intensive look at the picture reveals two more or less standard approaches to the problem, but usually there are as many variations as there are limbshops. The accompanying illustrations (Figs. 1 through 6) indicate the practice, if not the principle, of conventional fitting, together with some of the variants. A study of the principles of conventional fitting is even more revealing. The guiding one seems to be this: Take one standard above-knee leg and build on to it until it can be strapped to the amputee. The practice certainly bears this out. Even the term "tilting-table prosthesis" suggests working from the leg up to the stump, instead of beginning with the amputee, who properly should be the focal point in any attempt at rehabilitation.

This back-handed approach to problems is not something unique among limbfitters. The plumber is more interested in joining pipes than he is in the water requirements of a household. The airplane pilot is more concerned with the trim of the aircraft than

with the comfort of the passengers' seats. The prosthetist's main interest lies in making a leg he can fit on the customer, and in so doing he has shown a considerable amount of ingenuity. Perhaps had the variations not been local in nature, more progress could have been made. Many fitters have come surprisingly close to the Canadian-type prosthesis, and no doubt others actually envisioned the basic principles without achieving the mechanical design.

Generally speaking, the hip-disarticulation case has been considered very unfortunate when compared with other above-knee cases. Perhaps some of this attitude is owing to the fact that a great many cases are not of traumatic origin and that therefore the life expectancy is short. In any event, the result is that the amputee is not encouraged to expect much from his prosthesis. The usual complaints are mechanical in nature—rattling in the joints and the need for frequent repair. Accordingly, most innovations in the prostheses have been directed toward solving these mechanical problems, and more by chance than by design functional advantages evolved.

Conventional hip-disarticulation prostheses are usually classified into two main categories, the saucer type and the more common tilting-table type.

THE SAUCER-TYPE PROSTHESIS

The saucer type of prosthesis, shown in Figure 1, is essentially a standard above-knee leg with a saucer-shaped socket on top of the thigh. Suspension is by means of a single-axis joint and pelvic band and may include fore

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and aft straps that pass over the shoulder. This type is most suitable for short-femur amputations because adequate stability is difficult to achieve without the additional bone structure. In accord with common practice with above-knee legs, the hip joint is placed well forward, thus providing some measure of stability. A lock may or may not be used at the hip joint. If a lock is used, it is of the semiautomatic type. A lever is pressed to release the lock for sitting, and the lock engages automatically on full extension. The lock provides stability (at some loss of function), but it offers mechanical difficulties because all the loads are funneled through the relatively small joint.

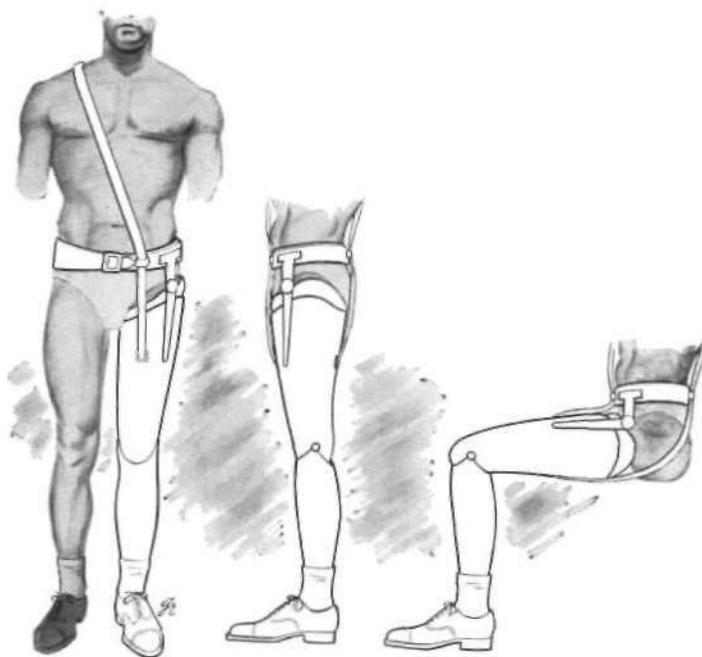


Fig. 1. Saucer-type prosthesis for hip disarticulation.

THE TILTING-TABLE PROSTHESIS

Although not so simple or as light as the saucer type, the tilting-table prosthesis is more generally used because of the additional

support. Figure 2 shows a typical prosthesis. A socket, usually of leather, is made to fit the stump and attached by a belt around the pelvis and often with a strap over the shoulder. The socket is articulated on the thigh section with a metal joint lateral to the acetabulum. Again the joint may or may not have a semiautomatic lock. Without a lock, the wearer has little control over the limb, most of the stability during the stance phase being afforded by friction between the socket and the thigh section.

Because it is extremely difficult to make a hip joint strong enough to bear the entire load, contact between the socket and the medial edge of the thigh section is essential in weight-bearing, and this expedient is of course equally important when a lock is used. Figures 3 and 4 illustrate two meth-

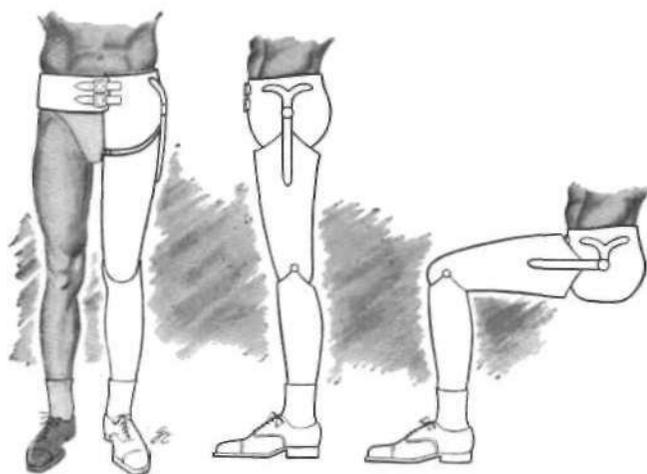


Fig. 2. Tilting-table prosthesis for hip disarticulation, basic design.

ods that have been tried. In Figure 3, a strap is fastened to the socket and passed under rollers attached near the medial brim of the thigh. These rollers also take the downward thrust of the socket, and a metal track may be attached to the socket for the rollers to bear upon. Figure 4 illustrates a dead-center latch mechanism. When the hip joint is fully extended, the latch flips by dead center and secures the socket to the thigh. A hip lock is necessary with this arrangement.

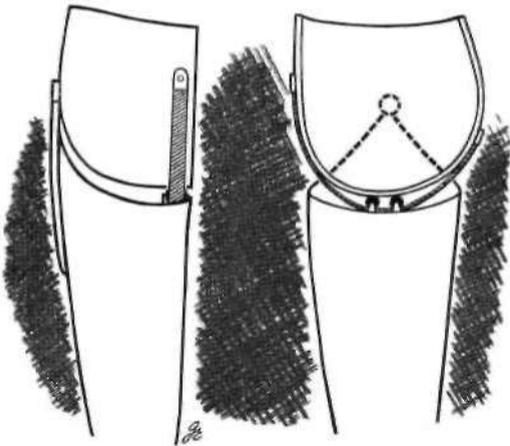


Fig. 3. Variations in tilting-table prostheses: strap-and-roller medial support. Left, anterior view; right, medial view.

Figure 5 illustrates a fairly common departure in design. The walking function is identical, but the hip joint has been lowered to a position beneath the socket where a full-width bearing may be made much lighter. Because of the position of the joint directly below the center of gravity, however, a lock must be used. Along with the usual inconveniences and mechanical difficulties, this type also has distinct disadvantages in sitting. The thigh section is much shorter than normal, and the bulk of the joint raises the socket about an inch above chair height.

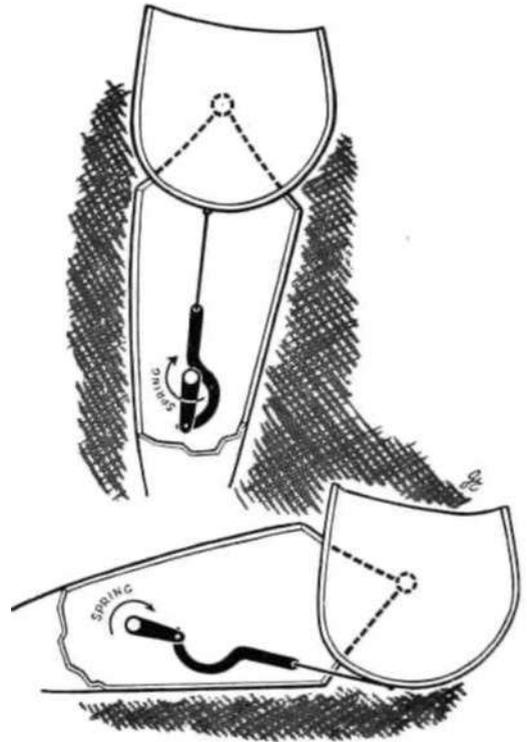


Fig. 4. Variations in tilting-table prostheses: latch-type medial support, cross-sectional view. Above, standing; below, sitting.

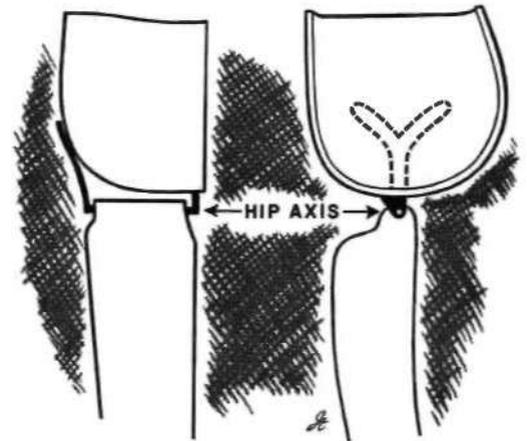


Fig. 5. Variations in tilting-table prostheses: hip joint below socket. Left, anterior view; right, medial view.

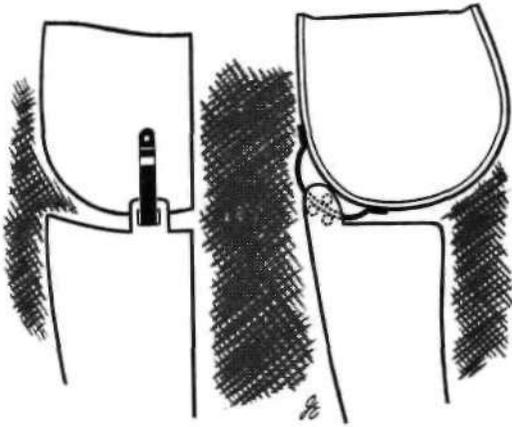


Fig. 6. Variations in tilting-table prostheses: track-and-roller joint. Left, anterior view; right, medial view.

Figure 6 shows a rather interesting deviation. This design uses a track-and-roller mechanism in which the center of rotation is a few inches lower and anterior to the acetabulum. The actual model seen by the writer was heavy and crude in construction so that binding of the rollers on the tracks prevented free motion, but it is worth noting since in principle it is almost identical to the present Canadian type, and it seems to be designed with a view toward improving function.

THE U. S. NAVY HYDRAULIC PROSTHESIS

At the close of World War II, the U. S. Navy designed and fitted a hydraulic prosthesis with the primary purpose of improving function. Figure 7 illustrates the main features of the device. The very large ball-bearing hip joint was made strong enough to bear all the weight, thus obtaining a free joint. An extension controlled the motion about the knee joint. The cylinder in turn was controlled by a valve which was either automatically or manually actuated. Normal motion about the hip joint allowed the piston to move slowly, as in an automobile shock absorber, and the knee joint was thus permitted to flex and extend with some damping. But fast rotation about the hip joint (as in stumbling) caused the valve to close and thus stabilized the knee. The manual control also closed the

valve and locked the knee in any position. There were two disadvantages of this device—cost and weight. In addition, the application of hydraulics to prosthetics usually introduces problems of noise, leakage, and occasional erratic behavior.

THE INFLUENCE OF MATERIALS

A review of prosthetics practice in the hip-disarticulation case would be incomplete without reference to materials. The shank and thigh members are usually of wood covered with rawhide as in standard above-knee legs, but because of the saving in weight aluminum-alloy members are preferable when available. Steel is the almost exclusive medium for hip joints and locks, but in the Navy hydraulic prosthesis aluminum alloy was used to save weight. Sockets are usually made of two layers of leather, with Celastic core for stiffness. Aluminum alloy and monel (an alloy of copper and nickel) have been quite successful. They are usually lighter, more sanitary, and easier to attach to the joints. Plastic laminates are light, strong, sanitary, and easily molded to complex shapes, and it is not surprising to find them successfully used in hip-disarticulation sockets. It was the ease

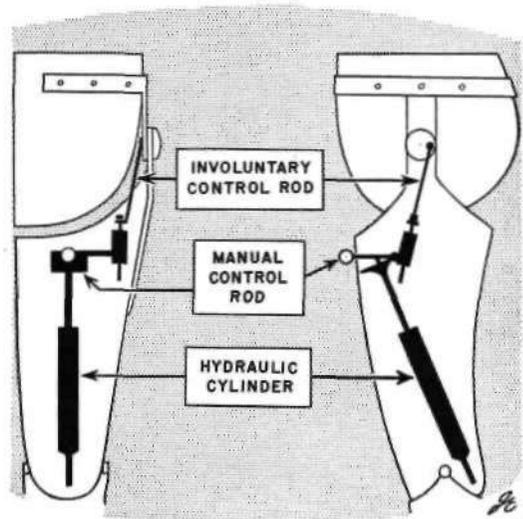


Fig. 7. Navy hydraulic prosthesis for hip disarticulation, schematic.

of fabrication that made possible the plastic socket with the wrap-around pelvic band (page 33).

Generally speaking, the materials and the mechanical designs were chosen with a view toward solving the mechanical problems, and it was with this thought in mind that design study was begun at Sunnybrook Hospital in Toronto. The highlights of this study are worth noting as an illustration of how an indirect approach to a problem can achieve results.

EVOLUTION OF THE CANADIAN DESIGN

The primary objective at Sunnybrook was to construct a hip-disarticulation prosthesis that would avoid the stress concentrations in conventional locks and to provide a simple method for releasing the locks. The first experimental prosthesis employed a four-link mechanism, as shown in Figure 8. The links were about 4 in. wide to provide adequate lateral strength. The socket was plastic and the thigh section aluminum alloy. It was intended that a posterior strap be used to lock the leg in full extension, but initial trials indicated adequate stability without a lock owing to the fact that at or near full extension the effective hip center was well forward of the center of gravity and because the posterior brim of the thigh prevented hyperextension. In order to achieve simplicity in assembly and to increase mechanical rigidity, the forward link was lengthened and made strong enough to support all the main loads (Fig. 9). The rear link thus acted only as a guide and could be made light and adjustable.

One difficulty remained—there was a chopping action between the top of the thigh and the socket such that serious pinching could result. Owing to the geometry of the linkage system, the gap between the thigh and the socket was present whenever the thigh was neither fully flexed nor fully extended.

The next step in the evolution was to extend the front link to include the knee joint and to replace the rear link with a simple rubber stop to prevent hyperextension. This final configuration, shown in Figure 10, permitted the use of a single broad joint without

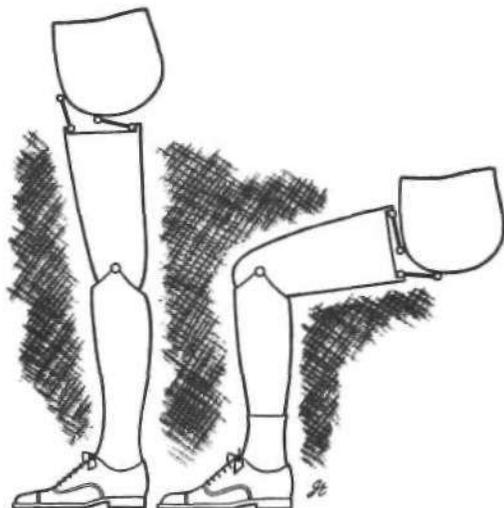


Fig. 8. Steps in the evolution of the Canadian-type hip-disarticulation prosthesis: four-link mechanism.

locks. At first it was felt that the position of the stop would be critical, and accordingly the first unit included a stop that could easily be adjusted by the amputee. It was soon found that this feature was not critical and

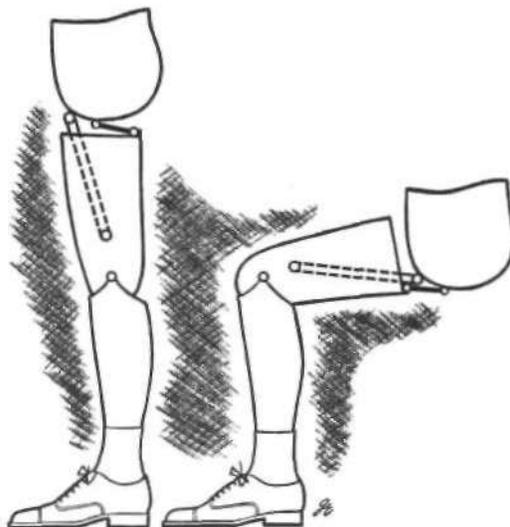


Fig. 9. Steps in the evolution of the Canadian-type hip-disarticulation prosthesis: modified four-link mechanism.

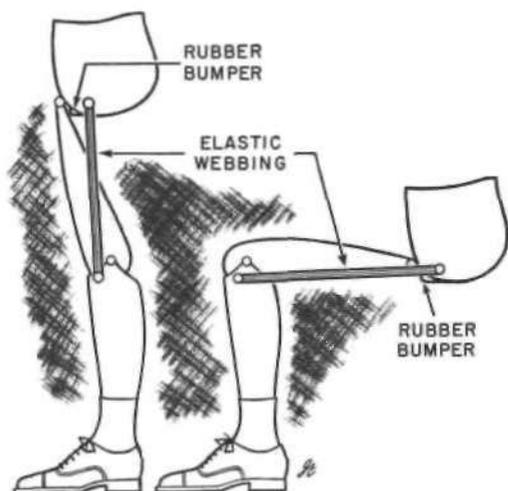


Fig. 10. Steps in the evolution of the Canadian-type hip-disarticulation prosthesis: final design.

that initial adjustment by shimming or grinding was adequate. The most apparent difficulty was the tendency for too long and too slow a stride, and thus the elastic webbing was added to restrain hip flexion. Cosmetic appearance was improved by a floating thigh cover (Fig. 11) made of horsehide and attached to the socket only. A foam-rubber

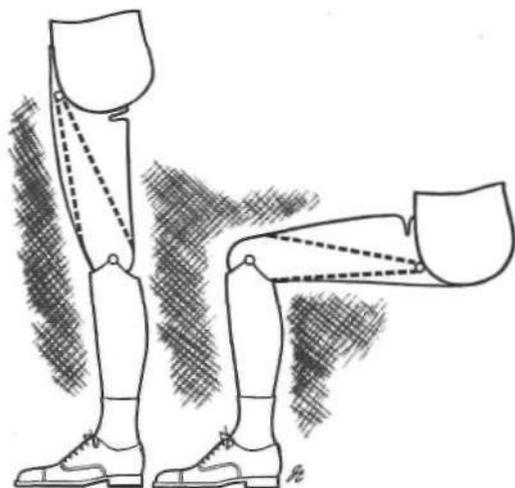


Fig. 11. Steps in the evolution of the Canadian-type hip-disarticulation prosthesis: floating thigh cover for cosmesis.

liner was glued to the horsehide to give it stiffness.

Apart from the mechanical simplicity of the new prosthesis, functional advantages soon became apparent. Little effort was required in the swing phase, and a full stride was easily obtained. Previously, with a locked hip joint, hip flexion was simulated either by pelvic rotation or by motion of the socket on the stump. The resultant gait was usually jerky and tiring, although some amputees had learned to walk surprisingly well. Since the amputee is actually "sitting" in the socket, complaints of discomfort were not common, but obtaining adequate security in the socket was a different matter.

Too seldom have the bony prominences of the ilium been used for secure fitting. Usually a broad, leather pelvic belt, as in Figure 2, was used for lateral support and a shoulder strap was added to prevent the socket from dropping down during the swing phase. The excessive weight of many prostheses necessitated the shoulder strap. The ischial seat is nearly always available for direct weight-bearing, and the areas for taking pressure elsewhere are large. If the socket is extended in the form of a band across the back of the pelvis and around to the opposite iliac crest, then three points of the innominate bones are firmly gripped, as shown in Figure 12. Since

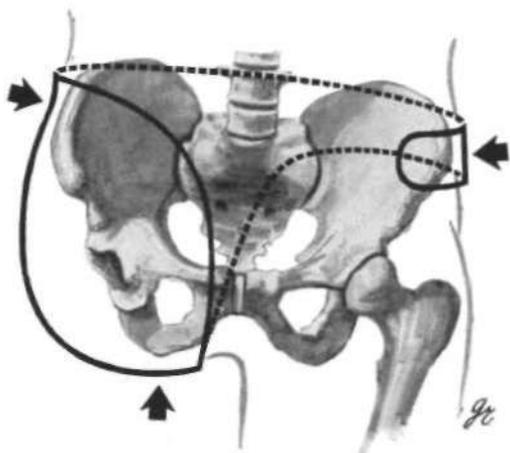


Fig. 12. Anterior view of socket-waistband showing three points where the skeletal structure is firmly gripped.

these three points are well spaced, excellent lateral stability is obtained. It is undesirable to have the socket extend above the iliac crests since doing so causes restriction and discomfort. Adequate vertical support can be obtained by ensuring a close fit in the area between the crests and the anterior-superior spine of each ilium.

CONCLUSION

The Canadian-type prosthesis has been fitted to many amputees at various centers and over a period of several years. Stability with the free hip and knee joints is adequate if correct alignment is attained and if some gait training is provided. In a fall, the prosthesis is usually safer, since the joints collapse and prevent vaulting. One amputee has sustained several falls without injury to himself or the prosthesis. There are, however, several

improvements possible in walking characteristics of the prosthesis. The elastic check-strap prevents excessive hip flexion, but some means should be provided for cadence control. Without restraining forces at the knee and hip, the leg tends to walk at its own pace as determined by its pendulum properties. Correctly applied friction or hydraulic devices could enhance the swing characteristics so that various speeds and strides could easily be attained. Furthermore, stability at the knee joint depends upon hyperextension. This means that knee flexion requires effort. A knee which would provide adequate stability at heel contact and yet flex easily when required would offer a big advantage. No doubt several years hence the present device will seem crude and clumsy; in the meantime it provides a light, strong, and relatively efficient prosthesis.

The Biomechanics of the Canadian-Type Hip-Disarticulation Prosthesis¹

CHARLES W. RADCLIFFE, M.S., M.E.²

Establishment of a rational procedure for the proper fitting of a leg prosthesis to an amputee at *any* level of amputation requires careful consideration of many factors. The process of evolution of a new and satisfactory method of fitting of prostheses has generally been a lengthy one involving trials on amputees by a number of experimenters over a period of many years. Recently, both in the United States and in foreign countries this process has been accelerated through the efforts of research teams, which through a combination of the skills of personnel from the fields of medicine, prosthetics, and engineering have attempted to solve problems in a more logical, scientific manner. The Canadian-type hip-disarticulation prosthesis is an excellent example of an improved device that has resulted from the efforts of organized research in limb prosthetics.

In a technical discussion of the principles of fitting of *any* prosthesis, it is often convenient first to describe the biomechanics involved, the term "biomechanics" referring both to the residual functional anatomy and to the mechanical implications of wearing a prosthesis applied to the stump. The biomechanical analysis establishes the pattern of force trans-

mission between the prosthesis and the stump. Once the force pattern is known, physiological and anatomical factors must be considered in determining whether or not the proposed areas of force transmission are pressure-sensitive or unsatisfactory for other reasons. If there are no physiological contraindications, it then becomes the responsibility of the prosthetist to fit and align the prosthesis in a functional and comfortable manner as dictated by the biomechanical and physiological requirements. Comfort is generally achieved by a distribution of any individual contact force over an area of the socket large enough to reduce the pressure on the stump to a tolerable magnitude.

The biomechanical analysis of the Canadian-type hip-disarticulation prosthesis can be divided conveniently into two parts: first, an evaluation of the stump-socket forces required to support the torso in the stance phase and, second, a review of the dynamic behavior of the combined amputee and his prosthesis in level walking.

PRINCIPLES OF MECHANICS

FORCE

A "force" is the physical action of one body upon a second body which tends to change its position in space (Fig. 1). In interpreting the diagrams to follow, it will be necessary to consider the concept of force as a vector quantity. Force vectors, for example that shown in Figure 2, must be specified by magnitude (indicated by length of a particular force arrow), sense or direction (indicated by

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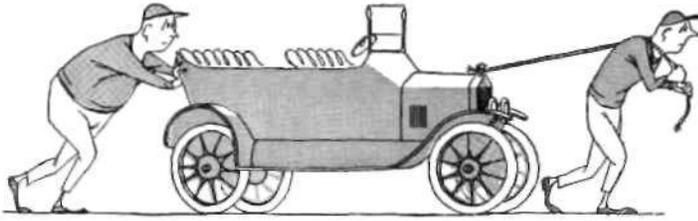


Fig. 1. "Force" defined. A "force" is the physical action of one body upon a second body. It may be either a push (compression) or a pull (tension).

the arrow head), and the line of action (indicated by location of the shaft of the arrow).

PRESSURE

"Pressure" is a measure of the distribution of force over an area. Since pressure is defined as force per unit area, it is calculated by dividing the force by the area over which it acts. This would give an "average" pressure. Pressure is seldom uniform, and its variation is often indicated by a series of pressure vectors such as shown by the smaller arrows in Figure 3. Where both force and pressure vectors are shown on the same diagram, the force vector indicates the "resultant," that is, the sum of the effects of the distributed pressures in a particular region.

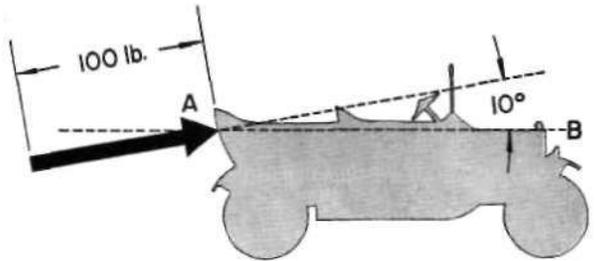


Fig. 2. The "force vector." The one shown here represents a 100-lb. force applied by a "second body." The force acts to the right, through point A, along a line inclined 10 deg. from the horizontal line AB. The scale factor for this force vector is 100 lb. per inch of length.

EQUILIBRIUM

In force analyses, use is made of two fundamental principles of analytical mechanics: the concept of "force equilibrium" and the concept of "moment equilibrium."

Force Equilibrium

The principle of force equilibrium, first stated by Newton, can be interpreted in the following form: In order for a body to remain at rest (fixed, relative to a point in space) the vector sum of all forces acting upon it must be zero (Fig. 4).

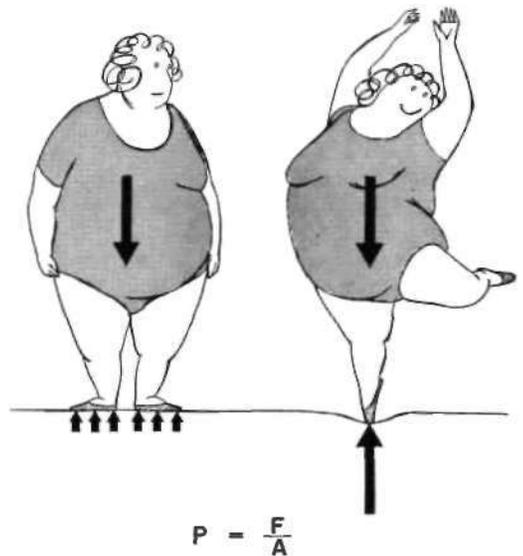


Fig. 3. "Pressure" defined. "Pressure" is force supported per unit area. A broad area of support results in lower values of average pressure.

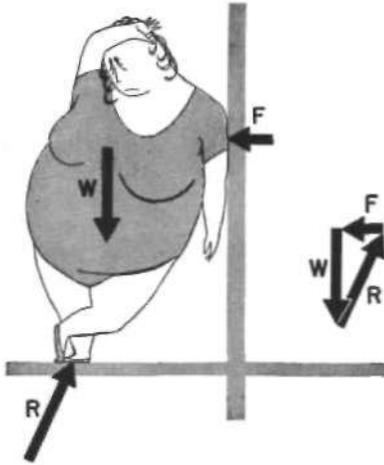


Fig. 4. "Force equilibrium" defined. In force equilibrium, the vector sum of all forces is equal to zero. The force diagram must form a closed polygon.

Moment Equilibrium

A "moment" is the product of a force acting through some perpendicular distance from a reference point or "moment center." A moment tends to cause a physical body to

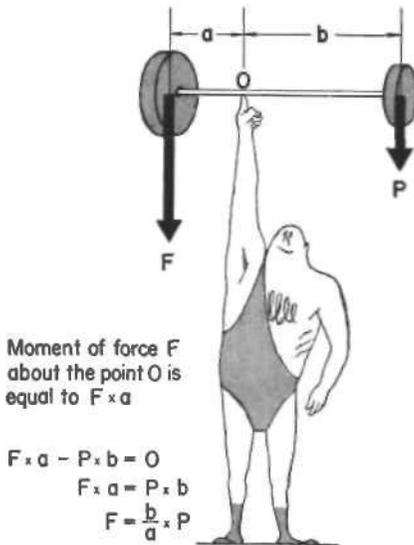


Fig. 5. "Moment equilibrium" defined. For moment equilibrium, the moments acting about a center of rotation must be in balance.

