MYOPLASTIC TECHNIQUES [a]

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There is a considerable volume of literature relating to amputation techniques which have been or can be described as myoplasties, including more recent works by Mondry (1), Ertl (2), and Dederich (3). In none of these contributions is there any direct reference to muscle tension and most authorities now would include this as an essential part of the operative procedure.

It can be assumed that the level of amputation has been determined on the basis of a number of relevant factors, viz., pathological, anatomical, prosthetic, and most important the personal factors such as age, sex, and occupation. Amputation having been elected as the correct procedure for the patient, it is then our purpose to produce a functional organ which can be married to a modern prosthesis. This functional organ, the stump, must meet the demands of weight bearing. It must accommodate and transfer the force actions and this will be done via the socket of the prosthesis which at the present time has a fixed volume and a fixed configuration based on relevant biomechanical considerations. Accordingly, the stump must have a smooth and regular contour with minimal change in shape during the gait cycle. It should be as powerful as possible and be covered with skin, with normal sensation and with a well placed mobile scar.

To achieve these objects it would seem appropriate to consider the different tissues of the stump separately in the first instance.

The most important thing in the treatment of the skin is to insure that there is an adequacy of skin for the proposed level of amputation and to do this we must envisage the proposed terminal bulk of the stump. Those surgeons who are practiced in the technique of amputation surgery and can guess with some accuracy the terminal bulk of the stump may be in a position to delineate precisely the size and shape of the skin flaps at the beginning of the operation. Even so the inexperienced would be wise to retain a sufficiency of skin in the flaps which can be tailored to the needs of the stump at the end of the operation. The general rule will be that the ratio of

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the base of the flap to its length will be as great as possible. In my view this ratio should never be less than one to one. In amputations through a segment of the leg equal flaps are usually satisfactory but it may be necessary in certain instances, for example, in vascular disease, to modify these flaps and in a below-knee amputation enable a larger posterior flap. In amputations through the limb segments it would seem that it is better to permit light tension to exist at the time of suture. This will enable the formation of a linear mobile scar with no distortion. In amputations through joints such as the knee and the ankle it is necessary to have the skin if anything, slightly loose. Certainly there should be no tension.

Differing views exist in regard to the treatment of the deep fascia. Dederich (3) suggests that the deep fascia should be excised, but his purpose in doing this has been to encourage an increased vascularity in stump revisions where no doubt excessive avascular scar tissue has been the rule. In other circumstances it would seem wise to raise the integument, the subcutaneous tissues, and the deep fascia as one undisturbed flap of tissue. In some circumstances it might seem appropriate to leave the deep fascia in relation to the muscles and thus allow better security for muscle sutures.

It is necessary to consider briefly the function of the muscles in normal locomotion to remind ourselves that muscle acts with maximum force when it is at a length slightly greater than its rest length, and that it acts for a very short period of time in each walking cycle. It is, in other words, essentially isometric. In the amputee where there is less muscle to do apparently more work, muscle contractions may be of longer duration thus limiting blood flow in the muscle during contraction with an earlier onset of fatigue. Furthermore, the speed of the contraction varies with the length of the muscle. Thus, in a muscle halved in its length, e.g., in an above-knee amputation, the velocity of the contracture is approximately halved and the excursion of the muscle is also reduced proportionate with its length. In the conventional amputation the belly of the muscle is cut transversely and allowed to retract with a reduction in the speed, amount, and effective range of shortening. In the adductor group, which in normal locomotion contributes to stability both statically and dynamically during lateral rotation of the thigh, muscle action following amputation is grossly distorted (Fig. 1) whereas the abductors, short and powerful as they are, are normally intact. This produces an imbalance and possibly even an abduction contracture. Certainly the gait will have a wider base, there will be a tendency to pressure in the crotch, and probably excessive rise and circumduction of the artificial limb. The hamstrings, notably two-joint muscles, stabilize the pelvis in the stance phase and decelerate the leg during swing phase. In amputation, their main purpose is to stabilize the prosthetic knee. It is, therefore, important that they should be in a position to act as powerfully as possible. It is important too that they should be in a situation to