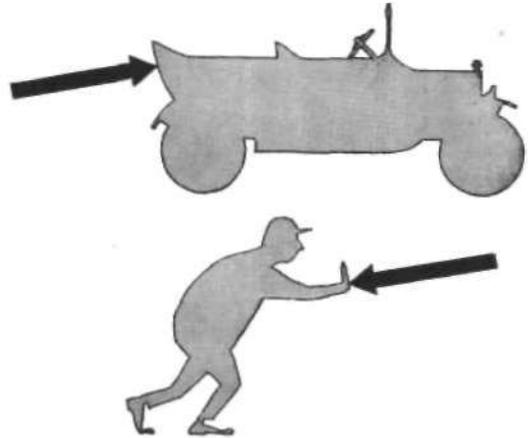


Fig. 6. Free-body diagrams of the individual, isolated bodies, with the action of the second body represented by a force vector. Note that "action" on one body results in a "reaction" on the second.

rotate. In the simple lever shown in Figure 5, the force F exerts a moment $F \times a$ about the point O . In order for the body to have no tendency to rotate, the sum of all moments acting upon it must be zero, such as when a force P on one end of the lever, acting through distance b , balances a similar force F on the opposite end, acting through distance a , as in Figure 5.

FREE-BODY DIAGRAMS

Another useful concept is the "free-body diagram" used extensively in engineering mechanics. When a system or structure involves more than one distinct physical body, the parts are often shown separately, as in Figure 6, and the effect of each mating part is accounted for by a vector representing the force exerted by it on the part being considered as a free body.

FUNCTIONAL DESCRIPTION OF THE CANADIAN-TYPE HIP-DISARTICULATION PROSTHESIS

The functional features of the original design of the Canadian-type hip-disarticulation prosthesis are shown in Figure 7, which is reproduced from the Canadian report of March 1954. Although there has since been minor modification of the methods for fitting

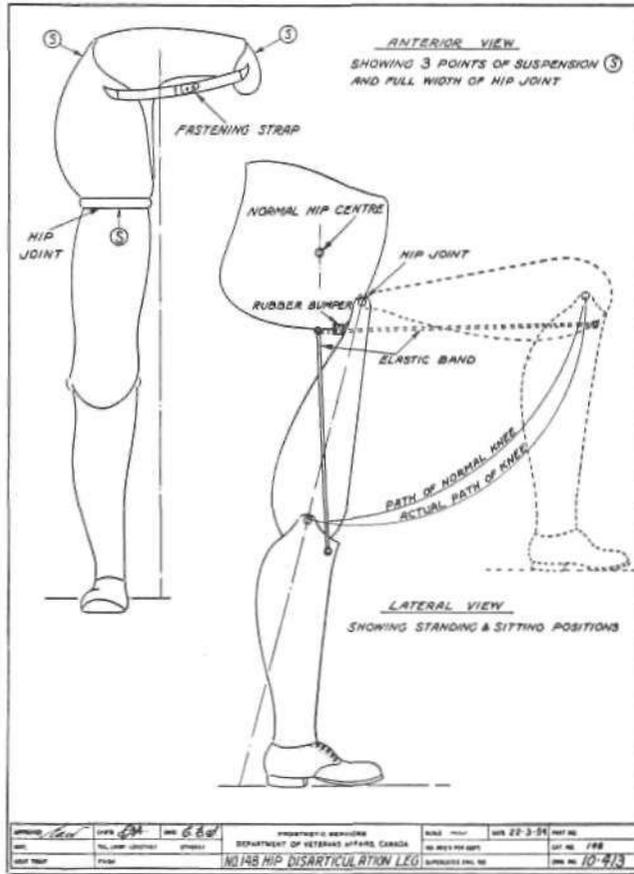


Fig. 7. Original design of the Canadian-type hip-disarticulation prosthesis. From McLaurin (1).

and alignment of the device, its functional features remain unchanged (Fig. 8). They include:

A continuous, laminated-plastic socket-waistband. The socket-waistband is fitted so as to provide three reaction points (points of suspension), as shown in Figure 7. The weight-bearing area of the socket is constructed of rigid plastic laminate, while the waistband is made flexible to permit easy donning of the prosthesis.

Alignment stability. A unique arrangement of joint locations results in improved security against buckling of the knee in any normal walking situation, the hip joint being located below and forward of the normal axis of the hip (Fig. 7). With the hip joint so located, the effective length of the leg is the same in both standing and sitting. A reference line extended through the hip and knee joints passes a minimum of 1 in. behind the heel, so that as long as the prosthesis bears

weight the load transmitted between the foot and the hip joint always passes ahead of the knee joint, thus ensuring knee security. When required, flexion of the knee is initiated by contact of the elastic hip bumper (attached to the bottom of the socket) with a stop on the upper posterior portion of the thigh. As long as the hip bumper is not in contact, the knee joint is always completely stable.

Full-width hip joint. The full-width hip joint allows a much stronger connection between socket and thigh. The hip joint is similar to a prosthetic knee joint and is highly effective in resisting lateral bending at the connection between socket and thigh piece.

Hip-joint motion. In level walking, the hip joint allows approximately 15 deg. of relative motion between socket and thigh. The amount of motion is limited by the hip-flexion control strap (shown as "elastic band" in Figure 7). This arrangement allows the leg to assume a natural inclination at heel contact without backward tilting of the pelvis.

FUNCTIONAL SEQUENCE IN USE OF THE PROSTHESIS

The manner in which the amputee walks on the prosthesis can be described by dividing the stance phase of walking into three parts: heel contact, mid-stance (roll-over), and push-off.

Heel Contact

As the leg swings forward preparatory to heel contact, the hip-flexion control strap limits the free hip-joint motion to approximately 15 deg. This hip-joint motion, in combination with a slight pelvic motion, allows the leg to assume a natural backward inclination as the heel makes contact. The amputee moves forward over the prosthesis, and the heel is planted on the floor without hesitation.³ The weight-bearing prosthesis is extremely stable owing to the alignment of the hip, knee, and ankle joints, and the objective is to attain knee security by having an appreciable amount of force transmitted through the prosthesis at the instant of heel contact. Where additional security is desired, the amputee leans forward slightly at the time of heel contact. Doing so results in an increased tension in the hip-flexion control strap, which helps to hold the knee in full extension.

Mid-Stance (Roll-Over)

As the amputee rolls over the extended prosthesis during the mid-portion of the stance phase, knee security is increased as the weight-bearing line moves forward toward the ball of the foot. Hip-joint motion causes the hip-flexion control strap to relax, and the amputee rides forward with the socket balanced on the free hip joint. Pelvic stability is maintained by the momentum of the torso.

Push-Off (Start of Knee Flexion)

At the end of the stance phase, the prosthesis must be propelled forward into the swing phase. The amputee using a tilting-table prosthesis does this by a lifting and internal

³ The foot should not swing up and then snap back into contact with the floor.

rotation of the pelvis on the side of the amputation. A normal individual achieves knee flexion at the time of push-off by combined hip and ankle action.

The amputee using the Canadian-type hip - disarticulation prosthesis initiates flexion by a method somewhat similar to that used by an above-knee amputee wearing a suction socket. As the prosthesis inclines forward with the weight borne through the ball of the foot, the angle of hip flexion is reduced until contact is made between the elastic bumper system at the rear of the hip joint. As the socket continues to progress forward in a straight line (without pelvic rotation), continued forward inclination of the

thigh causes an increase in the compression in the bumper system. The moment thus developed about the hip joint eventually disturbs the knee stability and causes the knee to flex forward into the swing phase. By proper adjustment of the stiffness and point of contact of the hip-bumper system, a very natural knee flexion at the time of push-off can be achieved. The amputee should never lift the pelvis and swing the leg forward by internal pelvic rotation. Rather, the recommended action is exactly the opposite. The amputee "sits hard" on the prosthesis in order to start the knee flexing. Where more rapid knee flexion is desired, a slight backward

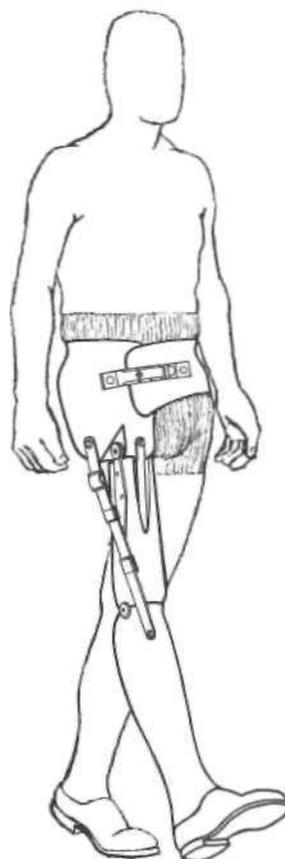


Fig. 8. The Canadian-type hip-disarticulation prosthesis as modified at the University of California (Berkeley).

rotation of the socket to increase the compression of the hip bumper will propel the prosthesis forward forcibly. If weight is transferred to the natural leg simultaneously, there should be no feeling of insecurity at this time.

ACTION OF THE SOCKET IN LATERAL SUPPORT OF THE TORSO

Foot Position

Figure 9, a series of free-body diagrams, shows, as viewed from the front, the rather simple force system which is acting when an amputee is walking on a Canadian-type hip-disarticulation prosthesis, the situation depicted being the period of mid-stance on the

prosthesis when mediolateral dynamic effects are negligible. Figure 9A shows the system of externally applied forces acting on the prosthesis alone. Figure 9B shows the forces acting on the combination of the amputee and the prosthesis.⁴ Figure 9C shows the external force system acting on the amputee considered as an isolated free body.

Figure 9B involves the simplest force system and is therefore discussed first. Two

⁴ In Figure 9B, contact forces between stump and socket are internal forces which cancel out when the combined system of amputee and prosthesis is considered.

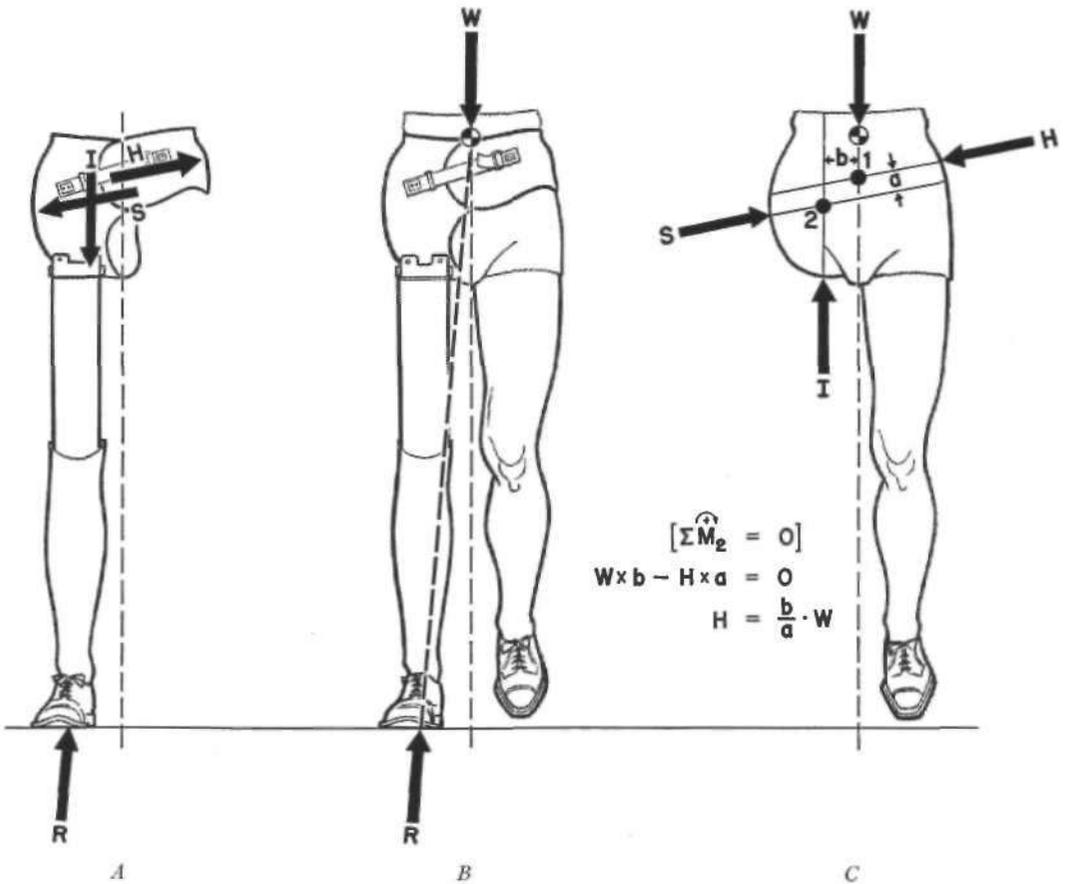


Fig. 9. Mediolateral force diagram of the Canadian-type hip-disarticulation prosthesis. A, Forces acting on the prosthesis (exerted by floor and stump); B, forces acting on combination of amputee and prosthesis (exerted by floor and gravity); C, forces acting on amputee (exerted by prosthesis and gravity).

forces are involved—the supporting floor reaction and the downward force of the body weight. The vertical component of the floor reaction is equal in magnitude to the downward force and hence just balances the body weight. The body can therefore be assumed to be in force equilibrium in the vertical direction. But the floor reaction, being inclined generally inward, has an inward component along the floor, which means that the entire body is being accelerated toward the sound side. This acceleration would result in a change in direction of motion of the torso, that is, in a movement toward the amputee's normal side. Such mediolateral oscillating motion of the body as a whole is characteristic of normal subjects as well as of amputees. To maintain mediolateral motion within normal limits in the amputee, the inclination of the floor reaction to the plane of progression must be minimized, and the hip-disarticulation prosthesis is therefore aligned to give a narrow walking base. Experience has shown that the walking base should be less than 4 in. from heel center to heel center.

Stump-Socket Forces as Viewed from the Front

The consideration of forces acting on the stump, which result in part from the requirement of a narrow walking base, is more complicated. As can be seen in Figure 9C, four forces act on the combined stump and torso of the hip-disarticulation amputee—the downward force of the body weight acting through the center of gravity, the distributed vertical support pressures acting upward on the ischial-gluteal region, and distributed socket pressure between stump and socket-waistband acting on both normal and amputated sides. A single force vector is used when necessary to approximate the effects of the actual pressure distribution.

Figure 9A shows the forces acting on the prosthesis considered as an isolated free body. It is to be noted that the body weight, that is, the effect of the downward pull of gravity, does not act on the socket *per se*. The effect of the body weight is made apparent by the opposite reaction (acting downward) of the vertically upward ischial-gluteal support seen acting on the stump-torso in Figure 9C.

If the body weight and ischial-gluteal support forces were the only two forces acting on the torso, the body would have a tendency to rotate about the point of support and to drop toward the unsupported normal side. This tendency is counteracted by the moment of the couple formed by the two mediolateral forces H and S . For moment equilibrium, taking the summation of moments about point 2 equal to zero, $W \times b = H \times a$. Or,

$$H = (b/a)W$$

Thus the magnitude of the reaction against the normal hip, or the tension in the waistband, or both, can be reduced by increasing the distance a . Moving the concentration of lateral forces on the stump to a lower level by alteration of fit is practical only within certain limits. Too low a position would result in shear forces along the bottom of the stump and in considerable relative motion between stump and socket. It is also apparent that, owing to the limitations on increasing dimension a , the lateral forces H and S are of the same order of magnitude as the vertical forces W and I , since dimensions a and b would be approximately equal.

Stump-Socket Forces as Viewed from the Side

Figure 10 shows the pattern of forces acting on the amputee and/or his prosthesis as viewed from the side during level walking. Figure 10A indicates the force system acting on the prosthesis isolated as a free body at heel contact. Figure 10B shows the forces exerted by the socket on the stump-torso, plus the action of the body weight, during the three major divisions of the stance phase in level walking—heel contact, mid-stance, and push-off. Figure 10C is a free-body diagram of the isolated prosthesis at push-off. Again the use of free-body diagrams allows a clear distinction between forces acting on the amputee and forces acting on the prosthesis.

At the time of heel contact on the prosthesis, the normal leg is completing push-off. The force acting on the normal foot is then transmitted through the normal leg to the pelvis. This thrust of the normal leg is shown in

M.

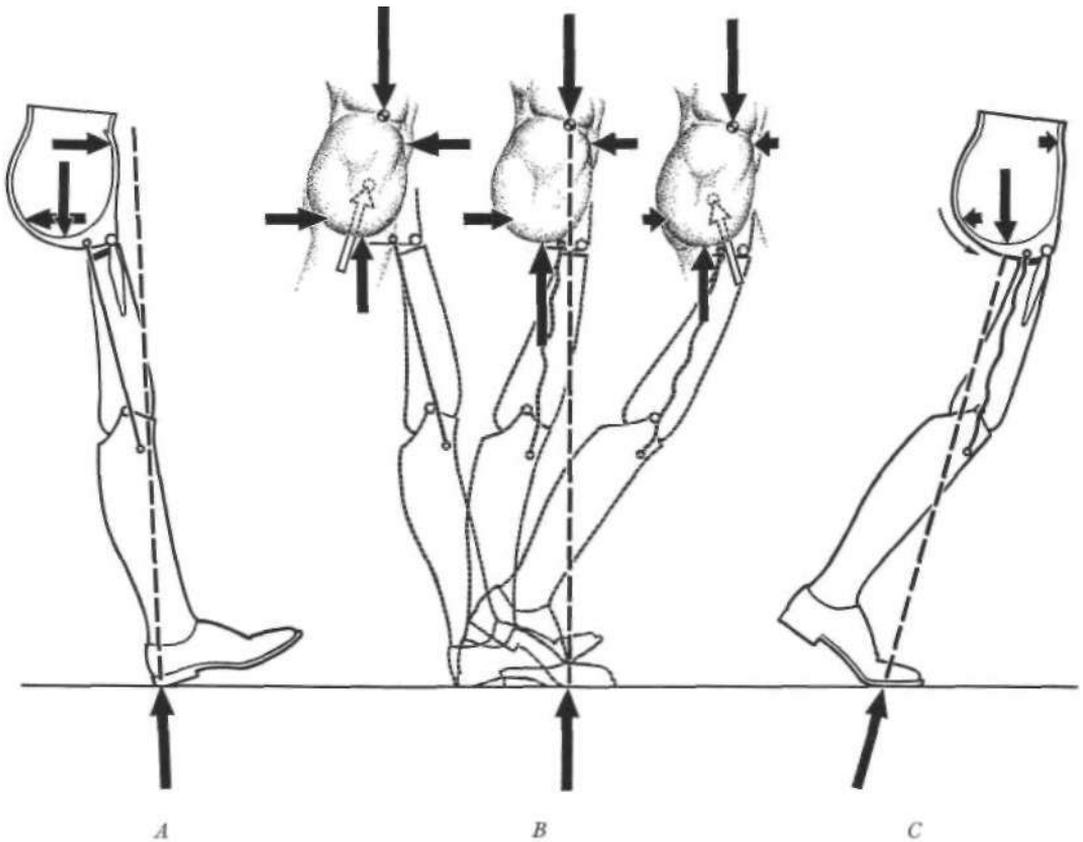


Fig. 10. Anteroposterior force diagram of the Canadian-type hip-disarticulation prosthesis. A, Forces acting on prosthesis at heel contact; B, forces acting on stump at heel contact, mid-stance, and push-off; C, forces acting on prosthesis at push-off.

Figure 10B acting on the normal side of the pelvis. Shown in addition to the force from the normal leg are the force of body weight and the distal, posterodistal, and anteroproximal stump-socket forces. The floor-reaction force is not transmitted directly to the stump but results in the system of stump-socket forces shown acting on the socket in Figures 10A and 10C. For example, the isolated prosthesis must be in equilibrium under the action of stump contact forces plus the floor reaction. The same system of stump contact forces react to appear as forces applied in the opposite sense in the diagrams of Figure 10B. Because of the offset lever arm between body weight and the line of vertical support through the ischium, as shown in Figure 10B, a counter-

acting stabilizing force is required in the anteroproximal region. The thrust of the normal leg tends to increase the unbalanced moment about the distal point of support and hence to increase the need for anteroproximal counterpressure in the inguinal region.

In the mid-stance phase, the normal leg is off the floor, and the four forces shown in the middle diagram of Figure 10B are acting. The anteroproximal pressure on the stump is reduced as compared to that existing in the heel-contact phase. This circumstance indicates that errors in fitting would be more noticeable at the time of heel contact than in the succeeding mid-stance phase. If the dynamic effects of acceleration are ignored, two forces are acting on the combined amputee

and prosthesis during the mid-stance phase—the body weight and the upward floor-reaction force on the sole of the foot. This situation prevails until the normal foot again contacts the floor ahead of the prosthesis.

At about the same time that the normal foot strikes the floor, the hip-bumper system in the prosthesis makes contact and tends to flex the knee forward. During this push-off phase, there is again a thrust on the pelvis from the normal leg, this time from the front, as shown in Figure 105. The thrust of the normal leg counteracts the offset body weight and further reduces the need for anteroproximal support from the socket. This feature gives the amputee a greater degree of perceptive control of the prosthetic knee, since the stump-socket forces are reduced and the effects of the hip-bumper force acting on the bottom of the socket are therefore more readily distinguishable. With a properly adjusted hip-bumper system, the amputee is able to exercise a more than adequate control and timing of knee flexion even though some of the body weight is still being carried by the prosthesis at this time.

Owing to the ever-changing nature of the stump-socket force system as viewed from the side, it is necessary to fit the distal portion of the socket snugly in the posterior region in order to prevent relative motion between stump and socket in the more highly stressed areas of vertical support under the ischial tuberosity.

SURGICAL IMPLICATIONS

Figures 11A and 11B show front and side views of a typical hip-disarticulation stump. Cross-hatching on the surface of the stump indicates those areas where biomechanical analysis shows a functional need for supporting or stabilizing contact pressure between stump and socket. Clearly indicated are those areas where surgical incisions should be avoided, in particular the ischial-gluteal, inguinal, and lateral-distal areas. The incision and resultant scar should be located along the anterodistal portion of the stump, as shown in Figure 11A. This area is not required to tolerate localized pressure and is generally relieved during the fitting process

in order to avoid pressure-sensitive areas over bony prominences in the pubic region.

IMPLICATIONS FOR FITTING

Biomechanical force analysis shows certain regions over the stump where particular attention must be paid to socket fit. They include the ischial-gluteal, inguinal, and waistband contact areas.

In the ischial-gluteal area, functional pressures must be developed on a bony prominence and a neighboring area of atrophied gluteal musculature. This requirement calls for careful location and fitting of the bony prominence of the tuberosity. In order to develop pressure on the soft tissues, considerable modification of the cast is required. This displaces the soft tissues upward in the socket, and the necessary functional contact pressure is achieved. The pressure in the gluteal area is an absolute necessity in order to stabilize the distal end of the stump on the bottom of the socket. Otherwise chafing due to shearing motions between stump and socket will result.

The inguinal region must provide a major contribution to the anteroposterior stabilization of the torso. An inaccurate fit in this region will result in concentration of pressure at a lower level in the generally sensitive pubic areas. The soft tissues of the inguinal and abdominal areas must be displaced inward if the proper functional stump-socket pressure

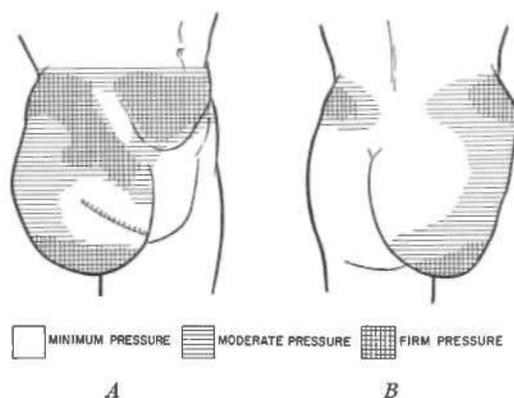


Fig. 11. Typical dynamic pressure distribution on the hip-disarticulation stump when wearing the Canadian-type hip-disarticulation prosthesis.

is to be achieved. This is most easily accomplished by wrapping the cast in this region while the patient is supine.

The mediolateral force which must be transmitted by the waistband extending around the normal hip approaches the body weight in magnitude. The waistband must be fitted very carefully to avoid local concentration of pressure on bony prominences.

TRAINING IMPLICATIONS

Training a hip-disarticulation amputee to walk on a properly fitted, aligned, and adjusted Canadian-type prosthesis is not a difficult or time-consuming process. If the therapist is thoroughly acquainted with the functional principles of the prosthesis and with the methods of fitting and adjustment, a well-coordinated amputee should walk unaided, without a cane, after less than 10 hours of training. Proper adjustment of the hip bumper, hip-flexion control strap, and ankle-foot characteristics is absolutely essential for efficient use of the prosthesis. For this reason, therapist and prosthetist should work together during the initial training sessions.

Particular points which should be stressed by the therapist in working with the amputee are:

1. Develop confidence in the stability of the knee at heel contact. Emphasize the necessity for a confident placing of the prosthetic heel and simultaneous weight-bearing. Show that the knee stability will increase in direct proportion to the amount of force transmitted by the prosthesis.

2. Show the action of the three-point mediolateral support of the torso. Do not allow the amputee to bend his trunk over the prosthesis. If painful pressure develops over a bony prominence, have the prosthetist provide relief or padding.

3. Place considerable emphasis on the timing and use of the pelvis to propel the prosthetic knee forward. Remember that the amputee "sits" to flex the knee while the prosthesis continues to bear a portion of the body weight. The amputee should not lift the prosthesis off the floor and then propel it forward by internal rotation of the pelvis.

SUMMARY

A biomechanical analysis is presented for the forces involved when an amputee stands and walks with a Canadian-type hip-disarticulation prosthesis. The results of the analysis are applied to the specialized topics of stump surgery, socket fitting, and training of the amputee.

LITERATURE CITED

1. McLaurin, C. A., *Hip disarticulation prosthesis*, Report No. 15, Prosthetic Services Centre, Department of Veterans Affairs, Toronto, Canada, 19 March 1954.

Construction and Fitting of the Canadian-Type Hip-Disarticulation Prosthesis¹

JAMES FOORT, MASc.²

True hip disarticulation connotes removal of the femur at the acetabulum. But loosely within the hip-disarticulation category a residual length of femur, too short to control a prosthesis effectively, may be left. A much more drastic operation, the hemipelvectomy, removes all of the ischium, all of the pubis, and most or all of the ilium on the side of the amputation. In this discussion, a classical and idealized hip-disarticulation amputee is considered in outlining a method for making the Canadian-type hip-disarticulation prosthesis. Certain adaptations have been found suitable for the short-stump above-knee amputee and for the hemipelvectomy.

Consider the remaining functions of the hip-disarticulation amputee. The gluteal muscles have been pulled anterior and fastened at the suture line to form a rugged pad which supports the body's weight. Support forces are transmitted through this gluteal musculature and the ischial tuberosity to the stable pelvic base. Movement of the pelvis relative to the normal leg permits the amputee to position the artificial foot at the beginning of the stance phase of walking and aids in flexing the knee

at the end of the stance phase and in sitting down. Pelvic movement relative to the rest of the body enables him to secure balance on and to control the prosthesis. The tuberosity on the side of the amputation, the iliac crests, and the sacrum provide excellent keying points for securing the body in the socket. To minimize movement between the body and the socket for the most efficient transmission of forces, the socket must snugly enclose those areas providing support, suspension, and stabilization and must give relief for any sensitive areas or bony prominences.

The socketmaking technique, as worked out by the Prosthetics Research Group at the University of California, Berkeley, is described in detail in the report by Foort and Radcliffe (2). The socket is made by taking a female impression of the pelvis with plaster bandage, forming it into a check socket and making the necessary modifications, making a male model from the check socket, and using the model as a mold for the plastic-laminate socket to which the rest of the prosthesis is attached.

TAKING THE CAST

To provide relief pockets for the anterior-superior spines, the posterior-superior spines, the spinous processes of the vertebral column, and any other sensitive areas, patches of 1/4-in. skived felt are attached to the body with adhesive tape (Fig. 1). To protect the body from plaster, a covering of cotton stockinet is pulled up over the lower part of the torso and extended well beyond the area where the socket is to be shaped (Fig. 2). In order to

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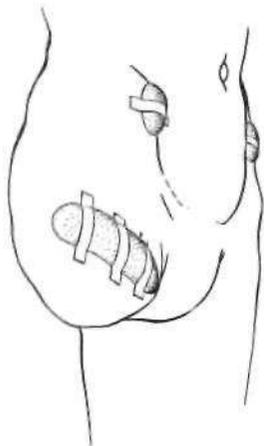


Fig. 1. Application of skived felt patches over pressure-sensitive areas of the stump and torso.

define accurately the areas which may require modification, the iliac crests and those areas which have been covered with felt are marked on the stockinet covering with indelible pencil. A mark around the waist, marks on the front and back mid-lines, and a mark extending from mid-line to mid-line around the normal leg at the level of the inguinal crease will define the approximate trim lines of the plaster

cast (Fig. 3). Metal strips may be placed over the mid-line marks to facilitate subsequent cutting of the wrap cast.

One way to get a good, snug fit for the socket is to take the wrapping of the upper part of the pelvis with the subject lying on his back on a cast table (Fig. 4, A). This position causes the viscera to move upward and backward and flattens the abdomen, thus reducing the distance from the anterior to the posterior wall of the cast and more sharply defining the iliac crests (Fig. 4, B and C). The cast of the lower

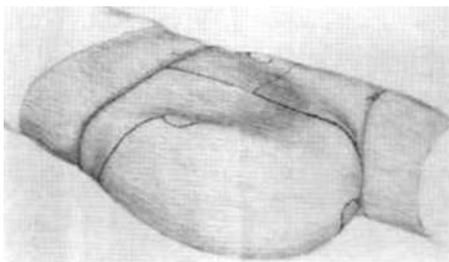


Fig. 2. Stockinet pulled over lower part of the torso well above the waist, tied at waist and around proximal end of sound thigh. Waist, mid-line, and bony prominences marked with indelible pencil.

pelvis is taken as a second step (Fig. 4, D). Snug fit is achieved by having the amputee bear weight on the stump as the cast hardens (Fig. 4, E). Three or four layers of plaster bandage are wrapped firmly around the upper part of the pelvis *(i.e., from about 2 in. above the iliac crests to just above the pubic symphysis)* and then, with tension, diagonally over the iliac crest on the amputated side and under the crest on the normal side (Fig. 4, A and B). After the wrap is complete, a block of firm sponge rubber 2 in. thick is placed under the patient's lumbosacral region to force the back portion of the cast against the body (Fig. 4, C). By molding over the iliac crests with the hands while the cast is setting, and by pressing in firmly while the cast hardens, the operator obtains good suspension hooks.

When the upper portion of the cast has set, the amputee stands, and the stump area is wrapped with plaster bandage. To unite the two portions completely, the bandage is applied back and forth over the stump with several turns around the upper section of the cast (Fig. 4, D). While the cast is setting, the amputee bears full weight on the sponge-rubber pad now placed under the stump area (Fig. 4, E). Weight-bearing at this time keys the body within the socket between the weight-bearing platform and the suspension hook over the iliac crest on the side of the amputation. Up-and-down motion of the body within the socket is thus minimized. There may be some gapping of the cast in the gluteal area and lateral to the pubic area, but such

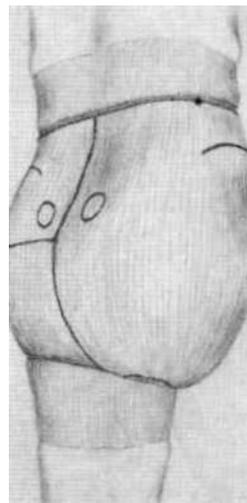


Fig. 3. Waist, mid-line, and bony prominences marked in the rear.

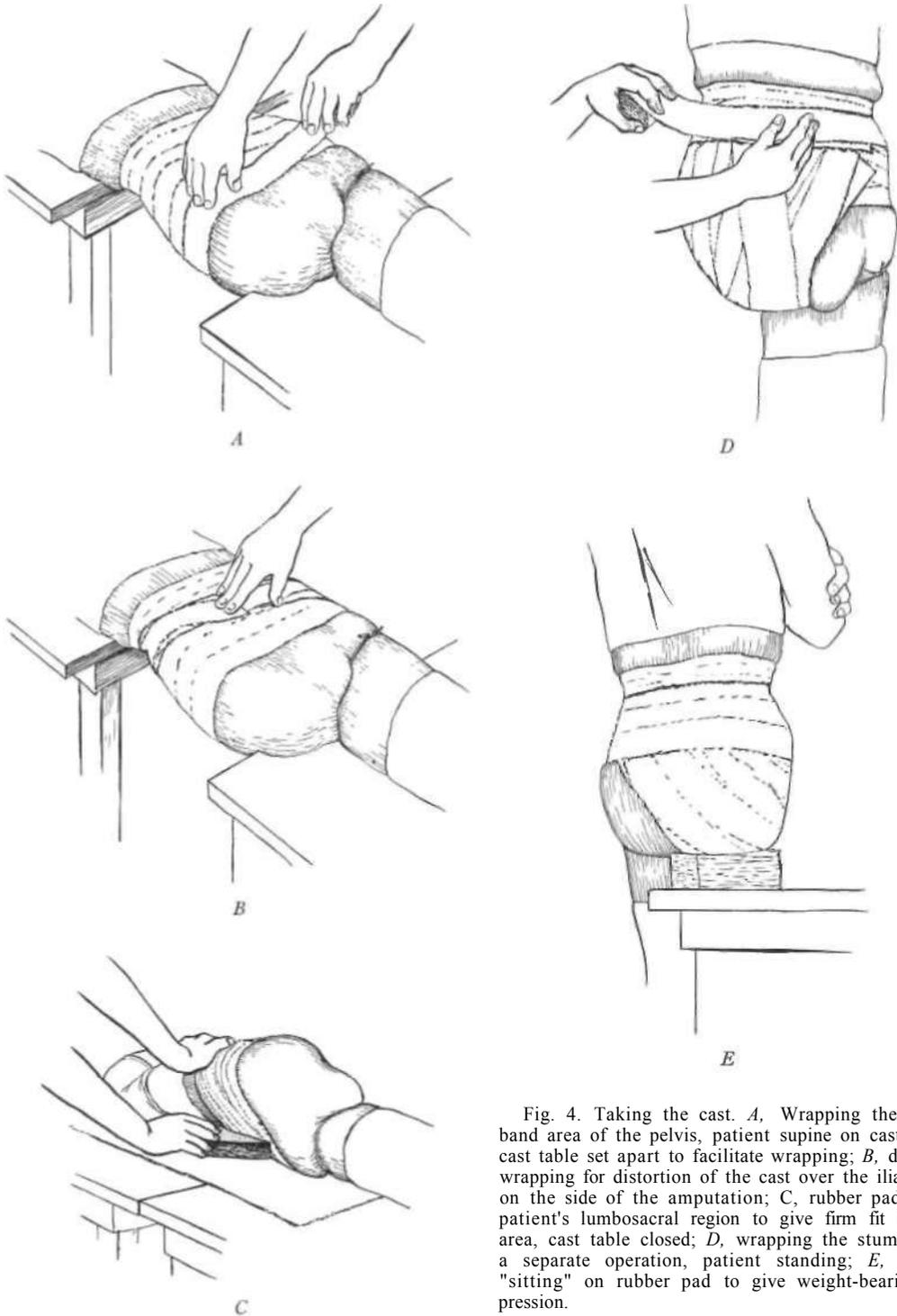


Fig. 4. Taking the cast. *A*, Wrapping the waist-band area of the pelvis, patient supine on cast table, cast table set apart to facilitate wrapping; *B*, diagonal wrapping for distortion of the cast over the iliac crest on the side of the amputation; *C*, rubber pad under patient's lumbosacral region to give firm fit in that area, cast table closed; *D*, wrapping the stump area, a separate operation, patient standing; *E*, patient "sitting" on rubber pad to give weight-bearing impression.

gapping will be closed with plaster when the cast is modified.

When the cast has set, it is removed from the torso by cutting at the approximate mid-lines, front and back (Fig. 5).

THE CHECK PROSTHESIS

The cast is rejoined, reinforced, split again, hinged posteriorly, provided with a buckled closure anteriorly, and attached to a pylon base (Fig. 6). To rejoin the two sections, they are aligned in their original position, and plaster bandage is wrapped around the outside. Plastic laminate, consisting of polyester resin, stockinet, and glass cloth, is applied over the plaster cast to strengthen it. Two layers of glass cloth about 4 in. wide are laid over the outside on the posterior mid-line. One layer of 8- to 10-in. stockinet is then pulled over the cast and tied at the opening for the normal leg. Polyester resin is painted over the fabric and allowed to cure, after which excess material is trimmed away.

The cast is now sawed along the posterior mid-line, and a hinge is fastened over the cut. When the hinge is secured, the cast is sawed along the front mid-line, and a buckle-and-strap arrangement is attached. A block of wood about 4 x 4 x 4 in., scooped out to fit the bottom of the cast roughly, is attached to the cast with "gunk," a mixture of resin and sawdust, to serve as the base for the pylon.

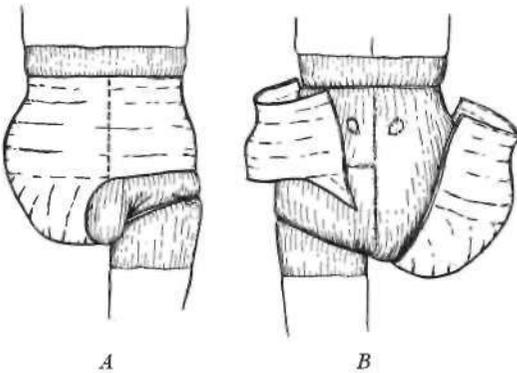


Fig. 5. Cutting and removing the cast. A, Cast marked on mid-line, front view; B, cast cut along anterior and posterior mid-lines, rear view.

The pylon must now be attached to the wood block in the proper alignment and the socket tried on the amputee for any necessary modifications. With the plaster socket on the amputee, marks are made on the side and front of the block to indicate the inclination of the peg. It should be so set that it will make the same angle with the floor at the beginning and end of the stance phase of walking and so that it will clear the normal leg in the swing phase. Typically, this will mean that the distal end of the pylon will be set somewhat forward as viewed from the side and somewhat lateral as viewed from the front. A hole is drilled in the middle of the block at the required angles, and a length of crutch-tipped dowelling is inserted.

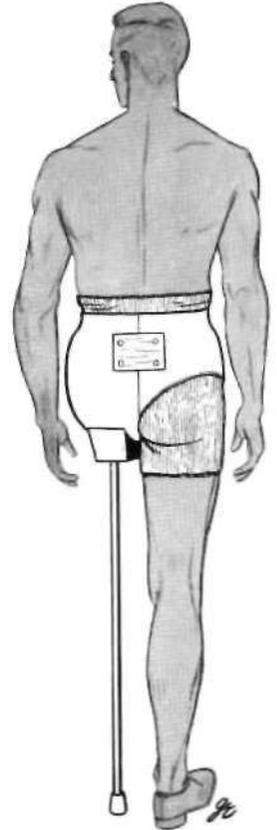


Fig. 6. The check prosthesis.

To test for discomfort, excursion, and restriction of body motion, the amputee now performs on the check prosthesis. He is asked to bend his body and normal leg in every direction, and the cast is cut down until there is complete freedom of motion. Taking care to leave the ischial seat intact, the medial side is cut away to relieve rubbing against the normal leg and the genitalia. The edges of the cast are then smoothed and flared with plaster, and gapping in the areas of the gluteus and pubis is similarly closed.

If there is ramus contact, the amputee usually will complain of it. This detail can be checked by locating the ramus with a finger

and having the amputee put full weight on the socket while dropping his pelvis on the normal side. If there is contact, the ischial seat and other weight-bearing areas should be built up with 1/8-in. layers of plaster until the ramus is sufficiently cleared. Fore-and-aft excursion can be detected by placing a finger alongside the tuberosity while the amputee steps back and forth on the prosthesis. Any fore-aft excursion will be reduced if the prosthetist slips a hand between the torso and either the anterior or the posterior wall of the socket. If the amputee then feels more secure, the anterior and posterior walls should be built up appropriately with plaster so laid that the forces are evenly distributed.

If the body has not been sufficiently stabilized in the socket in the up-and-down direction, the prominences will move along and out of the relief pockets established for them, and chaffing and painful pressures will occur. As a final check on excursion, therefore, the amputee should be walked in the check socket. Two hours of walking is usually enough to prove any discomfort. Further refinements may then be necessary:

1. If the musculature in the area of the iliac crest on the side of the amputation has atrophied, the extent of the hook in this region may need to be increased. An increase is indicated if a hand placed inside the socket under the hook makes the socket seem more secure on the amputee.

2. If, without causing discomfort, security is increased by inserting 1/8-in. pads between the stump and the weight-bearing area of the socket, the weight-bearing area should be built up accordingly.

3. If the body seems stabilized in the up-and-down direction but there is still pressure on the prominences, either the areas around the relief pockets must be built up with plaster, 1/8-in. at a time, or material must be sanded out of the pockets.

THE MALE MODEL

A hollow model is now made in the check socket. After the inside of the cast has been coated with petroleum jelly, a section of 8-in. stockinet is pulled over the check socket and tied closed around the pylon base. Sufficient thin plaster is then poured into the cast through the waist opening to coat lightly both the check socket and the stockinet closing the end (Fig. 7). When the first layer of plaster has set, successive layers of somewhat thicker



Fig. 7. Making the male model.

plaster are added until the model is approximately 1 in. to 1 1/2 in. thick. When the shell has hardened, a quart more of plaster is poured in, the stockinet is pulled across the opening, and the cast is inverted and placed on a table so that the plaster seals the end. The completed male model is removed from the check socket and dried.

THE PLASTIC SOCKET

To prepare the model as a mold for construction of the plastic socket, a hole is cut in the top (the waist), and a mandrel of 1-in. pipe about 2 ft. long is inserted and fastened with "gunk." The edges of the mold are trimmed so that the flares are not more than 1/4 in., and the whole is smoothed with fine sandpaper. To the surfaces which will become the open ends of the completed socket wooden blocks approximately 1/2 to 1 in. are attached with "gunk" (Fig. 8). They will later be used to secure the layers of fabric to the mold. A 1/4-in. pad of dense sponge rubber is placed over what will be the weight-bearing area of the socket. This pad will later be transferred to the corresponding area of the completed socket. A truncated cone of polyvinyl alcohol film is then pulled over the cast and tied to the mandrel at one end and to the leg-opening surface at the other (Fig. 9).



Fig. 8. Wooden blocks bonded to the model.

To reinforce the polyester resin, dacron tricot (a very strong fabric with one-way stretch) and glass cloth are used in construction of the socket. The dacron waistband will be limber enough to allow the socket to open, while areas of force concentration, reinforced with the glass cloth, will be strong and rigid.

Six layers of dacron tricot are used, each layer being stapled into place individually. The six layers of dacron are cut with enough material to wrap around the cast horizontally and with an overlap great enough to span the distance between the crests. These are fitted

and seamed to pocket the stump area (Fig. 10). Beginning at the vertical line of the normal iliac crest, the end of the material is stapled to the wooden blocks at either end of the model. As it is brought across the abdominal area, then around the back, continuing to its starting point, the dacron is stapled to the blocks (Fig. 11), the excess length of material being allowed to hang free. Alternating with the dacron, four layers of glass cloth are laid up over the stump area, extending upward to the crest (Fig. 12), and the lay-up is finished off with the final two layers of dacron tricot (Fig.

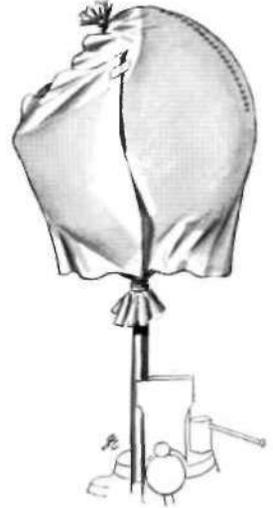


Fig. 10. Dacron tricot tailored to fit the model.

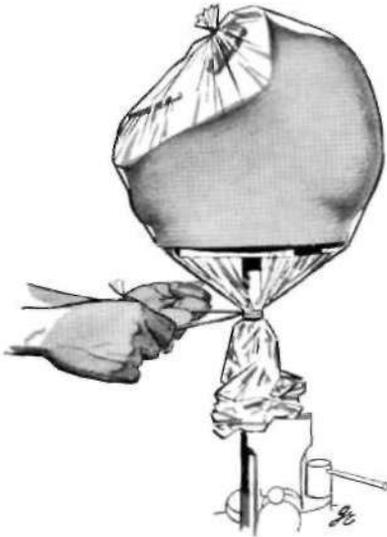


Fig. 9. Truncated cone of polyvinyl alcohol film drawn over the model and fastened top and bottom.



Fig. 11. Securing the fabric to the model.



Fig. 12. Glass cloth applied over the stump area.

13). When all the fabric has been applied in this way, the loose sections of dacron are brought across the front and stapled into position over a sheet of polyvinyl alcohol film (Figs. 14 and 15). The film separator prevents the overlap from bonding to the underlying section.

In order to get resin to the fabric under the film separator, it is helpful to place a polyvinyl alcohol funnel, approximately 2 to 3 in. wide and 2 ft. long, under the film separator before it is stapled into position (Fig. 14). The mouth of the funnel will be at the mandrel. After the film separator and the overlapping material have been stapled to the wooden blocks in final position, two similar funnels are placed over the front and back surfaces of the lay-up with the mouths at the mandrel (Fig. 16). A final truncated cone of polyvinyl alcohol film

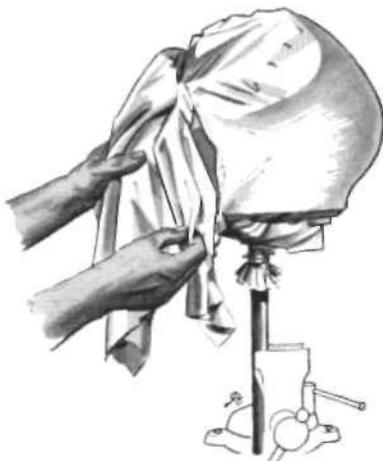


Fig. 13. Final lay-up of dacron fabric.

is pulled over the entire mold and tied in the area of the wooden blocks at the stump end (Fig. 17).

The required quantity of resin is weighed, mixed with catalyst, promoter, and pigments, and introduced into the fabric through the funnels, after which the funnels are removed (Fig. 18). The polyvinyl alcohol bag is tied closed at the mandrel, and the resin is squeezed through the fabric. When the fabric is completely saturated, excess resin and air bubbles are worked out toward both ends by "roping" (Fig. 19). Sponge-rubber pads are then bound over the undercut areas with Ace bandage in order to guarantee close adherence of the lay-up to the mold (Fig. 20).

The socket is released from the mold by cutting around the waist and around the opening for the normal leg approximately 1/2 in. from the final trim lines (Fig. 21). Care should be taken not to cut the hands on the sharp edges of the overlapping sections (Fig. 22). After the socket has been removed from the mold, the edges are trimmed on a sand-

ing drum.

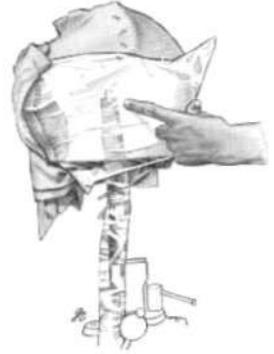


Fig. 14. Application of PVA funnel and film separator under overlap of waistband.

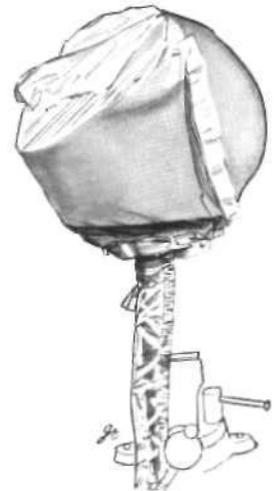


Fig. 15. Film separator and overlapping fabric stapled into position.



Fig. 16. PVA funnels applied to front and back of lay-up.

base, hollowed out to fit the front-bottom corner of the socket, is



Fig. 17. Truncated PVA cone placed over entire lay-up.

THE TRIAL LEG

The fixtures are attached to the socket, the socket is attached to a thigh section through the hip-joint assembly, and the thigh section is attached to the adjustable leg and the foot (Figs. 23, 24, 25, and 26). Attachments for the socket are the weight-bearing pad (Fig. 23), the belt-and-buckle arrangement, and the wooden base for the hip joint (Fig. 24).

WOODEN BASE

A block of wood 4 x 4 x 4 in. for the base, hollowed out to fit the front-bottom corner of the socket, is bonded in place with "gunk." When the resin has cured, the front-bottom corner of the block is cut off as close to the socket as possible to provide a surface to which to attach the hip-joint bearing. When the socket is in its normal position, this attachment surface will face downward and forward at a 45-deg. angle to the floor, so that when the hip-joint bearing is attached its axis will be approximately perpendicular to the line of progression and parallel to the floor (Fig. 25).

HIP-JOINT ASSEMBLY

The hip-joint assembly (Fig. 25) consists of a special bearing, a shaft, and two metal sidestraps. The bearing, which is lined with a bronze bushing, is machined out of a block of aluminum and includes four tabs with screw holes for attachment to the base of the socket. The shaft and sidestraps of the hip-joint assembly are from a 3 1/2-in. standard prosthetic-knee assembly.

THIGH SECTION

The thigh section is made from a 6- x 6-in. block of wood 12 in. long, with a core drilled from the middle at the edge of one end through the center of the block at the other. This hole facilitates pulling out wood from the interior of the thigh section later. A line is marked off 2 in. from the cored edge at one end, and, starting at this line, a diagonal cut is made to the opposite corner at the other end. The 6- x 6-in. face becomes the knee end, the 2- x 6-in. surface the hip end, and the vertical surface (6 x 12 in.) the front face of the thigh.

The sidestraps of the assembled hip joint are traced on the front face of the block equidistant from the sides, and the block is



Fig. 18. Resin introduced through the funnels, funnels ready to be removed.



Fig. 19. Saturation of the fabric and removal of air bubbles by "roping."



Fig. 20. Sponge-rubber pads applied to undercut areas to guarantee adherence to mold.

cut along these lines to extend somewhat beyond the side- straps and to flare out toward the end. The straps are then attached to the cut sides flush with the front of the block at the bolt end and so that the axis of the bolt will be approximately $3/4$ in. above the top surface of the thigh block. The portion of the block which extends behind the axis of the hip joint is sawed as necessary to provide the platform for

the hip-stop bumper (Fig. 24).

To position the hip joint on the base, the amputee dons the socket and sits down.



Fig. 21. Cutting the socket free of the mold.



Fig. 22. Removing the socket from the mold.

Viewed from the front, the prosthetic thigh should be approximately parallel to the normal thigh and as close to the mid-line as possible, and the hip joint should be parallel to the floor and high enough on the base so that the back edge of the hip-stop platform is flush with the chair. The position of the bearing is traced on the block, and the free end of the thigh section is marked 2 in. back from the normal knee axis.

TRIAL-LEG ASSEMBLY

The socket is removed from the patient, the thigh section is cut where it was marked, and the components of the trial leg are assembled. The adjustable leg is attached to the knee end of the thigh piece, and the socket is attached to the thigh with screws through the hip-joint bearing. To prepare the trial leg for alignment checks, a temporary hip-stop bumper, a temporary hip-flexion con-



Fig. 23. Finished socket with weight-bearing pad installed.

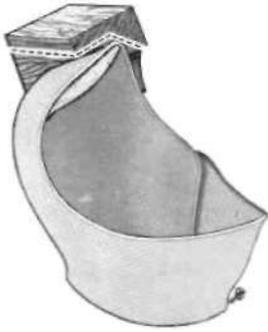


Fig. 24. Socket with wood block attached. Dotted lines indicate the saw lines.

trol strap, and a kick strap are attached to the leg, and the knee joint is located in a stable position (Fig. 26).

TEMPORARY BUMPER

A bumper of foam-crepe shoe-sole material is tacked temporarily to the hip-stop platform in such a manner that when the socket is

against the bumper the vertebral spine will be in its natural position.

HIP-FLEXION CONTROL STRAP

One end of the hip-flexion control strap is attached laterally to the socket 2 in. behind the hip joint; the other is attached to the shank 3 in. below and 1/2 to 1 in. ahead of the knee joint.³ The distance between these attachments is adjusted to provide the correct stride length.

KICK STRAP

The temporary kick strap is attached to the front of the shank at the same level as the hip-flexion control strap, passes over the knee in front, and attaches to the front of the socket 3 in. above the hip joint. The length of the strap is adjusted to provide the correct balance between heel rise and knee extension. Knee stability will be satisfactory if, when the knee is in full extension, the knee joint falls behind the line projected from the hip joint to the back of the heel.

³ If the amputee is well adjusted to using a prosthesis and does not need the added stability offered by attaching the hip-flexion control strap below the knee, the distal end of the strap may be attached to the thigh section.

The prosthesis is now ready for sitting, standing, and walking adjustments. When the amputee is sitting, the prosthetic shank should be vertical, the knee axis approximately level with the normal knee center and the toe-out equivalent to that on the normal side. In the standing position, with a 2- to 3-in. standing base, the length of the leg should be such that the hips are level. The thickness of the hip bumper is adjusted to eliminate humping or arching of the spine. The patient now walks on the trial leg, and checks are made of knee stability, width of walking base, stride length, toe clearance, whip in the swing phase, and swing-phase control.

KNEE STABILITY

Although the knee has been stabilized on the bench, a number of factors may affect it in action. If the knee buckles, it may be that the hip bumper is contacting too soon and that its thickness needs to be reduced. A knee axis too far forward also will cause buckling.

WALKING BASE

With the toe-out of the prosthesis consistent with the natural toe-out, the medial distance between the heels is the walking base. If this base is found to be over 2 to 3 in., it should be made narrower by moving the foot in. If the feet are not clearing each other sufficiently, the base should be increased to 2 to 3 in.

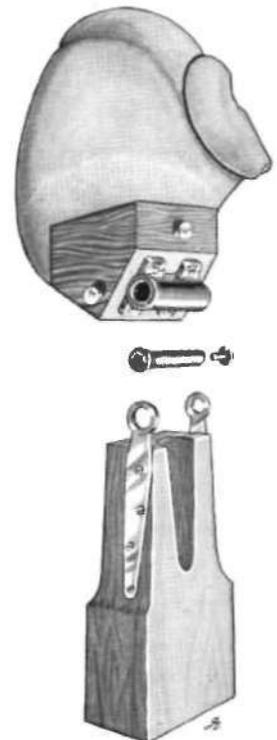


Fig. 25. Hip-joint assembly.

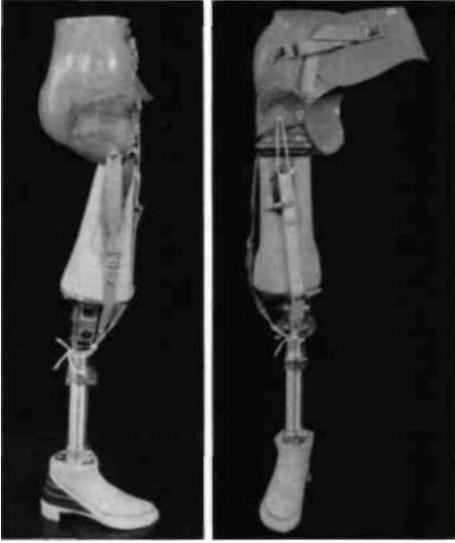


Fig. 26. Trial prosthesis set up on the UC adjustable leg.

STRIDE LENGTH

The distance between toe-off and heel strike should be approximately the same for the two legs. Stride length is adjusted by shortening or lengthening the hip-flexion control strap.

The thickness of the hip-stop bumper affects stride length. If the thickness of the bumper is increased, the angle at which the leg inclines forward at the end of the stance phase is reduced, and the stride is shortened. But bumper thickness should never be changed to improve control and stride length at the expense of comfort.

TOE CLEARANCE

A number of factors are involved in toe clearance—the length of the leg, the inclination of the foot, the amount of knee flexion in the swing phase, and suspension. Leg length is first adjusted, but the limb should not be shortened more than an inch. If scuffing persists, it is due to other factors. If the knee is not bending sufficiently, the toe will drag, and kick-strap tension should be reduced. If drop-off is causing the toe to scuff, a hand placed between the socket and the crest of the ilium on the side of the amputation should

eliminate it. In this case, either the suspension hook over the crest should be enlarged or the weight-bearing area should be built up with pads and the length of the leg reduced equivalently. Correction of scuffing may make the clearance too great, in which case leg length must be readjusted.

WHIP

Whip in the Canadian-type hip-disarticulation prosthesis typically takes a form comparable to circumduction in the above-knee prosthesis. Circumduction can be reduced by rotating the knee bolt externally. The degree to which the knee axis can be rotated is limited by the extent the foot will move medially in the sitting position. It may thus be necessary to effect at least some external rotation at the hip joint by cutting a wedge (with the apex medially) from the hip-joint base.

SWING-PHASE CONTROL

With alignment established, refinements can be made in swing-phase control. Heel rise at the beginning of the swing phase should be limited through adjustment of the kick strap rather than of the knee-friction units. The compound-pendulum system of the prosthesis does not allow the hip-disarticulation amputee to walk as fast as he would like, and it has been found that tensing the kick strap increases his speed more effectively than does increasing knee friction. This may mean that there will be some impact at the end of the swing phase, but it usually is quite tolerable because the hip joint flexes as soon as the knee comes against the extension stop, and the energy which would otherwise lead to impact is thus absorbed. Stride length may require periodic adjustment as changes are made in swing-phase control.

FINISHING THE PROSTHESIS

The leg is now ready to be used either as a training leg, or, after sufficient attention has been given to fit and alignment, to be duplicated (J). The only difference between duplicating the Canadian-type hip-disarticulation prosthesis and a standard above-knee prosthesis is that in the case of the former the thigh section rather than the socket is clamped in the jig.



Fig. 27. Hip-flexion control strap.

The thigh section, shank, and foot are shaped and reinforced according to standard techniques (2). Weight of the thigh section is reduced by pulling wood from the inside. The hip joint is faired to the wooden base on the socket with "gunk" and tied to the base with three layers of resin-impregnated glass cloth extending about an inch beyond the wooden block. This reinforcement is smoothed and finished with a light coat of lacquer. For ventilation, the socket is perforated with 1/8-in. holes at 1-in. intervals, and padded areas are covered with nylon-coated leather or leather substitutes. The permanent kick strap and hip-flexion control strap are installed, their connections to the limb being such as to allow the straps to rotate about the points of attachment. The hip-flexion control strap (Fig. 27) is made of 1-in. vinyon or dacron webbing sewed on either end of a 4-in. section of heavy elastic webbing. For attachment to the prosthesis, a piece of leather large enough to include a 1/4-in. metal grommet (such as is used in below-knee corsets) is sewed at each end of the hip-flexion control strap, and a clamping arrangement is installed on the webbing

to permit length adjustment. The conventional kick strap is used, with the exception that it is attached proximally to the socket instead of to the thigh. Final adjustments are made to socket edges and to the permanent swing-phase controls.

The last step in the construction and fitting of the Canadian-type hip-disarticulation prosthesis is to provide a cosmetic fairing for the thigh section. A truncated cone of sponge rubber is made to fit over the thigh section so that it extends from just above the knee to the socket. The rubber cone is in turn covered with leather or a leather substitute extending beyond the rubber fairing at both ends, so that the covering can be attached to the thigh at the bottom and to the front and side of the socket with snap fasteners (Fig. 28). In order to make the fairing neat in both the sitting and the standing positions, a triangle with a 3-in. side and with the apex on the hip-joint axis may be cut from the lateral side of the covering and a piece of light elastic webbing substituted.

The procedures outlined for checking the prosthesis during construction and fitting can be applied equally well to the evaluation of hip-disarticulation prostheses.

ACKNOWLEDGMENT

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Fig. 28. Cosmetic fairing.

at the University of California at Berkeley. The halftones are by George Rybczynski, free-lance artist of Washington, D. C.

LITERATURE CITED

1. Foort, J., *Fiberglas laminate reinforcement of wooden prostheses*, Prosthetic Devices Research Project, University of California (Berkeley), [Report to the] Advisory Committee on Artificial Limbs, National Research Council, February 1956.
2. Foort, J., and C. W. Radcliffe, *The Canadian type hip disarticulation prosthesis*, Prosthetic Devices Research Project, University of California (Berkeley), [Report to the] Prosthetics Research Board, National Research Council, March 1956.
3. Radcliffe, Charles W., *Mechanical aids for alignment of lower-extremity prostheses*, Artificial Limbs, May 1954. p. 23.

Some Experience with the Canadian-Type Hip-Disarticulation Prosthesis

JAMES FOORT, M.A.Sc.²

In the year 1953, the Prosthetics Research Group of the then Prosthetic Devices Research Project of the University of California, Berkeley, began a study of fitting and construction techniques for the Canadian-type hip-disarticulation prosthesis. At the time, the device was still undergoing evaluation at the Prosthetic Services Centre at Sunnybrook Hospital in Toronto and seemed to offer definite promise. The group at Berkeley started with attempts to make a prosthesis for a relatively "ideal" case with this type of amputation. As the study progressed, it became increasingly clear that the incidence of this and bordering disabilities was higher than at first had been suspected. As a result, the investigation was expanded to include two more cases for close study, and a number of cases fitted by the limb industry were selected for observation and follow-up.

From this experience, nine cases have been selected for discussion here. Each one highlights some special problem encountered during the study. Although each case is unique in its prosthetic problem, the principles and

procedures derived from the cases apply to all cases of similar kind.

CASE DATA

CASE 1

The first case was a young female (age 16 at time of fitting) with a true hip disarticulation. She was strong, athletic, healthy, and willing to devote a considerable amount of time to the study. In addition, she had for a number of years following her amputation used a conventional type of hip-disarticulation prosthesis with excellent results.

Examination showed a stump and pelvis with prominent bony structure and light subcutaneous tissue (Fig. 1), and the weight-bearing area was found to tolerate full body weight without discomfort. The terminal scar extended from a point 3 in. directly below the anterior-superior spine, across the anterior surface of the stump, to a point slightly lateral to and above the perineum. The scar was pressure-sensitive, especially at its lateral end. X-ray showed retarded development of the pelvis on the amputated side and that the ramus sloped downward abnormally from the ischial tuberosity (Fig. 2). The sloping ramus, the sensitive scar tissue, and the rather prominent, lightly padded bony structure were potential sources of difficulty in fitting but served to accentuate the requirements of the fitting procedure for this type of amputation.

From several plaster impressions taken, several plastic sockets were made. The earlier casts of the pelvis and stump were taken with the amputee standing, and the cast was

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Fig. 1. Case 1, anterior view of the stump.

wrapped over the entire pelvis and stump in one operation. No pressure was applied over the weight-bearing area. But this method resulted in sockets so roomy that the bony prominences moved in and out of the recesses



Fig. 2. Case 1, anteroposterior x-ray of the pelvis.



Fig. 3. Case 1, the prosthesis.

provided for them, and the tuberosity moved back and forth over the weight-bearing platform. Finally, the technique outlined in the preceding article (p. 39) was evolved. The cast of the waist area was taken with the amputee supine, the cast of the stump area being taken as a second step and allowed to set with the amputee bearing full weight on it against a hard surface. This procedure aided in keying the body to the socket closely so that relative motion between the body and the socket was minimized.

In order to find the combination of materials that would yield a socket strong enough where stresses were concentrated, yet flexible enough to be put on and removed easily, experiments were made with various combinations of materials. Earlier sockets, using cotton-stockinet reinforcement, were too rigid and bulky and had to be hinged at the back to permit the amputee to don them. As the result of an attempt to achieve flexibility, however, the first flexible socket turned out to be too flexible and sagged in stance phase, thus causing ramus discomfort. Subsequent sockets, made of six layers of dacron tricot and four or more layers of glass cloth to reinforce the general-purpose polyester resin in stressed areas, were successful.

The bony prominences were a problem initially. But through improvement in the cast-taking technique, the relative motion between the socket and the pelvis was reduced and this problem was solved. Once the upper portions of the pelvis were well stabilized in the socket, and once definite ischial-gluteal weight-bearing was established, discomfort of the ramus, discomfort in the area of the scar, and discomfort of the bony prominences were eliminated.

The amputee used the final prosthesis (Fig. 3) only occasionally at first, preferring the greater freedom and mobility she had had with crutches. The tendency for the thigh to flex excessively when sitting in soft seats, as in an automobile, was one feature to which the amputee objected. Gradually, however, she accepted the leg and now uses it extensively.

CASE 2

While the work was in progress on the first amputee, the second, a 56-year-old woman

who had recently undergone amputation for a malignancy, was brought into the study. Her general physical condition was satisfactory, but her balance was poor and her activity level low. The stump was extensively scarred in the crotch area and across the anterior surface (Fig. 4). In addition, there were redundant tissue knobs in the same areas. While the bony structure of the pelvis was light, subcutaneous tissue was heavy. X-ray showed an abducted femur which terminated just below the lesser trochanter, well above the perineal level (Fig. 5).

As yet the technique for taking the plaster impression had not been defined satisfactorily, and the cast of the entire pelvis was, here again, wrapped in one operation with the amputee standing, and no pressure was applied to the weight-bearing area as the cast hardened. Although not as dramatically as in the previous case (because of the heavier padding of

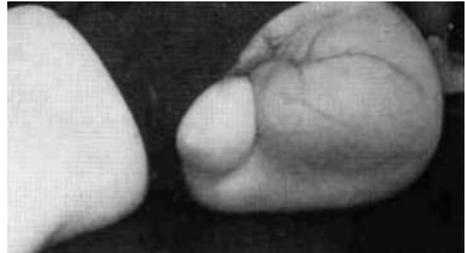


Fig. 4. Case 2, anterior view of the stump.



Fig. 5. Case 2, anteroposterior x-ray of the pelvis.

subcutaneous tissue over the pelvis), the same difficulties were experienced with bony prominences moving out of the relief pockets. Ramus discomfort was a problem immediately, there was discomfort from stretching of scar tissue in the crotch, and painful pressure was felt on the pubis. These difficulties were alleviated to some extent by building up the weight-bearing area of the socket, especially under the ischial tuberosity, and by trimming material from the edges of the socket.

But this socket was never really successful. Four layers of dacron, and three layers of glass cloth in the weight-bearing areas, had been used to reinforce the polyester resin, and this combination did not provide sufficient reinforcement to prevent the socket from sagging under load. As a result, there was intermittent ramus discomfort and stretching of the scar tissue in the crotch. While all the problems of fit were not resolved, the amputee was sufficiently well fitted to progress in the use of the limb to a remarkable degree considering her poor balance (Fig. 6). After three hours with the socket on the adjustable leg, she was able to walk using a crutch on one side and the walking rail on the other. After six hours of experience, she was able to walk using a cane, with some support from the trainer. Two more hours enabled her, though with considerable tension, to manage with one cane. With a total of 15 hours' experience, obtained over a three-month period, the amputee could manage stairs and ramps as well as level walking using one cane. At this time the leg was delivered, although proficiency on it was not considered good. Use of the leg at home over the next four months resulted in some improvement, al-



Fig. 6. Case 2, the prosthesis.

though the patient never became fully independent. About this time medical complications terminated the study.

Although the patient was tense and had poor balance, some of the difficulties she experienced on the limb were due to other factors. Partly because of the socket construction, partly because of the scar tissue in the crotch, at no time was the socket really comfortable. In addition, because the shank was too light, and because the hip-flexion control strap restricted knee flexion, it was difficult for her to swing the shank through.

CASE 3

About the time that the technique for taking the plaster impression in two steps had been outlined, the Prosthetics Research Group, co-

operating with a local limbshop, helped to fit a 30-year-old housewife with a Canadian-type hip-disarticulation prosthesis. Originally, she was dissatisfied with the Canadian type of prosthesis. The motion at the hip, in addition to poor foot function, was a source of insecurity. But she soon adapted and now much prefers this type of limb to the conventional hip-disarticulation prosthesis. She has worn the prosthesis successfully for three years. During this time she became pregnant. By loosening up the corset as the fetus grew, she was able to wear the prosthesis throughout her term. She wore it to the hospital for her delivery and put it on again five days later to go home. In her daily routine, she cares for her growing family unaided.

The first Canadian-type prosthesis for this patient was provided with a wooden foot with plantar-dorsiflexion ankle and with a 2-in. Cuban heel. But she experienced several falls until the foot was changed to a lower heel (Fig. 7). She has since been provided with a new Canadian-type limb with a high-heel SACH foot and has found the knee stable, even descending a 7- to 8-deg. incline (Fig. 8).

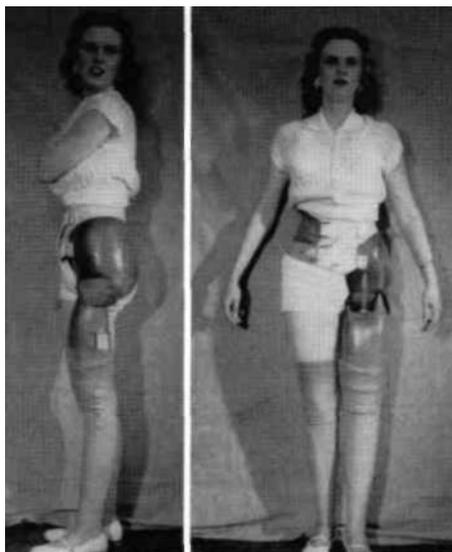


Fig. 7. Case 3, first Canadian-type hip-disarticulation prosthesis provided (after change to low heel).

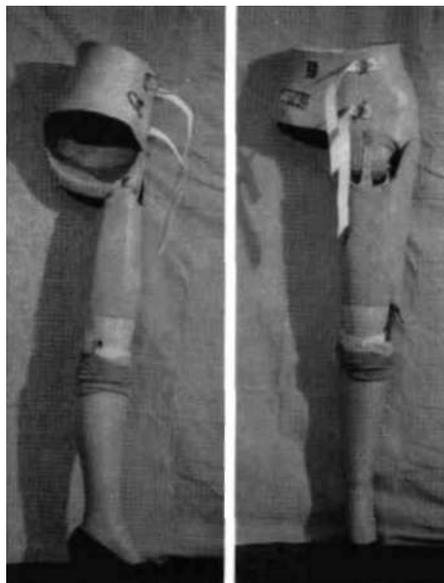


Fig. 8. Case 3, second Canadian-type hip-disarticulation prosthesis provided (with high-heel SACH foot).

This circumstance would indicate that the instability on the original limb was due to factors other than the height of the heel, probably to limited range of plantar flexion. One problem the patient reports is that, where an open or projecting type of stair construction is encountered, the prosthetic toe catches under the step. Catching occurs because the leg swings forward from the hip joint when the leg is lifted toward the next step. To prevent catching, the patient restrains the prosthesis manually.

CASE 4

The next two cases were fitted with Canadian-type hip-disarticulation prostheses at about the same time. Case 4, a 15-year-old female, was fitted by the Prosthetics Research Group. Case 5, a 16-year-old male, was fitted by a local limbshop.

Case 4 came to the Prosthetics Research Group three weeks after disarticulation at the right hip had been performed for bone tumor (Fig. 9). In order to enhance this amputee's quick adjustment to the prosthesis and to



Fig. 9. Case 4, anterior view of the stump.



Fig. 10. Case 4, anteroposterior x-ray of the pelvis.

forestall atrophy of the back and abdominal muscles, it had been decided to put her on a prosthesis as soon as the stump would permit. At the time of the initial examination, there was no edema and only limited sensitivity. There was fairly heavy subcutaneous tissue, the bony structure of the pelvis was not prominent (Fig. 10), and muscle padding was substantial. The amputation scar extended from the anterior-superior spine diagonally downward to a point just lateral to and 2 in. below the perineum.

Treatment started a week after examination. The cast and socket were constructed as outlined in the foregoing article (p. 39), considerable tension being applied to the plaster bandage during cast-taking in anticipation of stump shrinkage. It was thought by the study group that performance on a limb of the

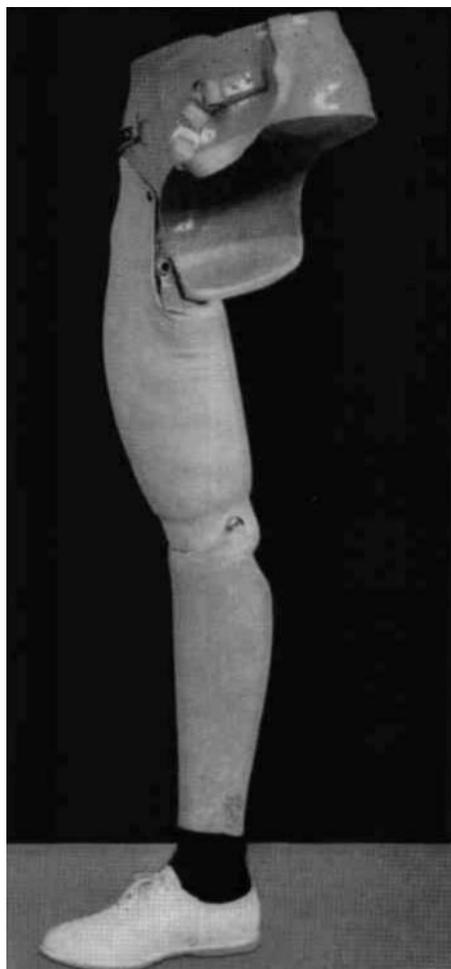
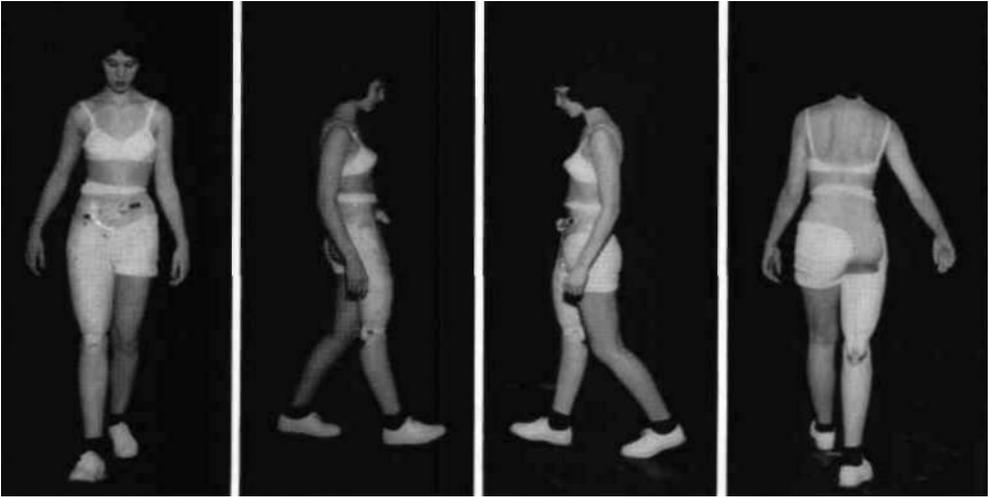


Fig. 11. Case 4, finished prosthesis.

Canadian type might be more a function of the prosthesis than of the wearer. Little training was given in order to check that hypothesis. After 33 hours of fitting time over a month's period, the prosthesis was finished (Fig. 11) and delivered in time for the summer vacation. During the summer the patient experienced few walking problems and adjusted very quickly (Fig. 12). After vacation, she attended high school fairly regularly throughout the first term and attended her usual social functions, including dancing. By the New Year, medical complications were in evidence, and the study ended a few months later.



CASE 5

Six months after he had undergone amputation following an injury received in a motorboat accident, Case 5 was observed by the Prosthetics Research Group in connection with the Industry Participation Program. The socket had already been made, and the unfinished components were ready for assembly. The stump, in good condition, tolerated full weight-bearing without discomfort (Fig. 13). The short residual femur, which did not extend to the perineal level, was abducted (Fig. 14). Subcutaneous tissue was light, and the bony structure was not unduly prominent.

The plaster cast (Figs. 15 and 16) had been wrapped with the amputee standing, and no pressure had been applied to the weight-bearing area while the cast hardened. The male model of the impression had been taken from the unmodified female cast. On the model, leather spots had been applied over bony prominences, including the iliac crests. The resulting socket, made of semiflexible polyester resin reinforced with glass cloth and cotton stockinet, was attached to the unfinished components of the leg for alignment and adjustments to socket fit.

The residual femur was not a fitting problem and gave no trouble in orienting the hip joint. Up-and-down motion in the socket between weight-bearing and non-weight-bearing resulted in the bony prominences moving in and out of the relief spaces, so that there was discomfort. As the socket was built up over the weight-bearing area, this movement was reduced, and there was a corresponding increase in comfort. No training was given, but the amputee adapted readily.

Because of stump shrinkage, the prosthesis became increasingly uncomfortable over the next six months, and a new leg was required. The new prosthesis (Fig. 17) has a leather-covered plastic socket, a friction-stabilized knee, and a SACH foot. The hip-flexion control strap is attached at either end with machine screws through ball-bearing races. Screw holes at 1/2-in. intervals on the thigh piece allow adjustment of the length of the strap. Up-and-down movement in the socket between weight-bearing and non-weight-bearing is very small—under 1/2 in.

It is of special interest that this prosthesis was suspended not by hooking over the iliac crests but by clamping the socket to the pelvis



Fig. 13. Case 5, anterior view of the stump.

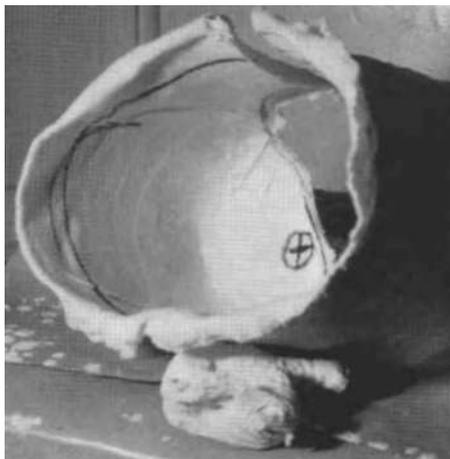


Fig. 15. Case 5, cast from plaster wrap.



Fig. 14. Case 5, anteroposterior x-ray of the pelvis.

between the iliac crests and the greater trochanter. Since the pelvis of a true hip disarticulation narrows below the crest of the ilium, it is necessary to suspend the prosthesis from the iliac crest on the side of the amputation. Where the greater trochanter is present, however, as it is in this case, it projects beyond the iliac crest. The resulting outward pelvic flare from the crest of the ilium to the trochanter makes it possible to suspend the prosthesis between the crests and trochanters. Besides offering effective suspension of the prosthesis, this method reduces confinement



Fig. 16. Case 5, plaster trial socket.

of the pelvic area. It may thus be suggested that wherever possible the surgeon should consider leaving some femur in the stump for purposes of suspension.

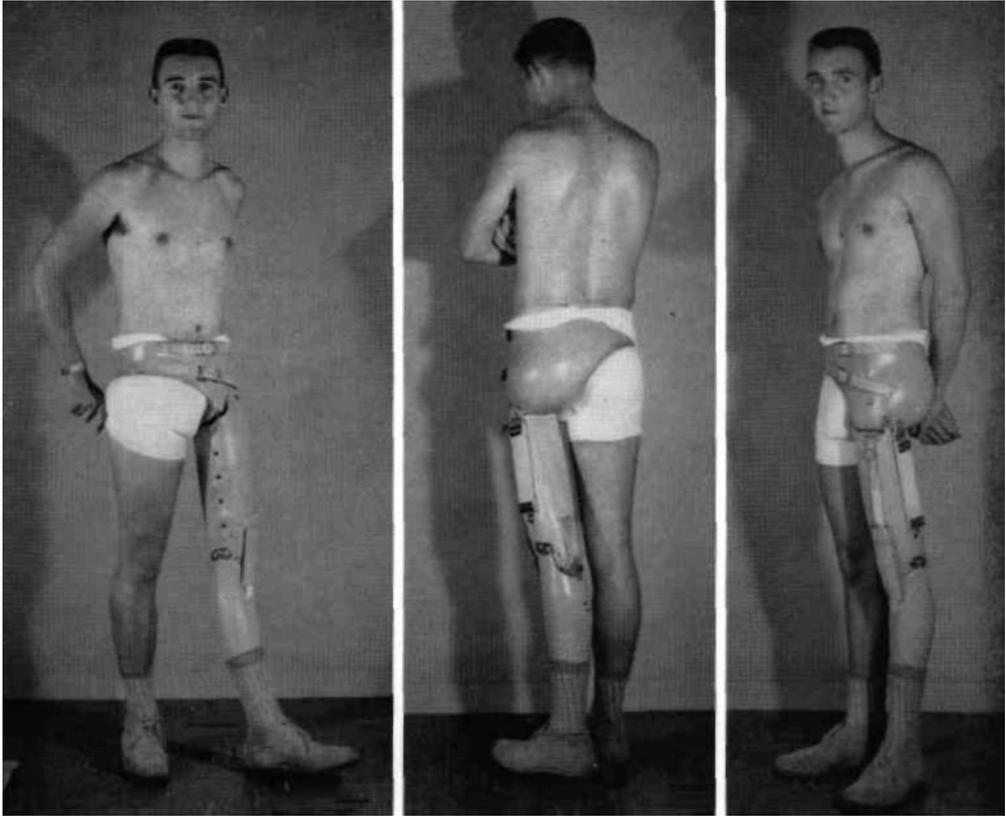


Fig. 17. Case 5, the prosthesis.

CASE 6

The next case, observed in a local limbshop, was a young man 32 years of age whose amputation had left a residual femur extending to just below the lesser trochanter, the distal end almost level with the perineum (Figs. 18 and 19). The femur was abducted 20 to 30 deg. Near the end of the femur the stump was pressure-sensitive and had a superficial trigger point. The femur length and the trigger point presented fitting problems. With sufficient room allowed in the socket for the femur in a relaxed position, and with added space to ensure relief for the trigger point, there was difficulty in locating the joint so that the prosthetic knee would be even with the normal knee in the sitting position. Had

the femur been flexed, and the soft tissue in the area under the joint distorted upward, joint placement would have been less of a problem.

The amputee had worn the conventional type of hip-disarticulation prosthesis successfully for 10 years. His first reaction to the Canadian type was one of criticism. He objected to the unyielding nature of the socket around his body and to having the prosthetic knee somewhat farther out and higher than the normal knee in sitting. After a short time on the new prosthesis in the fitting stage, however, he felt much more secure on the new limb than he had on the conventional one. He was impressed by the very positive suspension afforded by the molded plastic socket.



Fig. 18. Case 6, anterior view of the stump.



Fig. 19. Case 6, anteroposterior x-ray of the pelvis.

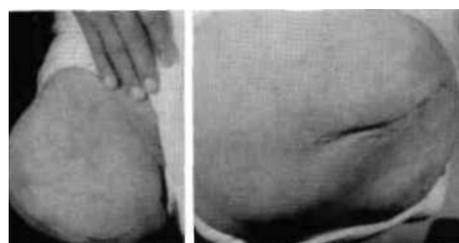
CASE 7

The longest residual femur that the Prosthetics Research Group attempted to fit with the Canadian-type hip-disarticulation prosthesis was in a 37-year-old male. It extended 1 1/2 below the perineum (Fig. 20). Failure to fit this amputee successfully with an above-knee type of prosthesis led to his referral by the Veterans Administration.

The stump was very short and powerful with a sensitive scar in the crotch area (Fig. 21). A trigger point on the anterodistal aspect made weight-bearing intolerable on the end of the stump, and there was a considerable volume change between flexion and contraction of the muscles. On the normal leg the knee was weak and buckled frequently, and a triple arthrodesis had been performed on the ankle joint.

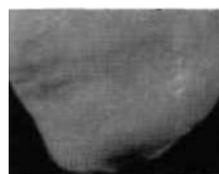


Fig. 20. Case 7, anteroposterior x-ray of the pelvis.



A

B



C

Fig. 21. Case 7, views of the stump. A, anterior view, sitting; B, lateral view, sitting; C, posterior view, standing.

Two possibilities for fitting this short stump were considered—suction-suspension above-knee prosthesis and Canadian-type hip-disarticulation prosthesis. Of the two, the suction-suspension method seemed to offer the greater challenge because on the medial side there were only 1 1/2 to 2 in. of stump available for effecting a suction seal. The scar tissue on the crotch was a potential source of discomfort, and the large volume change between tense and relaxed states might make it difficult to maintain a suction seal. Were a Canadian-type prosthesis to be used, the amputee would lose the function of his hip on the side of the amputation. Furthermore, since the patient lived in a very warm summer climate, the enclosing socket of the hip-disarticulation prosthesis might be a trial to wear.

The amputee was first fitted with a plaster socket for the Canadian-type prosthesis as in the method already outlined, the cast being molded with the stump in full flexion. The tissues under the stump, from the gluteal fold out to within about an inch of the end of the femur, were pushed up, thus immobilizing the femur to prevent any rubbing on the trigger point at the end of the stump,³ and the patient used the resulting check socket comfortably with a peg leg for about two hours. It was clear that this type of prosthesis had possibilities, but one objectionable feature would have been the unnatural appearance of the anterior protuberance for the flexed stump.

Along with evaluation of the Canadian-type prosthesis, a suction-socket above-knee prosthesis also was made and evaluated. Although because of previous disappointing experience with suction sockets the patient had been convinced that suction suspension would fail and had strongly favored the Canadian-type prosthesis, the suction-socket prosthesis was immediately successful and proved a more satisfactory means of treating this case. Confirmation was seen in the patient's increasing activity on the leg over a period of a year.

³ This indentation in the bottom of the socket would have allowed convenient installation of the hip joint.

CASE 8

During 1957, two hemipelvectomy amputees have been observed in local limbshops. The first was a young woman, 22 years old, whose amputation for a sarcoma removed all of the left portion of the pelvis with the exception of part of the iliac crest (Figs. 22, 23, and 24). Nearly two years after amputation she was fitted with a prosthesis. It is made according to the Canadian design, but the socket is of molded leather with Celastic for reinforcement. The socket is high, embracing the lower portions of the thoracic cage, and laces anteriorly (Fig. 25). The hip joint, 2 in. wide instead of the 3 1/2 in. reported here, is set 2 in. lateral to the medial edge of the socket, a feature which allows it to be positioned farther back toward the weight line, so that in walking over the leg the motion in the hip joint is continuous and smooth.

Weight is carried on the rib cage, the sacrum, and the compressed soft tissues of the amputated side. Up-and-down movement in the socket, approximately 1 1/2 in. between weight-bearing and non-weight-bearing, gives the



Fig. 22. Case 8, anteroposterior x-ray of the pelvis.

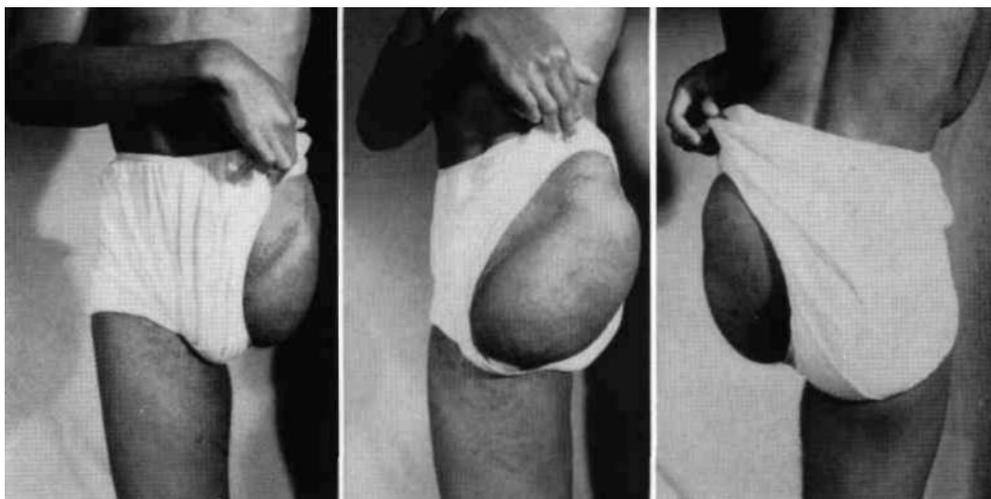


Fig. 23. Case 8, views of the stump.

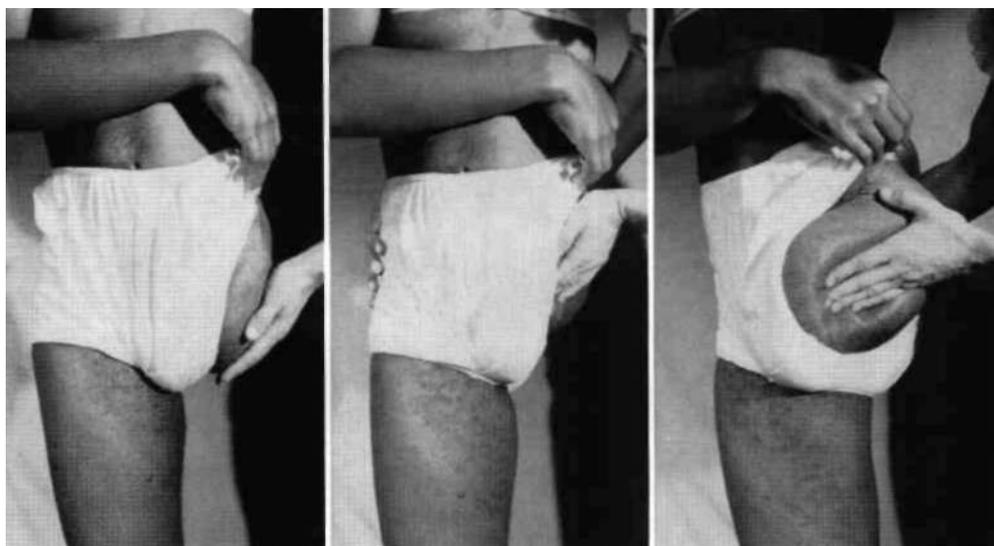


Fig. 24. Case 8, showing gross displacement of soft tissues of stump upon application of pressure. Lack of underlying bony structure prevents satisfactory weight-bearing in the stump area.

amputee the impression that the leg is heavy. But sitting and turning can be accomplished without difficulty (Figs. 26 and 27).

Before amputation this young woman was very active physically. Now she tires easily. Bearing weight on the rib cage greatly re-

stricts her body motion and also limits the amount of food she can eat at any one time. Heat dissipation and perspiration are real problems, so that after only three months of use the leather socket, with its odor, is becoming a hygienic nuisance.

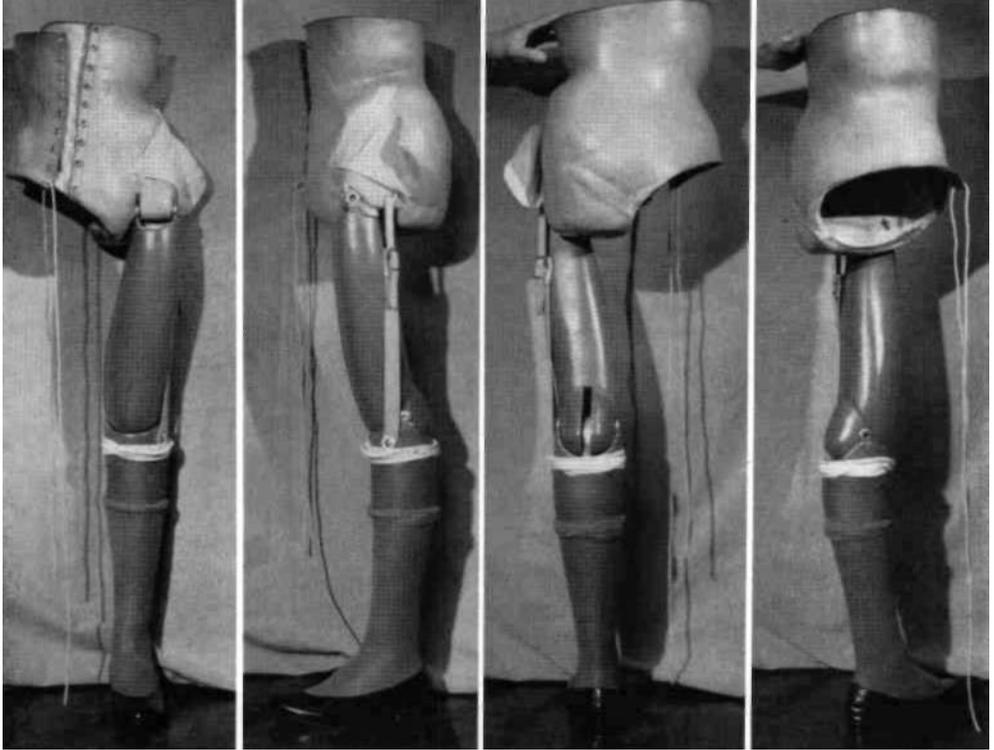
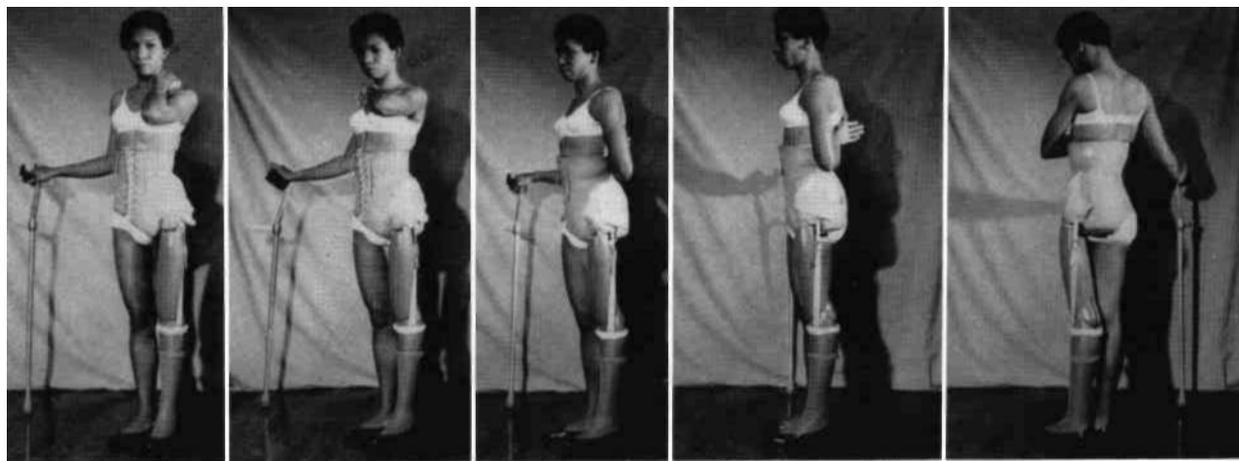


Fig. 25. Case 8, the prosthesis.



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10

Fig. 26. Case 8, turning sequence.

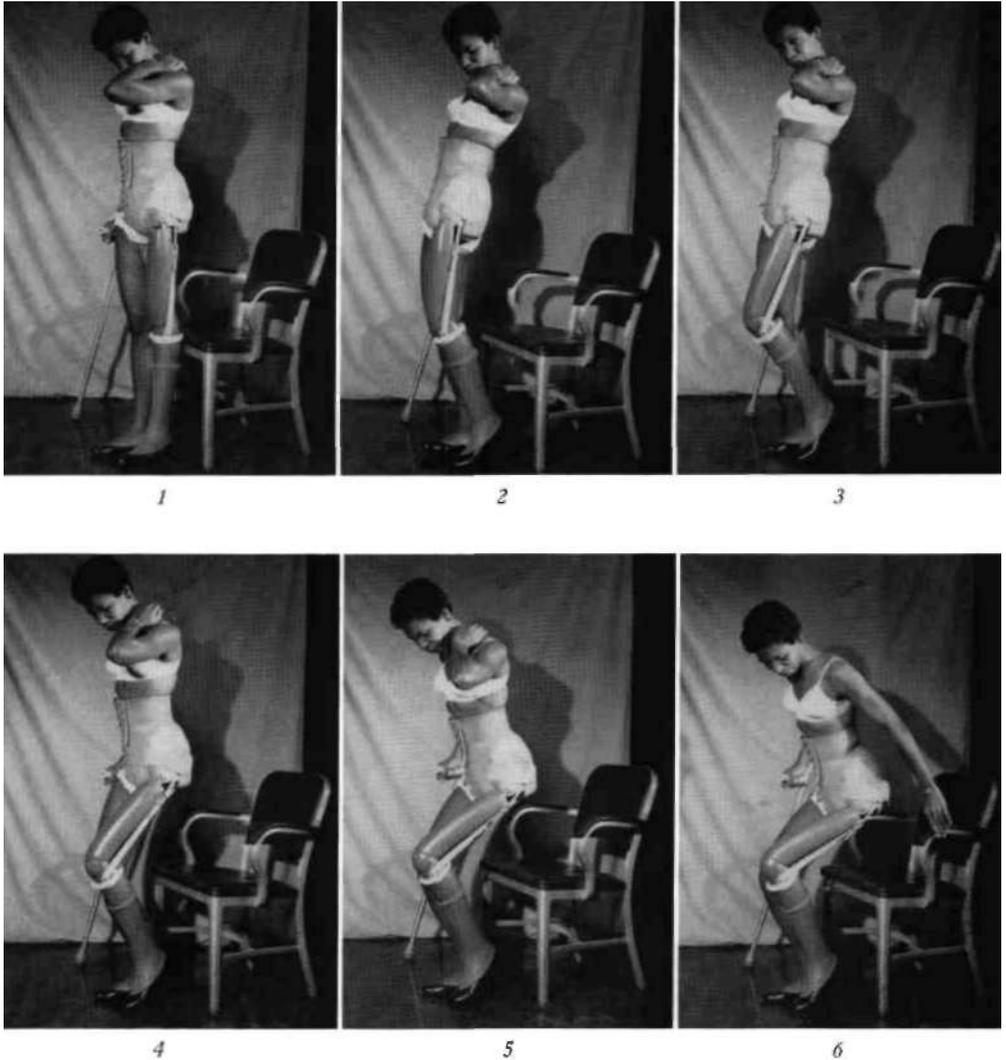


Fig. 27. Case 8, sitting and rising sequence.

CASE 9

The second hemipelvectomy was in a small, agile, and active man of 38, who underwent amputation in January 1957 for a malignancy (Fig. 28). In this amputation the pelvis was disarticulated at the sacroiliac joint (Fig. 29). A Canadian-type prosthesis was made for the patient in May 1957 by a local limbshop and the Prosthetics Research Group cooperatively.

The wrapping for the cast was made with

the amputee standing, and pressure was applied by hand under the remaining ischial tuberosity. Although it was planned to put the weight-bearing on the tuberosity if possible, there was no assurance that it could be done. Accordingly, the wrapping was continued well up on to the rib cage.

The wrap-cast was made into a check socket, and a peg leg was installed. When the amputee was checked on it, there was at least 1 1/2 in.

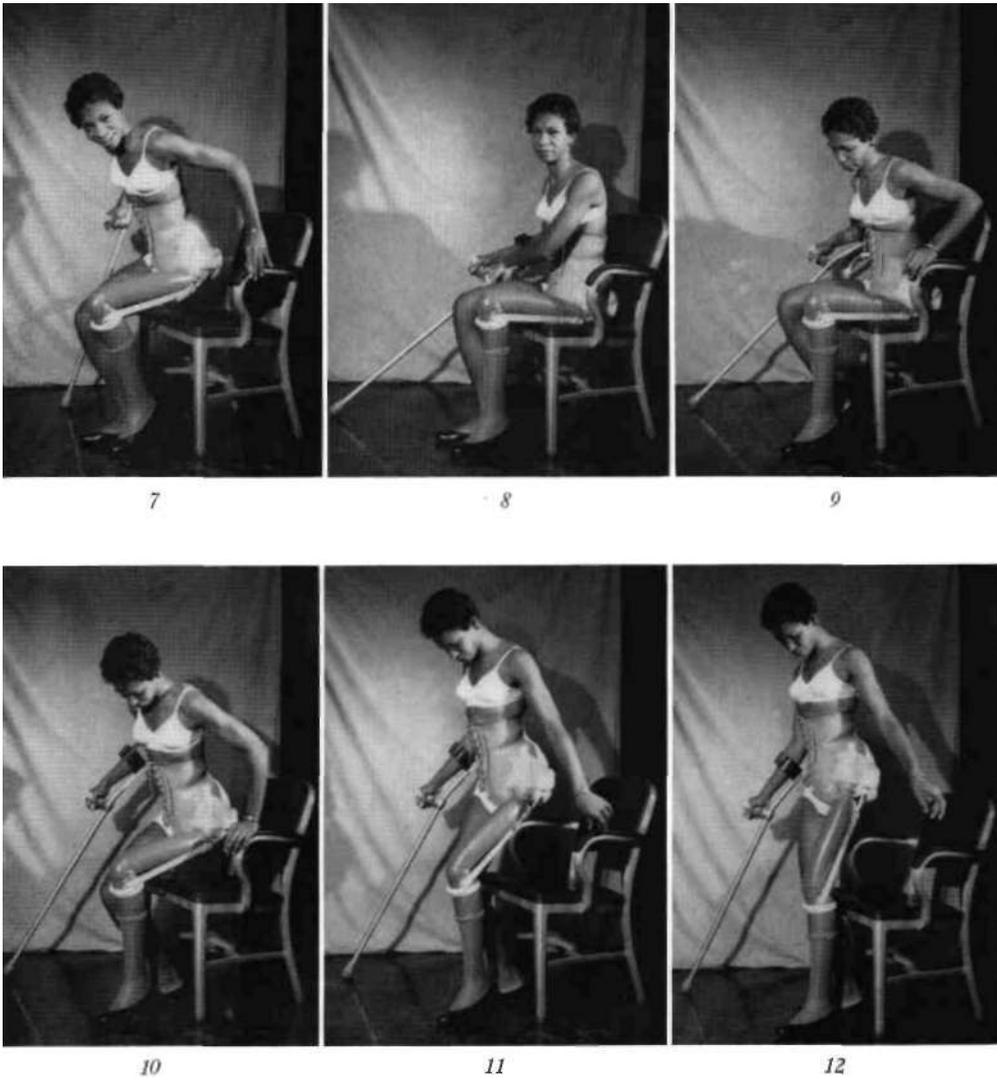


Fig. 27. Case 8, sitting and rising sequence, continued.

of up-and-down excursion in the socket between full weight-bearing and non-weight-bearing. To reduce excursion of the torso in the socket, the ischial seat was built up until the iliac crest was against the suspension hook. As walking trials proceeded, the brim of the socket was cut down from the rib cage to slightly above the crest level. Cutting the socket down freed the upper torso and had no apparent effect on stabilization.

A second check socket, this one of plastic laminate, was fabricated and installed on the adjustable leg. In checking the socket on the amputee, it was found that he was comfortable both in walking and in sitting, but adjustments to the weight-bearing platform had left other areas of the stump without support. To check clearance of the bony prominences, and to see just how closely the socket was contacting the stump, about a dozen 1/4 in.



Fig. 28. Case 9, lateral view of the stump.



Fig. 29. Case 9, anteroposterior x-ray of the pelvis.

holes were drilled through the socket in the sacral area and from the level of the iliac crest down. To check effectiveness of the suspension hook, holes were bored in the socket through the area over the normal crest. As much as 1/2 in. of space was found between the socket and the body in the gluteal region.

Then, with the subject standing in the socket but bent slightly forward, thin plaster was poured into the check socket at the depression

of the spinal column. When enough plaster had been poured into the socket so that it began to ooze out of the holes, the holes were masked off, and the amputee stood upright until the plaster had hardened. His immediate reaction was that he felt considerably more stable in the socket and that he had better suspension. After an hour's check for walking and sitting comfort, there were no further complaints. On the male mold made from this socket, the brim was undercut all around to increase the flare, which had been insufficient on the plastic check socket.

The final socket was fabricated from five layers of dacron with ten layers of glass cloth for reinforcement, especially across the weight-bearing area. Three layers of glass cloth were extended up to the level of the iliac crest on the side of the amputation, and two layers were brought up around the crest on the sound side. The socket did not overlap in front, but the anterior section was cut out between the mid-line and the crest on the normal side and a leather lacer was substituted. The final prosthesis (Fig. 30) was very satisfactory, and after two hours of walking between the bars the amputee was able to walk on a flat surface without the aid of canes or crutches.

This man reports that he has worn his prosthesis continuously every day for the past six weeks. An expeditor for a manufacturing concern, he is required to do much sitting, and

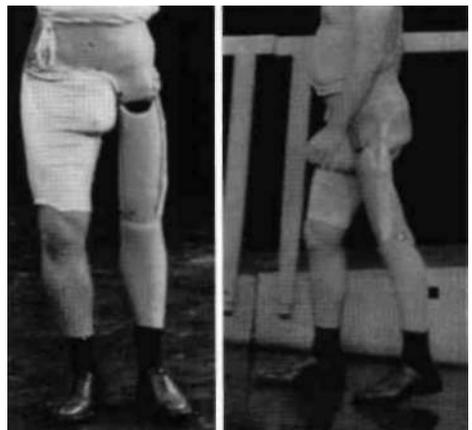


Fig. 30. Case 9, the prosthesis.

he finds that the balancing action of the prosthesis in sitting greatly reduces fatigue.

On the basis of their experience with the case, the prosthetists concerned felt that at another time they would begin the plaster wrapping from the bottom and sit the patient on a solid object shaped to give firm contact under the tuberosity, an expedient which would concentrate the forces there. With the amputee still sitting, the wrapping would be continued upward over the crest of the ilium and around the waist, thus keying the pelvis to the cast.

Making the plastic check socket was considered a very useful part of the procedure because it showed up a number of socket faults not easily found with the plaster-wrap socket and peg. Part of the reason was that using the check socket with the adjustable leg rather than with a peg allowed the socket to be checked under conditions closer to those of the finished prosthesis.

SUMMARY

The experience of the Prosthetics Research Group to date indicates that the Canadian-type hip-disarticulation prosthesis is highly satisfactory. Gait is fairly natural as a result of hip-joint action in the last part of the swing phase and in the first part of the stance phase. Elimination of a hip lock through arrangement of the joints allows the amputee to stoop, squat, and sit voluntarily without reference to manual controls (Fig. 31). The broad hip joint has proved very durable. No cases of hip-joint failure or wear have been seen thus far. The plastic-laminate type of socket has proved durable. Resistance to perspiration and ease of cleansing make the socket odor-free, and the relatively unyielding molded socket allows comfortable, efficient transfer of forces between the torso and the prosthesis.

Disadvantages of the prosthesis include the tendency for the hip to flex excessively when the amputee sits in soft seats and for the prosthetic toe to hook under overhanging steps. Another inherent disadvantage is that the speed with which the amputee can walk is limited by the characteristics of the compound-pendulum system of the leg. Available control mechanisms do not offer substantial improvement. In sitting, hip flexion can be restricted

by a stop between the socket and the top of the thigh, although this expedient limits the amputee in such maneuvers as squatting, or the amputee can prevent excessive hip flexion by crossing the prosthetic shank with the normal shank so that the prosthetic forefoot is restrained by the back of the normal shank (Fig. 32).



Fig. 31. Action of the Canadian-type hip joint in sitting and bending.



Fig. 32. Method of preventing excessive hip flexion during sitting. Normal shank restrains artificial shank.

Amputees who are accustomed to using a conventional prosthesis with a hip lock find the sensation of the free hip joint disturbing at first. Adaptation is rather rapid, however, at least for well-coordinated amputees. New cases do not sense the hip joint as a source of insecurity. Adaptation has been very rapid even in cases where a training program has been omitted.

For the hip-disarticulation amputee, the place of the Canadian-type prosthesis has been definitely established. Moreover, indications are that it can be applied successfully to borderline cases in the category "hip disarticulation." The two hemipelvectomy amputees studied have exhibited a degree of insensitivity to socket pressure that would not have been thought possible and have shown an astonishing level of ability on the prosthesis considering the extent of anatomical loss. In the case of the short-stump above-knee amputee, the aim must be to conserve all possible function compatible with making the amputee ambulatory in a comfortable and effective manner. More than 1 1/2 in. of tissue below the perineum would suggest that suction suspension should be attempted. If the stump is flexed, the Canadian-type prosthesis may be used, although remaining function is then sacrificed and cosmetic problems are introduced.

Components used with the Canadian-type hip-disarticulation prosthesis have included both standard and friction-stabilized knees and standard as well as SACH feet. The single-axis knee with friction for swing-phase control has been found satisfactory. Knee stability is adequate at heel contact if the leg is properly aligned, and there is the advantage that the knee can be flexed easily at the beginning of the swing phase. In the last analysis, consideration of biomechanical principles and of individual amputees' requirements serves as the best guide to selection of components.

ACKNOWLEDGMENT

The information offered in the preceding case summaries comes from some of the case files of the Biomechanics Laboratory at the University of California at Berkeley. Data dealing with the hip-disarticulation problem has been collected over the past four years by Charles W. Radcliffe, James Foort, Henry E. Loon, J. C. McKennon, W. H. Hoskinson, L. A. Wilson, J. Cross, and J. C. Bates. Information suggesting the course of study activity and conclusions on the problem have come from limbshops in the Bay Area and from other parts of the country.

Technical Notes from the Artificial Limb Program

This section of ARTIFICIAL LIMBS is intended as an outlet for new developments in limb prosthetics which, though not deserving of a long feature article, nevertheless ought to be brought to the attention of the readers of this journal. Notes may vary in length from a single paragraph to several pages of manuscript, as appropriate. Illustrations also are acceptable.

Color Stabilization of Polyester Laminates

Laminated forms made from polyester resins and stockinet exhibit a darkening effect when exposed to sunlight or to ultraviolet light. Since in the construction of such forms for use in prostheses much effort is put forth in the attempt to produce a laminate with homogeneous color, subsequent changes in the color are undesirable. It is known that the addition of such antioxidants as salicylic acid and other phenolic-type compounds to polyester resins will prevent darkening. Accordingly, a commercially available phenolic-type antioxidant—"U V Absorber 9" (2-hydroxy-4-methoxybenzophenone), manufactured by American Cyanamid Company—was selected by the Army Prosthetics Research Laboratory and evaluated thoroughly as a color stabilizer in polyester formulations.¹

In order to determine the minimum amount of "U V Absorber 9" necessary for maximum protection, a series of experiments was undertaken. Various amounts of "U V Absorber 9" were incorporated into the APRL standard polyester-laminate formulation.² In addition, laminates formulated with Laminae

¹APRL Technical Report 5733.

²APRL polyester-laminate recipe:

Paraplex P-43.60 parts
Paraplex P-13.	40 "
LupercoATC.	2 "
Naugatuck promoter.	8 drops/100 g. resin
Pigment05 part

polyester resins (manufactured by American Cyanamid Company) also were evaluated.

The fabricated laminates containing various amounts of "U V Absorber 9" were exposed to ultraviolet light for 240 hours, color readings being taken with a Hunter Color Difference Meter³ both before and after exposure. Color difference (ΔE) was derived from the formula:

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2},$$

where

$$\Delta L = 10\sqrt{R_d}$$

R_d , a , and b values were obtained directly from the color-difference meter, and the exposed laminates were compared visually with the corresponding unexposed laminates. The color-difference readings and the values of ΔE obtained therefrom for the Paraplex and Laminae polyester resins are recorded in Tables 1 and 2.

TABLE 1^a

Resin System	"U V Absorber 9" (parts)	R_d	R_d^1	a	a^1	b	b^1	ΔE
Paraplex P-44	0	27.7	23.3	13.0	14.6	17.3	22.6	7.06
Paraplex P-13	0.5	26.4	23.8	15.8	16.6	16.9	20.7	4.60
Paraplex P-13	1.0	26.9	25.1	13.1	13.7	17.2	19.5	2.92
Paraplex P-13	1.5	26.1	24.9	14.6	14.9	17.1	18.7	2.08
Paraplex P-13	2.0	27.0	25.8	13.8	14.1	17.7	19.2	1.94
Paraplex P-13	4.0	27.1	25.8	14.5	14.7	17.2	18.1	1.59

^a R_d , a , and b , before ultraviolet exposure; R_d^1 , a^1 , and b^1 , after 240 hours' exposure.

TABLE 2^a

Resin System	"U V Absorber 9" (parts)	R_d	R_d^1	a	a^1	b	b^1	ΔE
Laminac 4116	0	28.5	21.0	11.8	13.6	15.3	20.6	9.45
Laminac 4134	0.5	26.2	21.3	14.8	15.9	16.2	21.1	7.15
Laminac 4134	1.0	27.0	22.4	14.4	15.5	16.3	19.8	5.97
Laminac 4134	1.5	26.3	23.1	14.5	14.7	16.9	19.7	4.34
Laminac 4134	2.0	27.1	25.0	12.5	13.5	16.3	18.0	2.88
Laminac 4134	4.0	24.8	23.0	15.5	15.6	17.1	18.8	2.63

^a R_d , a , and b , before ultraviolet exposure; R_d^1 , a^1 , and b^1 , after 240 hours' exposure.

³ Manufactured by Gardner Laboratories, Bethesda, Md.

The results clearly indicate that in each series the laminates which contained no "U V Absorber 9" exhibited the greatest color change. A survey of the values of *AE* also showed that those formulations which contained 4 parts of "U V Absorber 9" per 100 parts of polyester resin imparted the greatest protection against ultraviolet exposure. Laminac-type laminates that contained "U V Absorber 9" exhibited less color stability than did the corresponding laminates fabricated with Paraplex polyester resins.

Comparison by visual inspection of laminates both before and after ultraviolet exposure showed that those compositions which contained 2 to 4 parts of the antioxidant per 100 parts of polyester resin were the most identical in color.

To ensure a permanent homogeneous color in polyester laminates, it is recommended that 4 parts of "U V Absorber 9" per 100 parts of resin be incorporated in subsequent polyester formulations.

—Joshua Nelson

Nylon Elastic Tape

One of the chief advantages of synthetic fabrics as harness materials for upper-extremity prostheses (ARTIFICIAL LIMBS, Spring 1956, p. 36) is their ability to dry quickly at room temperature. Yet until recently where elastic webbing has been required it has been necessary to employ cotton elastic webbing, thus negating the rapid-drying quality of the synthetic tapes.

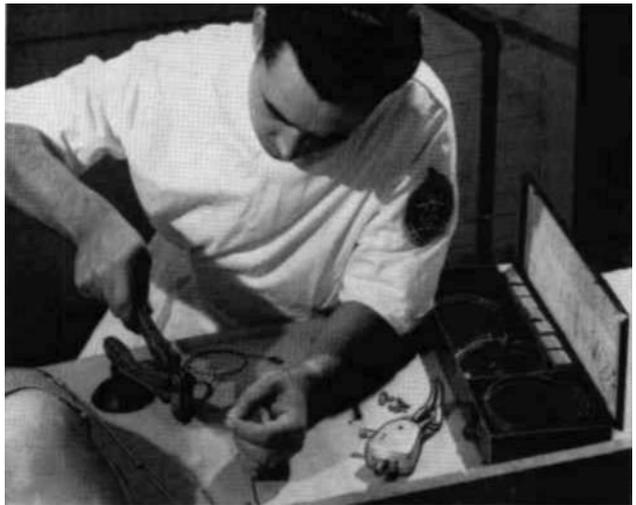
At the request of the Army Prosthetics Research Laboratory, the J. W. Wood Elastic Company, Stoughton, Mass., made a nylon elastic webbing available for testing. In tests both at APRL (APRL Technical Report No. 5654) and at New York University (NYU Report, *APRL Nylon Elastic Tape*, November 1956), the new material offered in 1-in. width as Style No. 6990 proved to be as satisfactory in every way as the 1-in. cotton

elastic tape now in general use. The main advantages are the shorter drying time and the nonabsorbing qualities. Nylon elastic tape dries completely in four hours, whereas cotton elastic tape requires more than eight.

The new tape is available through most of the prosthetics supply firms.

Improved Cable-Transmission System

An improved cable-transmission system for use in the control systems of upper-extremity prostheses is now available as a result of a cooperative effort by the American Chain & Cable Co. (ACCO) and the Army Prosthetics Research Laboratory (APRL). Advantages to be expected from use of the new system are increased efficiency, quieter operation, and longer cable life. The new ACCO-APRL system consists of a swaged steel cable 0.041 in. in diameter and a wrapped steel cable housing with a nylon liner insert used in conjunction with the ACCO swaged fittings which have previously been available.



IMPROVED CABLE-TRANSMISSION SYSTEM—Anton Leins, Jr., formerly Orthopedic Technologist with the Veterans Administration Prosthetics Center, New York City, demonstrates use of the hand swage which fuses the terminal connections to the cable to form an attachment as strong as the cable itself. Besides the swaging tool, the kit contains enough parts to provide control systems for about 30 complete arms.

Tests carried out at APRL during development, and later tests by the Prosthetic Devices Study at New York University, demonstrated the advantages of the new transmission system. The most recent tests cover a period of six months' wear by above- and below-elbow amputees who are active prosthesis users and who have a history of cable-maintenance problems. In every case there was an increase in control-system efficiency, the average increase being 8 percent for below-elbow amputees and 8.2 percent for the above-elbow cases. Every test amputee reacted favorably to the new system and stated that operation of the prosthesis was either "quieter" or "smoother."

Application of the new control system poses no special problems if the prosthetist is provided with the necessary components and with the "ACCO Precision Swaging Tool." These

are available from the manufacturer in kit form. Two points of technique need to be emphasized. First, the cable must be lubricated with the "lubrication stick" (provided in the kit) before it is inserted in the nylon liner. Second, the liner is best retained inside the housing by fitting ferrules to each cut end, and care must be exercised in applying them to assure that the liner does not protrude beyond the housing.

Further information and all necessary materials and equipment for application of the new system may be obtained from the Automotive and Aircraft Division, American Chain & Cable Co., Inc., 601 Stephenson Bldg., Detroit 2; 2216 So. Garfield Ave., Los Angeles 22; or Bridgeport 2, Conn. A descriptive advertisement appears on page 6 of the *Orthopedic and Prosthetic Appliance Journal* for June 1957.

Abstracts of Current Literature

This section of ARTIFICIAL LIMBS is intended to summarize the current literature of limb prosthetics, especially the less accessible reports literature arising from the several research groups participating in the Artificial Limb Program. Authors are invited to submit, for review, copies of any such material, including papers published in scientific journals.

Manual of Above Knee Prosthetics [for Prosthetists], Edited by Miles H. Anderson and Raymond E. Sollars, Prosthetics Education Program, School of Medicine, University of California, Los Angeles, January 1, 1957. iv plus 252 pp., illus. \$4.

This volume, bound in loose-leaf form with soft, accordian-fold cover, was prepared by the staff of the Prosthetics Education Project at the University of California at Los Angeles for use as a textbook by prosthetists taking the courses in *Clinical Prosthetics: Above-Knee Amputations* (page 83). Intended as a classroom and laboratory aid, it has since been adopted for use in similar courses offered at New York University.

In a total of 19 chapters, the *Manual* outlines the functional anatomy of the normal lower extremity, describes the process of human locomotion, normal and amputee, and provides detailed, stepwise procedures for constructing, fitting, and aligning the unilateral above-knee prosthesis according to the principles evolved by workers at the Lower-Extremity Amputee Research Project at the University of California, Berkeley. Although the subject matter is aimed almost entirely at the suction-socket method of suspension, there is included a chapter on auxiliary suspensions and another describing some commercially available components (socket blocks, knee and ankle setups, various types of knees and ankles, and the several kinds of prosthetic

feet) that can be purchased ready-made. Included also are detailed instructions for use of the UC adjustable leg in obtaining proper alignment and for use of the alignment-duplication jig in producing the established alignment in the finished prosthesis. Rather profuse illustrations support the text throughout.

Produced under the sponsorship of the Prosthetics Research Board, this publication was made possible by a training grant provided by the Office of Vocational Rehabilitation, U. S. Department of Health, Education, and Welfare.

Manual of Above Knee Prosthetics for Physicians and Therapists, Edited by Miles H. Anderson and Raymond E. Sollars, Prosthetics Education Program, School of Medicine, University of California, Los Angeles, April 1, 1957. v plus 211 pp., illus. \$4.

This volume, a sort of companion piece to the *Manual of Above Knee Prosthetics [for Prosthetists]* (see above), was prepared by the staff of the Prosthetics Education Project at the University of California at Los Angeles for use as a textbook by physicians and therapists taking the courses in *Clinical Prosthetics: Above-Knee Amputations* (page 83). Like the *Manual* for prosthetists, it too has been adopted for use in courses in above-knee prosthetics at New York University.

Although, as might have been expected, almost half of the material presented in this volume (locomotion, fabrication and fitting of above-knee prostheses, use of the adjustable leg and the alignment-duplication jig, auxiliary suspensions, and commercially available components) overlaps that given in the *Manual* for prosthetists, the remainder (amputation surgery, preoperative and postoperative care, stump complications, stump hygiene, pain, and a 40-page section on amputee training) is clearly in the professional areas of the physician and the therapist.

Again like the *Manual* for prosthetists, this volume too was published under the auspices of the Prosthetics Research Board, was financed by a training grant from the Office of Vocational Rehabilitation, is devoted wholly to the unilateral case, and is bound loose-leaf to accommodate future revisions.

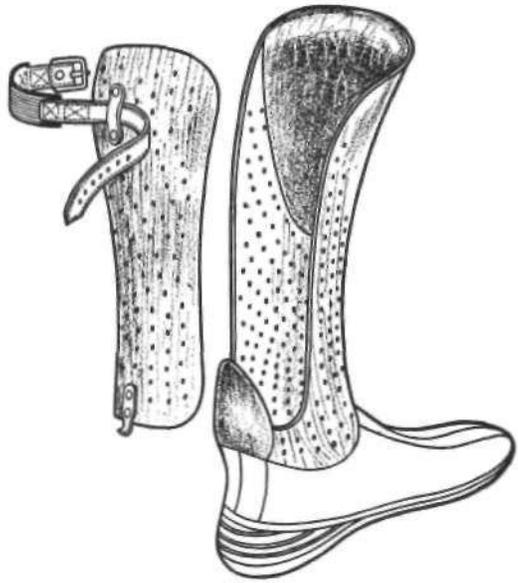
A Manual for Occupational Therapists on the Rehabilitation of Upper Extremity Amputees, Thelma L. Wellerson, College of Physicians and Surgeons, Columbia University, [and] Institute for the Crippled and Disabled, New York City, April 1957. vi plus 144 pp., illus. Free.

This manual, the result of a training grant by the Office of Vocational Rehabilitation, U. S. Department of Health, Education, and Welfare, is intended to augment the instruction of undergraduate students in the treatment of arm amputees. In addition to a brief history of upper-extremity prosthetics, it includes an outline of the functions of the prosthetics clinic team, a description of all recommended prostheses for the upper extremity from the wrist-disarticulation case to the fore-quarter, instructions for preprosthetic treatment, a detailed outline of prosthetics training for arm amputees (including suggested ways of accomplishing routine tasks of daily living), and specimen forms used by the Institute for the Crippled and Disabled in evaluating the performance of arm amputees. Presented in outline form, and classified by type of case (below-elbow, above-elbow, bilateral, and so on), the material covers all necessary treatment of the arm amputee from initial evaluation to final checkout. With the exception of one chart, *fabrication* of arm prostheses is omitted. But the text is profusely illustrated with drawings taken for the most part from established sources. Especially interesting, and unusual, are some of the "tricks" offered difficult cases for the performance of essential activities.

The Canadian Type Syme Prosthesis, J.

Foot, Series 11, Issue 30, Lower-Extremity Amputee Research Project, Institute of Engineering Research, University of California (Berkeley), [Report to the] Prosthetics Research Board, National Research Council, December 1956. 36 pp., illus. Free.

The Syme amputation, which removes the foot at the ankle while retaining the tough heel pad for weight-bearing, provides one of the most satisfactory end-bearing stumps known. In general, a person with such an amputation is able to walk with all weight supported directly on the end of the stump. But, because



THE CANADIAN-TYPE SYME PROSTHESIS—A modification incorporating the features of the SACH foot. From the UC report.

of the loss of some 2 1/2 to 3 1/4 in. of the length of the normal limb, gait without a prosthesis is lopsided. Moreover, absence of the fore-foot causes drop-off at the end of the stance phase, and loss of normal ankle function produces knee extension during weight-bearing. A functional prosthesis for the Syme amputation must therefore lengthen the limb so as to match the natural one in the standing position, supply a forefoot to increase effective leg length at toe-off, and provide the equivalent of plantar- and dorsiflexion.

The conventional Syme prosthesis, with laced leather socket and metal sidebars, fulfills all functional requirements satisfactorily, but it has a number of disadvantages. The sidebars are subject to frequent breakage. The leather socket deteriorates and loses shape. There is excessive bulkiness in the already broad area of the malleoli. Excessive weight often requires auxiliary suspension. And the shoe on the normal side often must be elevated to provide clearance for the ankle-joint assembly.

Early in 1954 (ARTIFICIAL LIMBS, September 1954, pp. 23-24), the Canadian Department of Veterans Affairs reported the development of an experimental Syme prosthesis, much lighter in weight and much better in

appearance, consisting of a plastic-laminate socket attached to a solid foot (no ankle joint) made of foam-crepe shoe-sole material built around a molded keel of Fiberglas-reinforced plastic. At the time, the device was under evaluation by 10 subjects, and the results were considered good. Subsequent experimental and design work at the University of California (Berkeley) toward application of the so-called "SACH foot" (Solid *Ankle, Cushion Heel*) to above-knee prostheses offered an improved method of construction of the Canadian-type Syme prosthesis, together with the possibility of improved function. Accordingly, the group at Berkeley undertook to develop improved techniques of assembly and fitting and to apply the SACH principle to the Canadian design. During 1955, more than 40 cases were fitted with the modified device, all seemingly with good results.

This report presents well-illustrated and detailed instructions for making and fitting the Canadian-type Syme prosthesis according to the latest methods. Included are the requirements of stump examination and measurement, details of cast-taking and construction of a male model, the method of preparing the socket from polyester resins with Fiberglas reinforcement, the procedure for constructing the foot (with templates for the component parts for shoe sizes 6 through 12), the steps involved in assembly and adjustment of the finished prosthesis, and a list of the necessary materials together with the names and addresses of suppliers.

Besides being lighter and less bulky at the ankle than the conventional Syme prosthesis, the Canadian type is said to exhibit fewer structural failures, to require little or no auxiliary suspension, to be free of noise, and to be completely resistant to weather and perspiration. Comfort is improved owing to better heat dissipation and to reduced shock at heel contact. Production time and material costs are lower, and the range of possible foot heights is adequate to fit the range of Syme stump lengths without elevating the shoe on the normal side. In addition, the technique may, it is claimed, be adapted for use with Boyd, Pirogoff, or Chopart amputations, in the latter case when residual ankle action cannot be utilized for physiological reasons.

A Survey of 48 Cineplasty Amputees, Prosthetic Devices Study, Research Division, College of Engineering, New York University, Report No. 115.25, Prepared for the Prosthetic and Sensory Aids Service, Veterans Administration, May 1957. vi plus 40 pp., 5 inserts, 15 tables. Free.

Since its invention late in the 19th century, and its more active pursuit in the early part of the 20th, the technique of cineplasty, the method of harnessing residual muscles in an arm stump for the operation of an upper-extremity prosthesis, has been the subject of much controversy and of waxing and waning interest both in the United States and abroad. One of the reasons for criticism related to the lack of suitable prosthetic components for use with cineplastic muscle tunnels. With the advent, after World War II, of enlarged research programs in the United States for the development of improved prosthetic devices, the Veterans Administration, the Army, and the Navy, all in cooperation with the Advisory Committee on Artificial Limbs (now the Prosthetics Research Board), established renewed studies of the surgical and prosthetic aspects of cineplastic treatment leading to improved surgical procedures and to better methods and materials for the construction of cineplastic prostheses. After the new methods had been employed for some time, the Prosthetic Devices Study of New York University undertook, by personal interview, a survey to obtain information on the utility and acceptability of cineplastic motors and prostheses in 48 male amputees who had been fitted through VA facilities.

In the selection of subjects, three criteria were employed. The first required that the amputee be willing to and capable of providing the necessary information; the second required that the subject live within 50 miles of a VA clinic; and the third limited the subjects to those who had worn cineplastic prostheses for a year or more. The following information was sought: personal history, experience with amputation and prostheses, and description of prostheses used (personal interview); biomechanical data, including length of stump and of sound arm, description of the cineplastic tunnel, and characteristics of the prosthesis (recorded by interviewer); comments on appearance, fit, comfort, and

function of the prostheses (recorded by amputee): comparison of conventional and of cineplastic prostheses (by those subjects who had worn both); and condition of stump, tunnel, and general health of the subject (recorded by VA staff physician).

Of the 48 amputees in the sample, 36 had below-elbow amputations, nine were above-elbow cases, and three were shoulder disarticulations. The below-elbow cases had undergone biceps cineplasty, while the above-elbow and shoulder-disarticulation cases had pectoral tunnels, of which seven were used to operate the elbow lock, five for terminal-device operation. Ranging in age from 21 to 57 years, the below-elbow subjects had an average age of 30 years. The three shoulder-disarticulation cases and the nine above-elbow cases (of which two with short stumps had been fitted as shoulder disarticulations) were from 23 to 36 years of age, and stump lengths in the above-elbow subjects ranged from 1 1/2 to 9 in. As a whole, the group seemed representative of veteran upper-extremity amputees with respect to age, amputation type, educational achievement, and experience with prostheses.

In general, the results indicated that biceps cineplasty was successful, as reflected by continuous wear of the prostheses and by the usually favorable opinions expressed by the subjects. Most of the deficiencies appeared to be related either to substandard condition of the mechanical components or to poor fitting. Despite the bad features, largely avoidable, of many of the below-elbow limbs, almost all of the subjects believed their prostheses to be serviceable and satisfactory in most respects. A few medical problems existed, but none prevented wear and use of the prostheses.

Pectoral cineplasty in the above-elbow and shoulder-disarticulation cases was, on the contrary, found to be of only marginal value. Four of the 12 subjects had discarded their cineplastic prostheses, two in exchange for conventional arms and two for an empty sleeve. Although the remaining eight subjects wore their cineplastic arms regularly, they used them for relatively few activities and expressed no preference for cineplasty over conventional limbs so far as usefulness, comfort, or ease of operation were concerned. Most of the subjects with pectoral cineplasty described their prostheses as offering only limited use.

Half of the subjects in this group had, or had had, medical difficulties with their muscle tunnels. Three pectoral tunnels had been closed, and of those remaining several exhibited bad features related to improper surgical construction.

The over-all conclusion was that biceps cineplasty in the below-elbow case is generally satisfactory, even with comparatively short below-elbow stumps having limited forearm flexion. Pectoral cineplasty was in general not considered particularly useful.

Upper Extremity Prosthetic Devices for Children, Michigan Crippled Children Commission (Carleton Dean, M.D., *Director*), Lansing, Mich., [1957]. ii plus 69 pp., illus. Free.

Early in 1946, the Michigan Crippled Children Commission, with the cooperation of the Mary Free Bed Guild Children's Hospital and Orthopedic Clinic at Grand Rapids, initiated a program of rehabilitation devoted entirely to the problems of the child amputee. The purpose was not only to fit the juvenile amputee with the best prosthetic equipment available but also to train him in its use, to continue to supply modifications of equipment, as dictated by growth factors, up to the age of 21 years, and to study the influence of cause of amputation (congenital or traumatic), age at time of amputation if traumatic, parental attitudes, and so on. Supported entirely by the Commission, the work up to 1955 afforded services to Michigan children only. In that year, the Children's Bureau of the U. S. Department of Health, Education, and Welfare, recognizing the success of the endeavor, made a special grant in order that similar services might be made available to child amputees from other states.

This report gives the frequency distribution of child amputees of all types (226 with upper-extremity amputations, 194 with amputations in the lower extremity) recorded in the Michigan State Register of Crippled Children as of June 30, 1956. Presented also—by drawings, photographs, and exploded views—are the types of arm prostheses found suitable for the various levels of amputation in the upper extremity in children 2 1/2 years to adult (21 years) and a statistical analysis of the devices fitted to 50 congenital and 46 traumatic cases

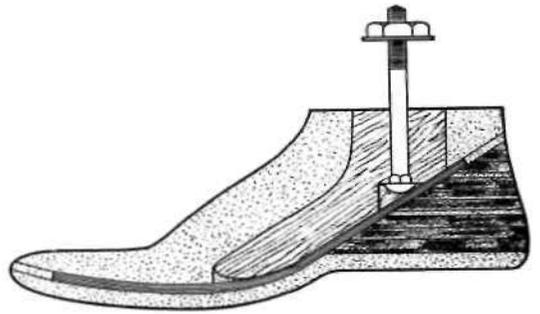
of unilateral upper-extremity amputation among Michigan children as of April 1, 1957. Detailed information on equipment and services furnished, plus the cost of such equipment and services, is given for 40 of the 96 cases cited.

Evidence is presented to the effect that the best results are obtained when child amputees are fitted at the earliest possible date (as early as five months), but it is pointed out that the requirements of the young amputee are in general quite unlike those of the adult and that the number of available devices especially designed for children is still unduly limited.

Evaluation of the Solid Ankle Cushion Heel Foot (SACH Foot), Prosthetic Devices Study, Research Division, College of Engineering, New York University, Report No. 115.23, Prepared for the Prosthetic and Sensory Aids Service, Veterans Administration, May 1957. vii plus 83 pp., illus. Free.

As early as 1955, the Prosthetic Devices Study of New York University undertook an evaluation of an experimental model of the so-called "SACH foot" (Solid Ankle, Cushion Heel) and found the device to be a desirable prosthetic component both functionally and psychologically. Because of the shock-absorbing qualities at heel contact and the comparatively smooth transition of weight from heel to toe during the stance phase, a high degree of amputee acceptance was afforded the device. But excessive maintenance requirements, owing largely to delamination of the heel components, constituted a serious deterrent to full acceptance. Subsequent refinements in heel construction led to a recommendation that the SACH foot be placed in production. This report summarizes the results obtained with revised production models and makes recommendations as to the future application of the SACH foot.

The investigation was divided into three parts. The first was concerned with an evaluation of the adequacy of existing instructions for fitting the production models. The second dealt with structural and functional comparisons between the production models and the previously tested experimental models, both under static conditions and under the dy-



THE SACH FOOT—Modification designed at the University of California, Berkeley, shown in cross-section. From the NYU report.

namic conditions of amputee use. And the third was aimed at an assessment of the relative value of heels of "medium" or "firm" stiffness when applied according to the instructions.

As for the first part, the experience of the prosthetists involved in the study led to the recommendation that the instructions [*Installation and Adjustment of the Solid Ankle-Cushion Heel (SACH) Foot for Adult Male Amputees*, March 1957, revised] be approved and distributed for general use. In the second part, the tests indicated that the improved SACH foot, both "firm" and "medium" heel, is an acceptable item and generally preferred over the conventional foot with articulated ankle. But in the third part (the evaluation of "firm" versus "medium" heels when applied according to the instructions), amputee reactions were so hopelessly confused as to prevent any clear interpretation. Engineering tests indicated that the differences between "firm" and "medium" wedges were actually very slight, thus leading to an unstructured situation with consequent ambiguity. On the basis of the general results, it is recommended that consideration be given to fabrication of a heel wedge considerably stiffer than either of the two types tested.

The objection to the SACH foot most frequently cited was the difficulty of donning and removing shoes and socks. Accordingly, it is recommended further that consideration be given to more optimal shaping, especially in the area of the heel. Some objectionable behavior in heel-to-toe transition is noted and proposed as an area for further investigation.

Digest of Major Activities of the Artificial Limb Program

This section of ARTIFICIAL LIMBS is intended to present a summary of principal news events of interest in the Artificial Limb Program during the several months preceding issue. Stories of activities in the various laboratories and associated agencies, reports of meetings, photographs, and items about individuals all are acceptable.

Annual Prosthetics Conference

During the period May 21 through 25, all committees and subcommittees of the Prosthetics Research Board met at the National Academy of Sciences in Washington for the 1957 Annual Spring Conference of the Artificial Limb Program. Tuesday and Wednesday, May 21 and 22, were given over to individual meetings of all committees and subcommittees except the Committee on Prosthetics Research and Development, which convened on Friday afternoon, May 24, to receive the reports of the three Phase Subcommittees and to discuss and act upon the recommendations.

Thursday, May 23, was devoted to an all-day Scientific Session presented under the joint auspices of the Committee on Prosthetics Research and Development, the Committee on Prosthetics Education and Information, and the newly authorized Committee on Child Prosthetics Problems. Brig. Gen. F. S. Strong, Jr., Chairman of PRB, led off a series of six presentations covering topics currently of special interest in the Artificial Limb Program. He spoke on *Planning and Organization of Research for Amputees*. Dr. Verne T. Inman, of the University of California Medical Center, San Francisco, covered the present status of research in the medical problems of the amputee, and Drs. H. F. Albronda and G. Hamilton Crook discussed the purposes, procedures, and goals of the Psychology Study Group of the Lower-Extremity Amputee Research Project, University

of California Medical Center, San Francisco. Dr. George T. Aitken, consulting orthopedist with the Michigan Crippled Children Commission, Grand Rapids, spoke on *The Status of Child Prosthetics*.

During the afternoon of the 23rd, there was a panel discussion of *Dissemination of Research Results to the Professions Involved in Rehabilitation of Amputees*. Serving as moderator for the panel was Dr. Charles O. Bechtol, Professor of Orthopedic Surgery at Yale University. He was assisted by Dr. Miles H. Anderson, Director of the Prosthetics Education Project at UCLA; Jack L. Caldwell, certified prosthetist with J. E. Hanger, Inc., of Tampa, Fla.; Dr. Sidney Fishman, Director of the Prosthetic Devices Study at NYU; Dr. Harriet E. Gillette, Director of the Physical Medicine and Rehabilitation Clinic, Atlanta; and Dr. Eugene F. Murphy, Chief of the Research and Development Division of the VA's Prosthetic and Sensory Aids Service. Closing the program for the day was Gerald E. Gwynne, engineer with the Engineering Artificial Limbs Project at UCLA. He presented *An Experimental Design Study of an Upper-Extremity Prosthesis*.

On Friday morning, May 24, various participants in the Artificial Limb Program and a group of volunteer amputee subjects joined forces in presenting a demonstration of progress before a special session of the U. S. Senate Committee on Labor and Public Welfare (page 80). The series of meetings was concluded Saturday morning, May 25, with the meeting of the Committee of the Whole. During that session, Chairman Strong received on behalf of the Prosthetics Research Board the reports of the Committee on Prosthetics Research and Development, the Committee on New Devices, the Committee on Prosthetics Education and Information, and the Committee on Child Prosthetics Problems.

Before the meeting adjourned, it was agreed by all that annual conferences are highly desirable, that Washington is probably the best site, and that they are best held in late spring, preferably after the end of the academic year. The next Annual Spring Conference of the Artificial Limb Program is scheduled to be held in Washington the week of June 16, 1958.



PRB EXPOSITION OF PROGEESS—Some highlights. The Honorable Lister Hill (D., Ala.) chats with Brig. Gen. F. S. Strong, Jr. (left), Chairman of the Prosthetics Research Board, and Dr. Harriet E. Gillette, Director of the Physical Medicine and Rehabilitation Clinic, Atlanta, during the presentation before the Senate Committee on Labor and Public Welfare May 24.

PRB Exposition of Progress

In Washington on May 24, at the request of the Committee on Labor and Public Welfare of the U. S. Senate, the Prosthetics Research Board, assisted by members of its committees, various other specialists, and almost a dozen volunteer amputee subjects, presented another demonstration (ARTIFICIAL LIMBS, May 1954, p. 41) aimed at illustrating some of the results of the Artificial Limb Program. Prepared under the supervision of Dr. Sidney Fishman, of New York University, the presentation was given in the historic old Supreme Court Chamber in the Senate wing of the United States Capitol before members of the Committee and more than 200 guests. Included for the first time were some of the results of work with child amputees. It was also the first time that accomplishments in the field of artificial limbs had been presented before a Senate committee.

In opening the session, the Honorable Lister Hill (D., Ala.), Chairman of the Senate Committee on Labor and Public Welfare, outlined the background leading to the development of

the Artificial Limb Program. He cited Public Law 729, 80th Congress,¹ which authorizes and provides funds for a continuing program of prosthetics research, and Public Law 565, 83rd Congress, which amended the Vocational Rehabilitation Act in such a way as to support the Prosthetics Education Program. Speaking of the work conducted during the past 12 years, Senator Hill said that the Artificial Limb Program had accomplished "striking results, the benefits of which accrue equally to civilian amputees and to veter-

ans," and he later made it clear that "out of these demonstrations must come the resolve and determination that this great program must and shall go forward."

Before presenting the several clinic teams and their respective amputee demonstrators, Brig. Gen. F. S. Strong, Jr., Chairman of the Prosthetics Research Board, expressed the appreciation of all the participants for the opportunity to show what, through systematic research, it has been possible to do for handicapped people and called attention to the debt owing to Congresswoman Edith Nourse Rogers (R., Mass.), who, as the then Chairman of the House Committee on Veterans' Affairs, was instrumental in the passage of the enabling legislation for continuance of the Artificial Limb Program. He said that ". . . without Mrs. Rogers' wisdom at the critical time in providing for continuity, many of these research projects would have had to fold up." As for the importance of continuity, General

¹ Public Law 729, 80th Congress, was superseded June 17, 1957, by Public Law 85-56, 85th Congress. —ED.

Strong pointed out that research workers cannot devote their time to such a specialized field as limb prosthetics unless they are assured of reasonable tenure.

Presenting upper extremities was Dr. Charles O. Bechtol, Chief of the Division of Orthopedic Surgery at Yale University, assisted by Lt. Sheila McDonnell (USA, MSC), Physical Therapist at Walter Reed Army Hospital, and William E. Hitchcock, Prosthetics Instructor in the Post Graduate Medical School of New York University. Lower extremities were demonstrated by Dr. Cameron B. Hall, Clinical Professor of Orthopedic Surgery in the School of Medicine at UCLA. His clinic-team associates were Irene Waters, Physical Therapist at the Institute of Physical Medicine and Rehabilitation, NYU-Bellevue Medical Center, New York City, and Charles A. Hennessy, Prosthetics Instructor at the School of Medicine, UCLA. The novel presentation of child prosthetics was under the direction of Dr. George T. Aitken, Consulting Orthopedist with the Michigan Crippled Children Commission, assisted by Lt. McDonnell.

Amputee demonstrators included: from the Washington, D. C. area, Daniel J. Dennehy, Jack R. Northrup, Lewis A. Rice, and Alonzo Spencer; from the New York area, Herbert Kramer and Leonard McCarthy. The child amputees were Diana Beckett, 4 1/2, of Beltsville, Md.; Donna DeYoung, 6 1/2, of Grand Haven, Mich., David J. Dodge, 6 1/2, of District

Heights, Md.; and Eugene Sanchez-Saavedra, 10, of New York City.

After the presentation and discussion of the amputees and their prosthetic appliances, Mary E. Switzer, Director of the Office of Vocational Rehabilitation of the U. S. Department of Health, Education, and Welfare, James J. Segars, Supervisor of Physical Restoration for the Georgia State Department of Education, and Dr. Harriet E. Gillette, Director of the Physical Medicine and Rehabilitation Clinic, Atlanta, outlined the current work of their respective organizations.

In closing the demonstration, Senator Hill and General Strong acknowledged the valuable contributions of a number of the principals in the Artificial Limb Program and expressed appreciation to Robert S. Allen, well-known Washington newsman and consultant to the Prosthetics Research Board, for his efforts in arranging for the meeting.



PRB EXPOSITION OF PROGRESS—Some highlights. Distinguished members of the Congress observe the accomplishments of Donna DeYoung, 63^-year-old bilateral knee-disarticulation amputee of Grand Haven, Mich., during the presentation on Capitol Hill May 24. Left to right beside Donna are Senator John S. Cooper (R., Ky.), Senator Pat McNamara (D., Mich.), Congresswoman Edith Nourse Rogers (R., Mass.), and Senator Lister Hill (D., Ala.), Chairman of the Senate Committee on Labor and Public Welfare. In right background (head aside) is Dr. Craig L. Taylor, Director of the Engineering Artificial Limbs Project at the University of California at Los Angeles.



A transcript of the hearing, entitled *Progress of the Artificial Limb Program*, has been published by the U. S. Government Printing Office. Copies may be obtained from Stewart E. McClure, Chief Clerk of the Senate Committee on Labor and Public Welfare.

Conference on Prosthetic Devices for Children

Pursuant to the proposal made during the exploratory Conference on Child Prosthetics Problems at UCLA last October 26 (ARTIFICIAL LIMBS, Spring 1957, p. 110), more than a score of persons actively engaged in work with juvenile amputees met April 3 through 5 at the Mary Free Bed Children's Hospital, Grand Rapids, Mich., to assess the prosthetic devices currently available for use on children, to outline areas in need of development, and to determine directions for research toward the improvement of artificial-limb components for children. The three-day session covered the entire field of prosthetic components for the child amputee, both upper and lower extremity, and included discussion of the present status of checkout procedures for this younger age group.

Among the immediate accomplishments of the conference was the development of special checkout and training-observation forms to be used by the various participating agencies in gathering data on the suitability and efficiency of prostheses applied to children. It is anticipated that the information thus collected will eventually offer valuable clues for the modification and improvement of children's mechanical components.

At the conclusion of the meeting on components, it was agreed by all present that a similar conference covering the nonmechanical, or psychosocial and medical, aspects of the child-amputee problem should be held in the near future. Accordingly, an *ad hoc* committee was appointed to recommend ways and means of organizing such a conference.

PROGRESS OF THE ARTIFICIAL LIMB PROGRAM—Dr. Charles O. Bechtol (with microphone), Dr. Cameron B. Hall (holding above-knee prosthesis); Dr. George T. Aitken (lower right, with the children), Charles A. Hennessy (kneeling to adjust trial leg), and Irene Waters (white uniform) demonstrate recent developments in limb prosthetics before a special session of the Senate Committee on Labor and Public Welfare May 24. Gentleman with the canes is Senator Charles E. Potter (R., Mich.), himself a bilateral leg amputee. Standing in background near center are Brig. Gen. F. S. Strong, Jr., and Dr. Harold W. Glattly, Chairman and Executive Director, respectively, of the Prosthetics Research Board.

Prosthetics Education Program

During the spring of 1957, the nationwide Prosthetics Education Program was continued with additional courses in above-knee prosthetics at New York University and at the University of California at Los Angeles and with one more course in upper-extremity amputations at UCLA. As in the case of the previous sessions (ARTIFICIAL LIMBS, Spring 1956, p. 39; Autumn 1956, p. 69 ff.; Spring 1957, p. 111), the courses were open to physicians and surgeons, therapists, and prosthetists and were so designed that the three groups worked together for at least a portion of the course time.

At New York University, the program for the 1956-57 academic year was completed with three courses in above-knee prosthetics, with the following attendance:

ABOVE-KNEE PROSTHETICS	SERIES			
	D	E	F	Total
Physicians	19	11	17	47
Therapists	16	16	17	49
Prosthetists	16	15	15	46

Students of these three classes were as follows:

COURSE 741D (Above-Knee Prosthetics)

*Physicians, April 1 (through 5)—*Dr. Richard D. Burk, Columbus, Ohio; Dr. William F. Enneking, Jackson, Miss.; Dr. William M. Ewing, Louisville, Ky.; Dr. Julius C. Felketti, Hempstead, N. V.; Dr. Maurice Gershman, Far Rockaway, N. V.; Dr. Emily R. Hess, Fort Thomas, Ky.; Dr. C. Hugh Hickey, Milwaukee; Dr. Hla Pe, New York City; Dr. Olbo C. Hudson, Hempstead, N. Y.; Dr. Saul N. Machover, Pittsburgh; Dr. Emilie Maxwell, Haverford, Pa.; Dr. Rex O. McMorris, Louisville, Ky.; Dr. Robert D. Mussey, Urbana, Ill.; Dr. Herbert Nogin, Brooklyn, N. Y.; Dr. William J. O'Rourke, Cincinnati; Dr. Kenneth S. Phillips, New Albany, Ind.; Dr. Thomas J. Radley, Cincinnati; Dr. Max A. Stoner, Philadelphia; and Dr. Frederick Ziman, New York City.



PROSTHETICS EDUCATION AT NYU—Students of the courses in above-knee prosthetics offered by New York University engage in shop practice in the construction of the above-knee prosthesis according to the principles developed at the University of California at Berkeley.

Cincinnati; George H. McKnight, Pittsburgh; Milton G. Manwaring, Nobelsville, Ind.; Howard V. Mooney, Lowell, Mass.; Heinz P. Murka, Dayton, Ohio; Neil E. Resico, Charleston, W. Va.; Jack M. Talbert, Indianapolis; and Frank Zeman, Caparra Heights, Puerto Rico.

COURSE 741E (Above-Knee Prosthetics)

Physicians, May 6 through 10—Dr. Charles Borzilleri, Charlottesville, Va.; Dr. Robert S. Hoffman, Albany, N. Y.; Dr. Wayne W. Kotcamp, Louisville, Ky.; Dr. Roswell Lowry, Shaker Heights, Ohio; Dr. James E. Mazzacane, Hamden, Conn.; Dr. Harry D. Morris, New Orleans; Dr. Russell P. Rizzo, Cleveland; Dr. Gabriel Rosenkranz, Brooklyn, N. Y.; Dr. Herman L. Rudolph, Reading, Pa.; Dr. William C. Schaefer, Detroit; and Dr. William S. Smith, Columbus, Ohio.

COURSE 742E (Above-Knee Prosthetics)

Therapists, May 2 through 10—Paul E. Beck, Augusta, Ga.; Loretta R. Boger, Lakewood, Ohio; Barbara A. Cossy, New York City; Walter G. Fitzsimmons, Fayson Lakes, N. J.; Barbara A. Gwynn, Cleveland; Louise Hayward, Albany, N. Y.; Marion L. Holmes, Utica, N. Y.; Ethel Kahn, Bronx, N. Y.; Jean L. Lamb, Philadelphia; Joseph Lederman, Brooklyn, N. Y.; Lewis F. Mantovano, Rockville Centre, N. Y.; Floyd L. Milbank, Dayton, Ohio; Reba E. Samuels, Richmond, Va.; Harvey Schirmmacher, Elmira, N. Y.; Ernest G. Sealo, New York City; and Frank R. Spohrer, Glen Ridge, N. J.

COURSE 742D (Above-Knee Prosthetics)

Therapists, March 28 through April 5—Florence G. Bailey, Cincinnati; Elizabeth M. Carey, Hudson Falls, N. Y.; William B. Daugherty, Worthington, Ohio; W. Wilson Fulton, Jackson, Miss.; Richard H. Goldstein, Hempstead, N. Y.; Richard A. Jessum, Jamaica, N. Y.; Kenneth F. Lonborg, Milwaukee; Earl W. Mason, Louisville, Ky.; Richard V. McDougall, Pittsburgh; John B. Murphy, Chillicothe, Ohio; Anne Pascasio, Philadelphia; Harold E. Potts, Montclair, N. J.; Alvin R. Rogerson, Bloomfield, N. J.; Dolores Shoulders, Urbana, Ill.; Joseph T. Strunk, Cincinnati; and Hazel A. Van Arnem, Troy, N. Y.

COURSE 743D (Above-Knee Prosthetics)

Prosthetists, March 25 through April 5—Wilfred J. Anair, Sr., New Britain, Conn.; Karl J. Barghausen, Venetia, Pa.; William R. Barnett, Peoria, Ill.; Herman J. Geisler, Fond Du Lac, Wis.; Carrol M. Gordon, North Little Rock, Ark.; Bernard G. Holland, Jr., Hattiesburg, Miss.; Bennie H. Huggins, Raleigh, N. C.; Ludwig F. Karsten, Milwaukee; Floyd J. Keeton,

COURSE 743E (Above-Knee Prosthetics)

Prosthetists, April 29 through May 10—Harold Calon, Detroit; Dale E. Clark, Minneapolis; John E. Dillard, Nashville; Ivan A. Dillee, Woodside, N. Y.; Arthur Finnieston, Coral Gables, Fla.; Dorsey P. Hildebrand, Mobile, Ala.; George I. Kinman, Toronto; Paul E. Leimkuehler, Cleveland; Dock M. Neal, Charleston, W. Va.; Lawrence Phillips, Jackson, Miss.; Elwood Pollock, Massapequa, N. Y.; Charles S. Schaeffer, Dearborn, Mich.; Daniel J. Seals, Montgomery, Ala.; Powell Simonton, Fort Wayne, Ind.; and James S. Wells, Merrifield, Va.

COURSE 741F (Above-Knee Prosthetics)

Physicians, June 10 through 14—Dr. John H. Allan, Charlottesville, Va.; Dr. Kenneth C. Archibald, White Plains, N. Y.; Dr. Joseph A. Baranowski, Fort Howard, Md.; Dr. Bedford F. Boylston, Houston; Dr. Richard A. Conlen, Haddonfield, N. J.; Dr. Nadene Coyne, Cleveland Heights, Ohio; Dr. William J. Erdman, Philadelphia; Dr. Joseph G. Furey, Cleveland; Dr. Otto G. Goldkamp, West Hartford, Conn.; Dr. Edward

C. Holscher, St. Louis; Dr. James Hurt, Louisville, Ky.; Dr. Ernest W. Johnson, Columbus, Ohio; Dr. John M. Pandy, Wood, Mich.; Dr. John A. Powers, Charlotte, N. C.; Dr. Peter S. Sabatelle, San Juan, Puerto Rico; Dr. Joseph N. Vizzard, Bala-Cynwyd, Pa.; and Dr. Reich L. Watterson, Parma Heights, Ohio.

COURSE 742F (Above-Knee Prosthetics)

Therapists, June 6 through 14—Demetrius Babiak, Louisville, Ky.; Philomena Cardone, Newark, N. J.; Edith Cole, Pittsburgh; Joan Erback, Hillside, N. J.; Patricia Golden, McKownville, N. Y.; Mrs. John Hedrick, Miami; Marie Heghinian, Jersey City, N. J.; Grace Horton, Durham, N. C.; Donald Humberger, Charlotte, N. C.; Donald Hurry, Wood, Wis.; Wilma Krans, New York City; Mary Mashburn, Augusta, Ga.; Joan Pape, Toronto; Norman Schreck, Philadelphia; Joan Stopiolo, Albany, N. Y.; Evelyn Washburn, Watertown, N. Y.; and Thomas Wells, Malton, Ontario.

COURSE 743F (Above-Knee Prosthetics)

Prosthetists, June 3 through 14—Robert Bennington, Rockville Centre, N. Y.; James L. Brazelton, Detroit; Walter H. Caleson, New York City; HungTong Chun, Seoul, Korea; Helmuth H. Fliess, Chicago; Gunter H. Gehl, Chicago; Stanley E. Hedges, Indianapolis; Milton N. Hinnant, Charlotte, N. C.; Anton Leins, Yorktown Heights, N. Y.; Nick Pechota, Buffalo; Alfred R. Sulima, Levittown, Pa.; William L. Vansant, Pittsburgh; Richard A. Walker, Tampa, Fla.; George D. Ward, Huntington, W. Va.; and Robert M. Williams, San Antonio.

At UCLA, educational activities of the Prosthetics Education Project for the year 1956-57 came to a close on the evening of June 28 at the graduation banquet for the June class (Section VII) in *Clinical Prosthetics: Upper-Extremity Amputations*. Earlier in the year, PEP had offered three additional classes (Sections IV, V, and VI) in *Clinical Prosthetics: Above-Knee Amputations*. Total enrollment for the four courses included 52 physicians, 39 therapists, and 45 prosthetists. Students were as follows:

SECTION IV

Prosthetists, February 25 through March 8—Earl Beall, Fresno, Calif.; Hughbert H. DuBois, Casper, Wyo.; Richard Fadely, Santa Monica, Calif.; Everett F. Haines, Des Moines, Iowa; James M. McFarlen, Dallas; Pat W. McKendrick, Salt Lake City; Samuel W. Peiffer, Oklahoma City; John A. Pentland, Vancouver, B. C.; Alvin E. Rupley, Fort Worth; Walter L. Sandberg, Salt Lake City; and Edward C. Wright, Drayton Plains, Mich.

Therapists, March 4 through 8—Elizabeth J. Ander-

son, Los Angeles; William R. Bird, Des Moines, Iowa; Jean M. Cummings, Los Angeles; Nerman E. Miller, Des Moines, Iowa; and Martha C. Wroe, Kansas City, Mo.

Physicians, March 4 through 8—Dr. Donald W. Blair, Des Moines, Iowa; Dr. Felix L. Butte, Dallas; Dr. Robert H. Fitzgerald, Independence, Mo.; Dr. Richard H. Jones, Minneapolis; Dr. James S. Miles, Denver; Dr. M. H. Morris, San Antonio; Dr. James W. Rae, Jr., Ann Arbor, Mich.; and Dr. Carl B. Tryggvi, Seattle.

SECTION V

Prosthetists, March 18 through 29—William T. Andrews, San Antonio; Richard G. Bidwell, Milwaukee; Robert N. Bidwell, Madison, Wis.; David S. Burton, Omaha; Glenn Grant, Milwaukee; Charlie Kymes, San Antonio; Lorrin H. Madsen, Minneapolis; Carl S. McCluggage, Nashville, Tenn.; Junior Odom, Nashville, Tenn.; Edwin W. Powell, Louisville, Ky.; and Ralph R. Snell, Nashville, Tenn.

Therapists, March 25 through 29—David Anderson, Van Nuys, Calif.; V. Kenneth Boyum, Milwaukee; Joseph S. Chasin, Los Angeles; Frances L. Eckland, South Gate, Calif.; Vera R. Ford, Los Angeles; Annie M. Grdjan, Los Angeles; Ned R. Kennedy, Jr., Los Angeles; Beverly A. Kindig, Buena Park, Calif.; Ruth F. Rosenfelder, Los Angeles; Rudolph V. Sellers, Denver; Gus Valdemar, Santa Monica, Calif.; and Nancy B. Ward, Los Angeles.

Physicians, March 25 through 29—Dr. Harry H. Bleecker, Pasadena, Calif.; Dr. Harold E. Elger, Vancouver, Wash.; Dr. David C. G. Monsen, Los Angeles; Dr. Richard W. Moore, Santa Monica, Calif.; Dr. Jacquelin Perry, La Mirada, Calif.; Dr. Thomas Roland, Los Angeles; Dr. Donald A. Smith, San Gabriel, Calif.; Dr. William L. Waldrop, Oklahoma City; and Dr. Edwin C. Welsh, Wauwatosa, Wis.

SECTION VI

Prosthetists, April 22 through May 3—Charles C. Buckner, Fort Worth, Texas; Jose S. Cross, Berkeley, Calif.; William E. Cummings, Sacramento, Calif.; Ivan A. Long, Denver; Fred C. Lucas, Lubbock, Texas; Leo P. Marcotte, New Orleans; James I. McFall, Dallas; Vance C. Meadows, Grand Rapids, Mich.; George E. Newton, Honolulu, T. H.; Walter H. Stauffer, Edmonton, Alta.; and Victor Tourluk, San Diego, Calif.

Therapists, April 29 through May 3—Elizabeth M. Barnett, Los Angeles; Mary E. Bennett, Los Angeles; Ronald D. Brown, Los Angeles; Gail W. Burns, Los Angeles; Lois A. Conway, Santa Monica, Calif.; Mabel E. Hurni, Spokane, Wash.; Donald F. Kimble, Hollywood, Calif.; Patricia Krueger, San Mateo, Calif.; John C. Nygaard, Oklahoma City; Frances L. Patton, Los Angeles; and I. Lucille Walsh, Los Angeles.

Physicians, April 29 through May 3—Dr. Howard R. Baker, Los Angeles; Dr. Karl E. Carlson, Palo Alto, Calif.; Dr. Thomas J. Cline, Los Angeles; Dr. John G. Davidson, Butte, Mont.; Dr. Fred E. Herzer, West Covina, Calif.; Dr. Ora L. Huddleston, Pacific Palisades, Calif.; Dr. John T. Jacobs, Denver; Dr.

Herbert Kent, Oklahoma City; Dr. Earl J. Miller, Norwalk, Calif.; Dr. William S. Mowrey, Los Angeles; Dr. Stanley Olejniczak, Detroit; Dr. Wiley L. Ren-

shaw, Beverly Hills, Calif.; Dr. Francis J. Schiller, Whittier, Calif.; Dr. Benedict W. Varco, Fargo, N. Dak.; and Dr. F. William Wagner, Arcadia, Calif.



PROSTHETICS EDUCATION AT UCLA—Continuation of the series. Pictured are the students and instructors in the courses in *Clinical Prosthetics: Above-Knee Amputations* presented by the Prosthetics Education Project at the University of California Medical Center, Los Angeles, during the spring of 1957. Top, Section IV, February 25 through March 8; middle, Section V, March 18 through 29; bottom, Section VI, April 22 through May 3.



PROSTHETICS EDUCATION AT UCLA—Continuation of the series. Pictured are the students and instructors in the course in *Clinical Prosthetics: Upper-Extremity Amputations* (Section VII) presented by the Prosthetics Education Project at the University of California Medical Center, Los Angeles, June 10 through 28.

SECTION VII

Prosthetists, June 10 through 28—Claude L. Brown, Jackson, Miss.; Jack E. Conry, Hondo, Calif.; Hughbert H. DuBois, Casper, Wyo.; Francis R. Jones, Warm Springs, Ga.; Walter M. Joslin, Glendale, Calif.; Ivan A. Long, Denver; George E. Newton, Honolulu, T. H.; Orlyn C. Ostereich, Sioux City, Iowa; Harold C. Prescott, San Antonio; Josef Rosenberger, Hartford, Conn.; Floyd D. Simmons, Memphis; and Lee R. Snelson, Van Nuys, Calif.

Therapists, June 17 through 28—Lois M. Barber, Los Angeles; Betty L. Chaffer, Los Angeles; Thomas B. Irwin, Seattle; Claire B. Kopp, Monterey Park, Calif.; Joe O. Luckman, Great Falls, Mont.; Hildegarde Meyers, Chicago; Patricia J. Pechtl, Los Angeles; Betsy A. Rosselot, Los Angeles; Trude Seligman, San Diego, Calif.; Dolores M. Shoulders, Urbana, Ill.; and Julie Werner, Los Angeles.

Physicians, June 24 through 28—Dr. Robert G. Addison, Chicago; Dr. Leonard F. Bender, Ann Arbor, Mich.; Dr. Russell S. Blanchard, Detroit; Dr. Harry H. Bleecker, Pasadena, Calif.; Dr. Bradley W. Carr, Evanston, Ill.; Dr. Robert W. Carson, Los Angeles; Dr. John G. Davidson, Butte, Mont.; Dr. Donald K. Hester, Santa Monica, Calif.; Dr. John T. Jacobs, Denver; Dr. Duane M. Kline, Cheyenne, Wyo.; Dr. Robert D. Kochsiek, Canoga Park, Calif.; Dr. Jack L. Lewis, Long Beach, Calif.; Dr. Jean E. Michels, Los Angeles; Dr. J. Garth Mooney, Seattle; Dr. Robert D. Mussey, Urbana, Ill.; Dr. Jacquelin Perry, La Mirada, Calif.; Dr. Robert L. Romano, Seattle; Dr. Donald H. Sitler, Santa Monica, Calif.; Dr. Donald A. Smith, San Gabriel, Calif.; and Dr. John E. Stewart, Seattle.

During the 1957-58 academic year, the Prosthetics Education Program will be continued at NYU and at UCLA on a somewhat broader base of subject matter. New York

University is planning to offer four series of courses in above-knee prosthetics, several three-day courses in above-knee prosthetic diagnosis for prosthetists, two series of courses in upper-extremity prosthetics, and a number of courses for nonmedical rehabilitation personnel, including supervisors of physical restoration, vocational counselors, social-service workers, directors of rehabilitation centers, and other administrative personnel concerned with the field of prosthetic rehabilitation. Tentative plans at UCLA also include a new series of courses in prosthetics. The accompanying schedules are subject to revision.

TENTATIVE SCHEDULE OF COURSES IN PROSTHETICS
NEW YORK UNIVERSITY

Academic Year 1957-58

DATE	COURSE NO.	TITLE
Sept. 26-28	749A	Prosthetic Diagnosis, Above-Knee, for Prosthetists
Oct. 7-Nov. 8	746A	Upper-Extremity Prosthetics, for Prosthetists
Oct. 28-Nov. 8	745A	Upper-Extremity Prosthetics, for Therapists
Nov. 4-8	744A	Upper-Extremity Prosthetics, for Physicians and Surgeons
Nov. 11-22	7410A	Prosthetics for Rehabilitation Personnel
Dec. 2-20	743A	Above-Knee Prosthetics, for Prosthetists

Dec. 9-20	742A	Above-Knee Prosthetics, for Therapists	Mar. 3-7	Orthopedic and Prosthetic Rehabilitation
Dec. 16-20	741A	Above-Knee Prosthetics, for Physicians and Surgeons	Mar. 10-21	Clinical Prosthetics: Above-Knee Amputations, for Prosthetists
Jan. 13-31	743B	Above-Knee Prosthetics, for Prosthetists	Mar. 17-21	Clinical Prosthetics: Above-Knee Amputations, for Physicians and Therapists
Jan. 20-31	742B	Above-Knee Prosthetics, for Therapists	Mar. 24-28	Orthopedic and Prosthetic Rehabilitation
Jan. 27-31	741B	Above-Knee Prosthetics, for Physicians and Surgeons	May 5-9	Orthopedic and Prosthetic Rehabilitation
Feb. 13-15	749B	Prosthetic Diagnosis, Above-Knee, for Prosthetists	May 19-23	Orthopedic and Prosthetic Rehabilitation
Feb. 17-Mar. 7	743C	Above-Knee Prosthetics, for Prosthetists	June 2-20	Clinical Prosthetics: Upper-Extremity Amputations, for Prosthetists
Feb. 24-Mar. 7	742C	Above-Knee Prosthetics, for Therapists	June 16-20	Clinical Prosthetics: Upper-Extremity Amputations, for Physicians and Therapists
Mar. 3-7	741C	Above-Knee Prosthetics, for Physicians and Surgeons		
Mar. 17-Apr. 11	—	Prosthetics for Rehabilitation Personnel		
Apr. 17-19	749C	Prosthetic Diagnosis, Above-Knee, for Prosthetists		
Apr. 21-May 9	743D	Above-Knee Prosthetics, for Prosthetists		
Apr. 28-May 9	742D	Above-Knee Prosthetics, for Therapists		
May 5-9	741D	Above-Knee Prosthetics, for Physicians and Surgeons		
May 19-June 20	746B	Upper-Extremity Prosthetics, for Prosthetists		
June 9-20	745B	Upper-Extremity Prosthetics, for Therapists		
June 16-20	744B	Upper-Extremity Prosthetics, for Physicians and Surgeons		

New Chicago Project

The Prosthetics Research Center of Northwestern University, operating under a contract between the University and the Veterans Administration, is now located in temporary quarters in the Rehabilitation Institute of Chicago (401 E. Ohio St., Chicago 11) awaiting remodeling and preparation of permanent quarters in the basement of the same building. Basement construction is expected to be complete about April 1958. In the meantime, research problems are being formulated, and visits are being made to other centers of prosthetics research.



DR. COMPERE

TENTATIVE SCHEDULE OF COURSES IN PROSTHETICS UNIVERSITY OF CALIFORNIA AT LOS ANGELES Academic Year 1957-58

DATE	COURSE TITLE
Oct. 21-Nov. 1	Clinical Prosthetics: Above-Knee Amputations, for Prosthetists
Oct. 28-Nov. 1	Clinical Prosthetics: Above-Knee Amputations, for Physicians and Therapists
Jan. 13-24	Clinical Prosthetics: Above-Knee Amputations, for Prosthetists
Jan. 20-24	Clinical Prosthetics: Above-Knee Amputations, for Physicians and Therapists

Under the direction of Dr. Clinton L. Compere, consultant to the VA's Orthopedic and Prosthetic Appliance Clinic Team in Chicago, the project has as its assistant director Mr. Colin A. McLaurin, an engineer formerly with the Prosthetic Services Centre of the Canadian Department of Veterans Affairs and a figure well known as the inventor of the Canadian-type hip-disarticulation prosthesis (to which this issue of ARTIFICIAL LIMBS is devoted). Complete cooperation is received from the staff and personnel of the Rehabilitation Institute, which is a center for the treatment and prosthetic rehabilitation of amputees of

all ages and with all kinds of medical complications. A study is being made of the full records of 400 amputees who have been through the training program of the Institute. Special consideration is being given to classifying and studying the various medical complications with a view toward determining the most suitable prosthetic treatment for each specific problem type. Particular emphasis is being placed on geriatric patients.



MR. MCLAURIN

Also under way is practical research on prosthetics for bizarre types of amputations and on certain components of upper- and lower-extremity prostheses not under active consideration at other projects. Complete photographic and research records will be kept on the majority of patients processed through the Institute and on all those under direct study in the project. Cooperation is extended to the Michigan Crippled Children Commission in Grand Rapids by helping to solve engineering problems which arise in the work with child amputees.

The project is assisted by an abundance of consultants—medical, prosthetic, and physiatric—and by the extensive clinical material so readily available at the Rehabilitation Institute.

New Biomechanics Laboratory

On July 1, the studies of the medical problems of amputees, of the fundamentals of human locomotion, and of lower-extremity prosthetics carried on at the San Francisco and Berkeley branches of the University of California were reconstituted under a new organization known as the Biomechanics Laboratory. The new unit is governed by a Biomechanics Research Board, under the chairmanship of Dr. Verne T. Inman, and is administered from the Laboratory quarters at the University of California Medical Center in San Francisco. Additional research facilities are located in the Engineering Department at Berkeley and at the U. S. Naval Hospital in Oakland.

The Biomechanics Laboratory is an outgrowth of the Prosthetic Devices Research Project, initiated on the Berkeley Campus in 1945, and of the Biomechanics Group which until 1953 met informally on the San Francisco Campus. Currently functioning under the joint auspices of the Department of Orthopaedic Surgery, School of Medicine, and of the College of Engineering, it is supported by government research grants obtained through the sponsorship of the Prosthetics Research Board, National Academy of Sciences—National Research Council.



DR. INMAN

Appointment for Bidwell

Early last spring, Brig. Gen. F. S. Strong, Jr., Chairman of the Prosthetics Research Board, announced the appointment of Richard G. Bidwell, of Milwaukee, as a member of the Committee on New Devices, a group which currently reports to the Office of the Executive Director, PRB. This move brings into active participation in the Artificial Limb Program another man with extensive background in the field.

Although still this side of forty, Bidwell dates his experience in prosthetic and orthopedic appliances from the year 1936, when he began an apprenticeship in his father's establishment, the House of Bidwell. During World War II, he served in the artificial-limb shops of the England General Hospital, Atlantic City, and the Fletcher General Hospital at Cambridge, Ohio. His special training includes the Orthopedic Appliance Symposium held at Mellon Institute in 1948, the course presented at the Warm Springs Foundation in Georgia and the Suction Socket School in New York



MR. BIDWELL

City, both in 1949, the lecture and laboratory course in upper-extremity prosthetics at UCLA in 1954, and the course in *Clinical Prosthetics: Above-Knee Amputations* at UCLA in the spring of this year. He is now head of the House of Bidwell, a Certified Facility, where, in 1951, he conducted a suction-socket school of his own.

Mr. Bidwell has been identified with Drs. Walter P. Blount and Albert C. Schmidt in the development of the "Milwaukee Brace" [J. Bone & Joint Surg., 39A:705 (June 1957)]. With Dr. Schmidt he presented a seminar on that device before the New Orleans Assembly of the Limb and Brace Profession in October of 1955, and he was cited by the American Academy of Orthopaedic Surgeons for his participation in the Scientific Exhibit of the brace shown at the 24th Annual Meeting of the Academy last January.

Bidwell has long been a member of the Orthopedic Appliance and Limb Manufacturers Association and was chosen by it as the first Regional Director for Region VI (Illinois, Indiana, Wisconsin, and Eastern Missouri).

Appointment for Klopsteg

Paul E. Klopsteg, formerly Professor of Applied Science and Director of Research at the Northwestern Technological Institute, Evanston, Ill., and professor emeritus at Northwestern University, has been appointed Associate Director for Research of the National Science Foundation, it was announced in July by Dr. Alan T. Waterman, Director of NSF. Having already served once before as an associate director of the Foundation, and more recently as one of its consultants, Dr. Klopsteg will now be responsible for the Foundation's activities in support of basic research in the sciences.

Dr. Klopsteg has long been associated with the Artificial Limb Program, first (1945) as Chairman of the old Board for Prosthetic and Sensory Devices, later as Chairman of the Committee on Prosthetic Devices, and still



DR. KLOPSTEG

later as Chairman of its successor, the Advisory Committee on Artificial Limbs. Besides being the author of numerous publications in his own special fields of engineering and of science administration, he is the senior author of Klopsteg and Wilson's *Human Limbs and Their Substitutes* (McGraw-Hill, New York, 1954), the 840-page collaboration produced under the auspices of the Advisory Committee on Artificial Limbs. Currently, Dr. Klopsteg is a member of the Prosthetics Research Board.

Appointment for Bechtol

Dr. Charles O. Bechtol, formerly Associate Professor of Surgery and Chief of the Division of Orthopedic Surgery at Yale University Medical School, has been appointed Professor of Surgery (Orthopedics) and Chief of the Division of Orthopedic Surgery at the University of California Medical School in Los Angeles. This new assignment takes him back to the West Coast, an area with which he is not unfamiliar. It also takes him back into more intimate association with the Prosthetics Education Program, an activity to which he has been an important party since its inception in 1953. Before going to Yale, Dr. Bechtol had been Assistant Clinical Professor of Orthopedic Surgery at the University of California Medical Center in San Francisco, and he thus has had experience with prosthetics research in the Bay Area as well. He has already taught 20 courses in prosthetics at UCLA, and in his new position he plans to continue active participation in prosthetics research and education.



DR. BECHTOL

Dr. Bechtol has been a well-known principal in the Artificial Limb Program for more than a decade and has held many committee posts, including chairmanship of the old Technical Committee on Prosthetics (1955). Currently, he is a member of the Committee on Prosthetics Research and Development and Chairman of the Subcommittee on Production-Model Development and Testing of the Prosthetics Research Board. In addition, Dr. Bechtol has long served the Veterans

Administration as a consultant for Orthopedic and Prosthetic Appliance Clinic Teams, both in California and at the VA hospital at West Haven, Conn.

Member of numerous medical societies, Dr. Bechtol is the author of more than a score of journal articles and has contributed to a number of the Instructional Course Lectures given by the American Academy of Orthopaedic Surgeons.

Job for Jackson

Glenn E. Jackson, Executive Director of the Orthopedic Appliance and Limb Manufacturers Association, was in charge of the arrangements for discussion at the 1957 meeting of the President's Committee on Employment of the Physically Handicapped held in the Interdepartmental Auditorium in Washington May 23 and 24. After hearing a message from President Eisenhower, the delegates to the President's Committee were divided into three groups for the discussion system planned

by Mr. Jackson, and each group was assigned an experienced moderator specially picked and trained by Jackson for the occasion. The topic for discussion by each group was *Ways and Means to Make Local and State Groups More Effective in Promoting the Employment of the Physically Handicapped*.

Each group was organized and began its discussions the afternoon of May 23. The following morning they reduced their discussions to written form. These summaries were reported at a mass meeting of all three groups and are now under further study by the staff of the National Committee.

For more than 30 years Mr. Jackson has specialized in the study of this group-discussion method of group leadership. Since pioneering the method with labor-management groups in 1926, he has been the author of two articles on the subject: *The Discussion Method in Trade Association Work: A Critique* and *When Group Thinking is Most Rewarding*. The first appeared in the *American Trade Association Executives Journal* for July 1952. The second is to be found in the July 1957 issue of the *Journal of the American Society of Association Executives*.



MR. JACKSON



RECOGNITION FOR VA PERSONNEL—Pictured are some of the employees of the New York Regional Office of the Prosthetic and Sensory Aids Service to whom the Veterans Administration recently presented certificates and cash awards for superior performance. Seated, left to right, are William M. Bernstock, Robert J. Pollock, Sidney Garbarsky, Werner Greenbaum, and Domenick B. Bonarrigo. Standing, left to right, are William J. Romahn, Jr., Frank D'Alessandro, George J. Kuehnlein, Stanley J. Kordasz, and Steven L. Purka. Four others receiving awards were not present when this picture was taken.

Awards for PSAS Personnel

Certificates and cash awards for superior performance were recently presented to a group of Veterans Administration employees engaged in prosthetic and sensory-aids activities in New York City. Recipients of the awards are on the staffs of the Veterans Administration

Prosthetics Center and of the Research and Development Division of the Prosthetic and Sensory Aids Service. They included William M. Bernstock, Assistant Chief of the Research and Development Division, PSAS; Domenick B. Bonarrigo, orthopedic technician with the Orthopedic Shoe Section, VAPC; Harry T. Cavanaugh, orthopedic technician with the Limb and Brace Section, VAPC; Frank D'Alessandro, administrative assistant in the Office of the Chief of VAPC; Ralph A. DeGaetano, orthopedic technician with the Limb and Brace Section, VAPC; Sidney Garbarsky, clerk-typist in the Limb and Brace Shop, VAPC; Werner Greenbaum, orthopedic technician with the Limb and Brace Shop, VAPC; Stanley J. Kordasz, orthopedic technician with the Limb and Brace Section,



AWARD FOR BERNSTOCK—William M. Bernstock (left), Assistant Chief of the Research and Development Division of the VA's Prosthetic and Sensory Aids Service, receives his Superior Performance Award from Dr. Eugene F. Murphy, Chief of the Division, at a special ceremony in New York.

VAPC; George J. Kuehnlein, laboratory machinist with the Testing and Development Laboratory, VAPC; Benjamin Orłowski, orthopedic technician with the Orthopedic Shoe Section, VAPC; Robert J. Pollock, orthopedic technician with the Testing and Development Laboratory, VAPC; Steven L. Purka, exhibit assistant for the Research and Development Division, PSAS; William J. Romahn, Jr., photographer with the Testing and Development Laboratory, VAPC; and Candido Suarez, clerk-stenographer with the Orthopedic Shoe Section, VAPC.

At a separate ceremony, Dr. Eugene F. Murphy, Chief of the Research and Development Division, PSAS, presented a certificate of superior performance to his assistant, Mr. Bernstock. Mr. Purka, who oversees the Prosthetics Reference Collection, received a similar certificate from Dr. Murphy and Mr. Bernstock.



AWARD FOR PURKA—Steven L. Purka (center), in charge of exhibits and the Prosthetics Reference Collection for the VA's Prosthetic and Sensory Aids Service in New York, receives his Superior Performance Award from William M. Bernstock, Assistant Chief of the Research and Development Division. Dr. Eugene F. Murphy, Chief of the Division, looks on.

PSAS Exhibit

The Prosthetic and Sensory Aids Service of the Veterans Administration, through the Orthopedic Shoe Section of the VA Prosthetics Center in New York City, operates a nationwide mail-order system of providing custom-built orthopedic shoes to veteran beneficiaries requiring them. A group of strategically located VA Last Clinics serves to furnish initial lasts, casts, patterns, and so on, and the Orthopedic Shoe Section, formerly known as the VA Shoe Last Depository, provides safe storage for all the materials needed to fill future orders from Central Office contractors. A system of mailing in double containers furnishes a ready means of returning (in the inner container) shoes in need of repair or replacement.

At the June meetings of the American Medical Association in New York, PSAS presented an exhibit, entitled *Better Prescription for Orthopedic Shoes*, in which it outlined graphically the modern methods of prescribing, fabricating, and fitting orthopedic shoes. In charge were Dr. C. F. Mueller, Chief of the Prosthetic Appliances and Accessories Section of PSAS, Washington; Dr. Herman Gladstone, Orthopedic Consultant to VAPC and to the Research and Development Division of PSAS,

New York; and Frank Schenck, Chief of the Orthopedic Shoe Section of VAPC. Numerous expressions of interest and praise were voiced by the doctors visiting the exhibit.

It is planned to show the exhibit again during the February 1958 meetings of the American Academy of Orthopaedic Surgeons in New York.

Seventh World Congress, ISWC

More than 1000 delegates from 45 nations gathered in London's Church House, Westminster, July 22 through 26 for the Seventh World Congress and Exhibition of the International Society for the Welfare of Cripples. Largest conference of its kind ever assembled, the Congress was organized and staged by the Society's affiliated member in Great Britain, the Central Council for the Care of Cripples, under the royal patronage of Queen Elizabeth II. Its theme was *Planning for Victory over Disablement—The Advance, Integration, and Application of Knowledge*.

Participating in the activities were a number of persons well known in the Artificial Limb Program, and the Prosthetics Research Board provided an exhibit (see cut) designed to show the organization, functions, and results of the prosthetics program in the United States. The



PSAS EXHIBIT AT AMA MEETING—This display, entitled *Better Prescription for Orthopedic Shoes*, was presented by the VA's Prosthetic and Sensory Aids Service at the 106th Annual Meeting of the American Medical Association in New York City June 3 through 7. It was received enthusiastically by visiting physicians.

relationship between the physician and the prosthetist was the subject of a paper delivered by William A. Tosberg, Technical Director of Prosthetic Service at the Institute of Physical Medicine and Rehabilitation, NYU-Bellevue Medical Center, and a member of the teaching staff of the Prosthetics Education Program at New York University. Dr. Carleton Dean, Director of the Michigan Crippled Children Commission, Grand Rapids, presented the problems involved in providing adequate services for child amputees, and Col. Maurice J. Fletcher, Director of the Army Prosthetics Research Laboratory, covered the status of research and development in prosthetic devices for children. Others in attendance included Capt. Thomas J. Canty, Director of the Navy Prosthetics Research Laboratory, U. S. Naval Hospital, Oakland, Calif.; Dr. Verne T. Inman, of the University of California Medical Center, San Francisco; Dr. Eugene F. Murphy, Chief of the Research and Development Division, Prosthetic and Sensory Aids Service, Veterans Administration, New York City; and

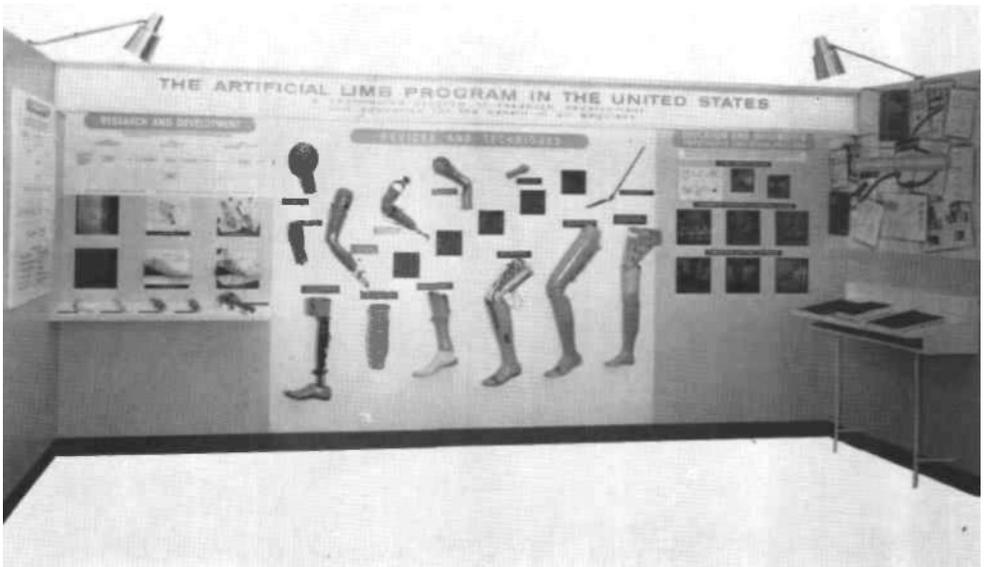
A. Bennett Wilson, Jr., Staff Engineer for the Prosthetics Research Board.

Retiring as President of ISWC was Dr. Howard A. Rusk, Director of the Institute of Physical Medicine and Rehabilitation and member of PRB. He was succeeded by Sir Kenneth F. Coles, Director of the Royal Alexandra Hospital for Children in Sydney, Australia, and President of the New South Wales Society for Crippled Children. Sir Kenneth is also a past-president of the Australian Advisory Council for the Physically Handicapped.

The next World Congress (the Eighth) of ISWC is scheduled to be held in New York City beginning August 24, 1960. It will be the first Congress to be held outside Europe.

First International Prosthetics Course

As a part of its endeavor to disseminate on an international basis useful information in the field of braces and limb prostheses, the Committee on Prostheses, Braces, and Technical



PRB EXHIBIT AT SEVENTH WORLD CONGRESS—This presentation, entitled *The Artificial Limb Program in the United States*, was offered by the Prosthetics Research Board at the Seventh World Congress of the International Society for the Welfare of Cripples in London July 22 through 26. It was subsequently shown in Copenhagen during the First International Prosthetics Course August 1 through 10 and will be shown again at the Clinical Meeting of the American Medical Association in Philadelphia, December 3 through 6, and before the American Academy of Orthopaedic Surgeons in New York City February 1 through 6, 1958.



FIRST INTERNATIONAL PROSTHETICS COURSE—Pictured are most of the students and instructors of the First International Prosthetics Course given at the Orthopaedic Hospital in Copenhagen August 1 through 10 under the sponsorship of the Committee on Prostheses, Braces, and Technical Aids of the International Society for the Welfare of Cripples. Some of the instructors were absent when the photograph was taken.



FIRST INTERNATIONAL PROSTHETICS COURSE—The faculty. Seated, left to right, are Arne Bertelsen, Denmark; D. S. McKenzie, Great Britain; G. G. Kuhn, Germany; Eugene F. Murphy, United States; Knud Jansen, Chairman of the Committee on Prostheses, Braces, and Technical Aids of the International Society for the Welfare of Cripples, Denmark; A. Bennett Wilson, Jr., United States; Verne T. Inman, United States; Ole Remvig, Denmark; and E. Lind Mossin, Denmark. Standing, left to right, Anna Conrau Thomsen, Denmark; Erik Lyquist, Denmark; O. Hepp, Germany; John Craft, Great Britain; Thomas J. Canty, United States; William A. Tosberg, United States; Masatora Hiyeda, Japan; Ilija Corkovic, Yugoslavia; and J. Saugmann-Jensen, Denmark. Absent when this photograph was taken were Svend Brandt, Denmark; Ellen Buttrup, Denmark; Maurice J. Fletcher, United States; Ulla Harpoth, Denmark; Henry H. Kessler, United States; S. William Levy, United States; Esther Lunning, Denmark; E. Marquardt, Germany; Karl Montan, Sweden; and Johnna Thomsen, Denmark. The scene is the Orthopaedic Hospital in Copenhagen.

Aids of the International Society for the Welfare of Cripples, under the chairmanship of Knud Jansen, initiated and organized the First International Prosthetics Course held at

the Orthopaedic Hospital in Copenhagen August 1 through 10. Sponsored by the ISWC national affiliate in Denmark, the Society and Home for Cripples, the course was attended by

some 60 physicians, therapists, and prosthetists from more than a score of countries. In addition to the extensive series of lectures offered during the ten days, tours were conducted through some of the centers of rehabilitation in the vicinity of Copenhagen.

Participating in the course as instructors were a number of people active in the Artificial Limb Program (see cuts). Total enrollment was as follows:

STUDENTS

From Argentina: Adolfo and Mrs. Mogilevsky, and Juan O. Tesone.

From Australia: G. G. Burniston.

From Belgium: Maurice Morlet.

From Denmark: Henriette Andersen, William Anthonson, Else Arnsø, Sven Bjerre, Hans Bohr, Jonna Bonnevie, Birger Eriksen, Bodil Eskesen, Niels Ditlev, Jørgen Ditlev, Otto Gottlieb, Bodil Hansen, K. P. Ho, H. Nordentoft Jensen, Birgitte Hoist Jørgensen, W. Kragstrup, Eskilde Larsen, Inge Larsen, Hugo Larsson, Ingeborg Lou, Anna Margrethe Mohr, Lise Nybo, Birthe Petersen, Emmy Petersen, Johnna Saltoft, Agnetha Strange-Hansen, Karen Teilmann, Ruth Teisner, Kirstine Thorlund, Gudrun Thrane, Hanne Trier, and M. Wind.

From Finland: Helmer Jernstrom, Erik Malmelin, Kanko Nicklen, and Pauli Pylkkanen.

From France: Noline Rossano.

From Germany: Fritz Blohmke.

From Holland: C. de Boer, J. J. Miedema, and H. Vlijm.

From India: Françoise Lamote.

From Israel: Zeew Neuthal,

From Korea: Kan Mo Chung.

From Norway: Martin Gøpken, H. Lystad, Bjørn Rogan, Alf Syversen, Else Trostheim, and Liv Tusberg.

From the Philippines: Benjamin Tamesis.

From Poland: Wiesław Miedzyblocki.

From Switzerland: Jules Rippstein, E. Rutschi, and Rosemary Sperry.

From Sweden: Anders Arkeryd, Helge Een, and Ulla Nilsson.

From South Africa: Emilia Krause.

From the United States: Margaret Pope Hovey and Rosa Muller.

From Yugoslavia: Ilija Corkovic, Zivorad Nikolic, and Zivojin Zee.

INSTRUCTORS

From Denmark: Arne Bertelsen, Svend Brandt, Ellen Buttrup, Ulla Harpoth, Knud Jansen, Esther Lunning, Erik Lyquist, E. Lind Mossin, Carl Helwiig Nielsen, Ole Remvig, E. Conrau Thomsen, and Johnna Thomsen.

From Great Britain: John Craft and D. S. McKenzie.

From Germany: O. Hepp, G. G. Kuhn, and E. Marquardt.

From Japan: Masatora Hiyeda.

From Sweden: Karl Montan.

From the United States: Thomas J. Canty, Maurice J. Fletcher, Verne T. Inman, Henry H. Kessler, S. William Levy, Eugene F. Murphy, William A. Tosberg, A. Bennett Wilson, Jr., and Donald W. Wilson.

GUESTS

From Germany: U. Mathias.

From the United States: Vladimir K. Volk.

Because only ten days could be devoted to the course, it was not possible to cover all aspects of prosthetics in detail, and consequently every effort was made to emphasize the principles involved. The Prosthetics Research Board has assumed responsibility for publication of the Proceedings.

OALMA National Assembly

Key figures in prosthetics research played a prominent role in the program of the 1957 National Assembly (the 40th Anniversary) of the Limb and Brace Profession when it convened at the Statler Hotel in Washington, D. C., September 29 through October 2. Sponsored by the Orthopedic Appliance and Limb Manufacturers Association, the meeting had as its theme *Education for Better Service to the Handicapped*. Robert C. Gruman, certified prosthetist with the Winkley Artificial Limb Co., Minneapolis, was Program Chairman.

Among the technical sessions on prosthetics were *Upper-Extremity Prosthetics*, by Col. Maurice J. Fletcher, Director of the Army Prosthetics Research Laboratory, with the assistance of Howard R. Thranhardt, of Atlanta, and Carlton E. Fillauer, of Chattanooga; *The SACH Foot*, by Charles W. Radcliffe, of the University of California, Berkeley; *Below-Knee Prosthetics*, by Charles A. Hennessy and Carlton E. Fillauer; *The Canadian Hip-Disarticulation Prosthesis*, by Charles W. Radcliffe and James Foort, both of the University of California, Berkeley; *The Canadian Syme Prosthesis*, by James Foort; and *Functional Anatomy Related to Orthotics and Prosthetics*, by John J. Bray, certified prosthetist and orthotist with the Prosthetics Education Project at the University of California at Los Angeles.

Among the presentations related specifically to orthotics was *The Newington Brace for Cerebral Palsy*, by Dr. Russell V. Fuldner and Josef Rosenberger, certified prosthetist



—Capitol Photo, Washington

OALMA ANNUAL BANQUET—Pictured is the speakers' table at the annual reception and banquet in the Presidential Ballroom of the Hotel Statler in Washington on the evening of October 2 at the close of the 1957 National Assembly of the Limb and Brace Profession. Left to right are Glenn E. Jackson, Executive Director of OALMA; W. Frank Harmon, Past-President; Mrs. Jackson; Carlton E. Fillauer, President of the American Board for Certification for 1956-57; Mrs. Fillauer; John A. McCann, newly elected President of OALMA for 1957-58; Mrs. Charles A. Hennessy; the Honorable Edward Foss Wilson, Assistant Secretary of the U. S. Department of Health, Education, and Welfare; President Hennessy (1956-58); Karl W. Buschenfeldt, 1st Vice-President (1956-57); Mrs. M. P. Cestaro and Mr. Cestaro, Secretary-Treasurer; Mrs. H. Hoover Hanger, daughter-in-law of the founder of the J. E. Hanger Company; 2nd Vice-President Paul E. Leimkuehler; and Mrs. Leimkuehler. Mr. Wilson received on behalf of the Eisenhower Administration the citation paying tribute "to the leadership in human rehabilitation which has been given the country by President Eisenhower and his associates in the Federal Government."

and orthotist, both of New Haven Conn. Other sessions concerned with brace design included *Balance in Brace Construction with Special Reference to Forefoot Drop and External Tibial Torsion*, presented by Alfons R. Glaubitz, certified prosthetist and orthotist, and Superintendent of the Brace Shop of the Pennsylvania State Hospital for Crippled Children at Elizabethtown, Dr. Tom Outland, Chief Surgeon, and Dr. Joseph C. Flynn, Chief Resident, at the hospital; *Bracing the Paralyzed Patient—Trunk and Lower Extremities*, a panel discussion led by Dr. Charles S. Wise, Professor of Physical Medicine and Rehabilitation at The George Washington University Medical School, assisted by Herbert J. Hart, certified prosthetist and orthotist with the C. H. Hittenberger Co., Oakland, Calif., H. H. Maddox, chief orthotist with the Georgia Warm Springs Foundation, and Karl W. Buschenfeldt, certified orthotist of Stoughton, Mass.; and *New Developments in Functional Arm Bracing Correlated with Reconstructive Surgery*, by Dr. Vernon Nickel, chief of orthopedic surgery, Dr. Jacquelin Perry, resident in orthopedic surgery, and Lee Roy Snelson, certified orthotist, all of Rancho Los Amigos Hospital, Hondo, Calif.

The problems of management in the limb and brace field were considered at four "workshops" organized around the group-discussion method which was used so successfully earlier this year at various Regional Meetings of OALMA (page 99). Among the problems covered were those of personnel, finance, shop efficiency, and the rehabilitation of veterans and civilians. Then, on the evening of September 30, there was a round-table conference of manufacturers in the field of orthopedic and prosthetic appliances. Glenn E. Jackson, Executive Director of OALMA, served as moderator.

For the first time, students and faculty of the NYU and UCLA courses in

prosthetics (page 83) had an opportunity to get together for discussion of mutual interests and to review the newer developments which the two schools are introducing. On the evening of September 30, the two groups staged alumni reunions, and on the following day President Hennessy served as moderator at a session devoted to a report on the Prosthetics Education Program as seen by the faculty and the alumni. Reporting for NYU were Dr. Sidney Fishman and William E. Hitchcock. Dr. Miles H. Anderson and John J. Bray covered activities at UCLA.

Besides the technical meetings and those devoted to matters of business administration, a number of interesting social functions were scheduled. At the OALMA President's Breakfast on the morning of September 30, Glenn B. Sanberg, Executive Vice-President of the American Society of Association Executives, spoke on his familiar topic, *A Giant Wakes*, of which the theme is that the common people of any trade or profession, when banded together mutually for any good purpose, become, like Bunyan, a giant in the earth capable of otherwise unexpected feats of accomplishment—that the giant may either sleep or come awake—and that, once aroused, the giant is invulnerable so long as he does not divert his purposes to evil. Sanberg pointed to the growth of the limb and brace profession during the

past decade and pursued the allegory by describing the contributions this "giant" had still to make.

On the evening of the same day, delegates and their ladies were guests at a reception given at the Chancery of the Germany Embassy. At that time, Charles A. Hennessy, President of OALMA, presented a message of greetings to the German Artificial Limb and Brace Profession.

As in the past, the American Board for Certification held its annual meeting in conjunction with the OALMA Assembly, and examination of candidates for certification was offered under the supervision of the Board of Examiners, with Edward W. Snygg, of San Francisco, as Examiner-in-Chief and Dr. Miles H. Anderson, of UCLA, as advisor to the Board. At the annual Certification Luncheon on October 1, a panel discussion of *Are We Becoming Professional?: The Role of Certification* was led by Dr. Edward C. Holscher, of St. Louis, with the assistance of Charles A. Hennessy, W. Frank Harmon, of Atlanta, John Buckley, of Providence, R. I., and Ivan Dillee, of New York City. The new officers of ABC elected for the year 1957-58 are Dr. Roy M. Hoover, of Roanoke, Va., President; McCarthy Hanger, Jr., of St. Louis, Vice-President; and M. P. Cestaro, of Washington, D. C., Secretary-Treasurer.



—Capitol Photo, Washington

CERTIFICATION EXAMINATIONS—Start of a session. Flanked by some of the members of the Board of Examiners, Glenn E. Jackson, Executive Director of the American Board for Certification, welcomes the class of candidates for the written examination given by ABC in Washington September 27 during the 1957 National Assembly of the Limb and Brace Profession. Left to right are Dr. Miles H. Anderson, advisor to the Board; Lee Roy Snelson; John J. Bray; Dr. Roy M. Hoover, new President of ABC; George A. Scoville; McCarthy Hanger, Jr.; Mr. Jackson; Erich Hanicke; Charles A. Hennessy; Carlton E. Fillauer; Bert R. Titus; and Alfons R. Glaubitz.

The annual OALMA Banquet, concluding event of the Assembly, was held on the evening of October 2, with the Honorable Edward Foss Wilson, Assistant Secretary of the Department of Health, Education, and Welfare in President Eisenhower's Cabinet, as guest of honor. Secretary Wilson received, on behalf of the President of the United States, a scroll of appreciation from OALMA in recognition of the Administration's development of an enlarged rehabilitation program. The U. S. Army Chorus entertained, and the officers of the Association for 1957-58 were formally installed. They are John A. McCann, of Burlington, N. J., President; Karl W. Buschfeldt, of Stoughton, Mass., 1st Vice-President; Paul E. Leimkuehler, of Cleveland, 2nd Vice-President; and M. P. Cestaro, of Washington, D. C., Secretary-Treasurer.



MR. McCANN

The next National Assembly is scheduled to meet at the Eden Roc Hotel in Miami Beach October 26 through 31, 1958.

OALMA Regional Meetings

Those who have been active in the Artificial Limb Program have from the very beginning felt a strong obligation to make the results of research known to the limb and brace profession on a broad basis. In the early days of the program, this educational activity had necessarily to be carried out largely through the medium of the printed page and through the national meetings of the Orthopedic Appliance and Limb Manufacturers Association. But the need to get at the "grass roots" has always been pres-

ent, for it was realized fully that only a limited number of technicians were reached at national conventions.

The development, in 1950, of a regional organization of OALMA provided the means by which the results of research—new appliances and new techniques—could be reported throughout the United States without the necessity for individual shop appointments and conferences. At that time, OALMA divided the country into 11 geographical Regions. Each Region elects one member of the OALMA Board of Directors, and each holds at least one local conference a year, usually in the spring. Some, like the New England Regional Council, hold several throughout the year. For quite some time now, key research personnel have appeared on the programs of these regional meetings.

This year a majority of the Regions experimented successfully with a new type of program, and research personnel were active in its implementation. There had been a feeling that the formal type of program, with speakers delivering the usual technical papers, was not well adapted to the informal nature of these regional conferences—that somehow the formal



OALMA REGIONAL MEETINGS, NEW STYLE—A group of specialists consider a veteran's problem during the meeting of OALMA Region VII in Minneapolis April 26 and 27. Left to right are Voigt W. Baker, Area Chief for the VA's Prosthetic and Sensory Aids Service; Dr. Einer C. Andreassen, VA Area Medical Director; Charles A. Hennessy, Prosthetics Instructor at the Prosthetics Education Project, UCLA, and President of OALMA; and William H. Talley, Chief of the Plans and Policies Division, PSAS, Washington.



OALMA REGIONAL MEETINGS, NEW STYLE—Panelists engage in "buzz" sessions during the meeting of OALMA Region V in Cleveland May 18 and 19. Top, left to right, Dr. Russell P. Rizzo, Assistant Clinic Chief for the VA at Cleveland; Paul E. Leimkuehler, certified prosthetist and Regional Director for Region V; Dr. Sidney Fishman, Director of the Prosthetic Devices Study, New York University; and L. B. Barghausen, certified prosthetist and President of Region V. Bottom, left to right, Ralph Storrs, Regional Director for Region VI; Charles W. Rosenquist, certified orthotist and Secretary of Region V; Roy A. Wing, Chief of the Prosthetic and Sensory Aids Unit in the VA Regional Office at Cleveland; and Dr. Miles H. Anderson, Director of the Prosthetics Education Project at UCLA.

presentation fell short of its maximum potential. Accordingly, a new kind of program session was scheduled, beginning this year in February with the Southeastern Regional Meeting (Region IV) at Tampa. In this method, the entire time is devoted to free discussion. Although noted authorities are present by invitation, their function is not to

deliver formal papers or lengthy addresses but rather to take part in discussion with the others. They are encouraged to contribute, from their wisdom and experience, to the solution of common problems, and the results of research are thus described as the various topics are taken up.

The meeting room is specially arranged for the convenience of those present. Instead of being isolated at a speakers' table, research personnel are seated with limb and brace technicians and visiting officials—experienced men *and* beginners—all at tables heading into an area containing large blackboards and a place for the moderator to stand. To start the meeting, the moderator turns to the tables and asks for a report from each one on current topics on which light is needed. These questions, as reported from the tables, are quickly summarized, restated, "sharpened" when necessary, and written on one or more of the blackboards. The moderator selects the questions from the blackboards and assigns them to one or more of the authorities. Discussion then flows back and forth, from "resource person," to the table originally asking the question, then to another

table where additional points may be raised, and so on.

The entire basis of this type of program lies in the proposition that a group when brought together can be trusted to identify the most important questions that are bothering them. Such informal give-and-take meetings produce better solutions than does the formal "paper,"

which often leaves unanswered some problem that is bothering the audience or, indeed, may miss its audience completely. A further advantage lies in the fact that the "experts," instead of being restricted to one set speech, are encouraged to put in their say at any time. In the course of a morning, a single individual may find himself speaking first as an expert, then as a seeker of information from some other expert, and later as an expert again.

So profitable was this new approach at the Southeastern Regional Meeting that it was adopted by other Regions holding meetings during the spring—in Houston March 16 and 17 (Region VIII), in Minneapolis April 26 and 27 (Region VII), in New York City May 3 and 4 (MOALMA), in Cleveland May 18 and 19 (Region V), and in Chicago May 25 and 26 (Region VI). Among the important figures who served as experts at some of these meetings were Col. Maurice J. Fletcher, Director of the Army Prosthetics Research Laboratory; Dr. Robert E. Stewart, Director of the Prosthetic and Sensory Aids Service of the Veterans Administration; William H. Talley, Chief of the Plans and Policies Division of PSAS; and A. Bennett Wilson, Jr., Staff Engineer for the Prosthetics Research Board.

The prosthetics courses at New York University and at the University of California at Los Angeles have attracted considerable interest in the limb and brace field, and many questions concerning arrangements and scope were raised at the several regional meetings. Fortunately, it was possible for several members of the two faculties to be present. Dr. Sidney Fishman and Dr. Miles H. Anderson, Directors of Prosthetics Education at NYU and at UCLA respectively, attended the meeting at Tampa and that at Cleveland. Charles A. Hennessy, President of OALMA and prosthetics instructor at UCLA, attended the Cleveland and Minneapolis meetings. William E. Hitchcock, prosthetics instructor at NYU, was one of the "resource persons" at the meeting in Chicago.

Similar regional meetings have been planned for the West Coast later in the year.

MOALMA Conference

In addition to its regular monthly meetings, the Metropolitan (New York) Orthopedic Appliance and Limb Manufacturers Association holds annually a Prosthetic and Orthopedic Conference. To it are invited limb and brace technicians and other interested persons from the entire Atlantic Seaboard. At the 1957 Conference, held at the Biltmore Hotel in New York City May 3 and 4, a principal feature was a panel discussion of the new developments in lower-extremity socket techniques that have come out of the Prosthetics Education Program. Headed by Fred J. Eschen as moderator, the panel included Martin Durec, Jerome S. Kessler, and William Spiro, all certified prosthetists. Lester A. Smith, editor of the *Orthopedic and Prosthetic Appliance Journal*, presented a report on *Reference Aids in the Field of Orthopedic Appliances*.

Among the guests of honor was Dr. Harold W. Glattly, Executive Director of the Prosthetics Research Board. Also in attendance were A. Bennett Wilson, Jr., Staff Engineer for PRB, and Glenn E. Jackson, Executive Director of OALMA.

NERC Meeting

The New England States, organized as the New England Regional Council, comprise Region I of OALMA. Customarily their monthly meetings are held at the facility of the Liberty Mutual Rehabilitation Center in Boston. For their concluding session of the last fiscal year, May 27, however, they met at the Medical Library in Boston. Appearing on the program were three staff members of the Prosthetic Devices Study at New York University. Edward R. Ford presented *Experimental Devices Still in the Research Phase*; William E. Hitchcock spoke on *Biomechanical Considerations in Lower-Extremity Prostheses*; and Warren P. Springer covered *Checkout Procedures and Gait Abnormalities*. The event was a homecoming for Mr. Hitchcock, who was formerly head of the Boston Artificial Limb Company.

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

The National Academy of Sciences—National Research Council is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare.

The Academy was established in 1863 under a Congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the Federal Government in scientific matters. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency.

The National Research Council was established by the Academy in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the Academy in service to the nation, to society, and to science at home and abroad. Members of the National Research Council receive their appointments from the President of the Academy. They include representatives nominated by the major scientific and technical societies, representatives of the Federal Government, and a number of members-at-large. In addition, several thousand scientists and engineers take part in the activities of the Research Council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the Academy and its Research Council thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the Government, and to further the general interests of science.