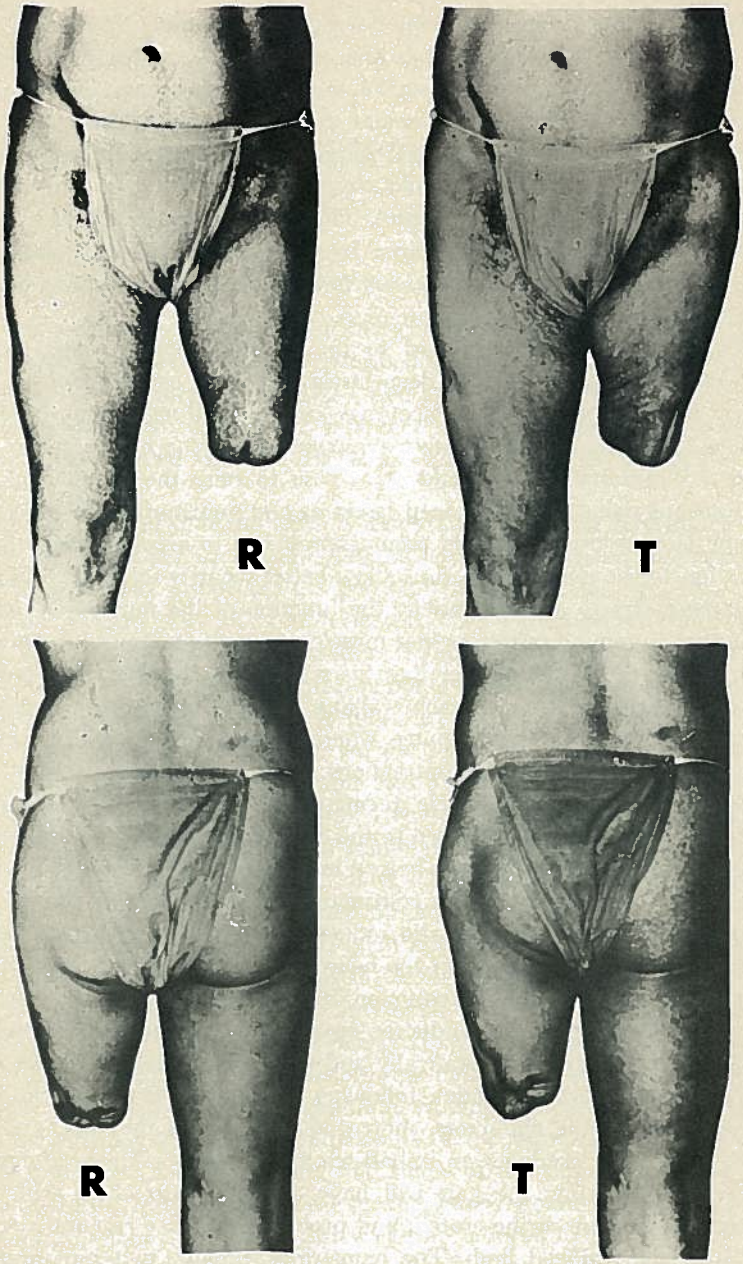

FIGURE. 1.—"Conventional" amputation. View from the front above and from behind in lower photograph. R=relaxed and T=tensed. Note distortion of scar, "retreat" of muscles, prominence of femoral end at outer aspect, and marked change in configuration of stump.

act as best as they can in order to reduce the load on the ischial seat of the prosthesis. The quadriceps bring the knee into extension and stabilize that joint in positions just short of full extension. In the amputee this function is both lost and unnecessary and the muscles act as hip flexors. They also have an isometric value as those components which are isometric following amputation will act in concert with the rectus which is now a one-joint muscle and improves the venous return and tends toward a firming of the stump, that is to say, increase its mechanical stiffness. The ilio-tibial tract, normally taut in the stance phase, helps in stabilizing the pelvis in the normal person. It is important, therefore, to preserve if one can. At the same time the shortening of the muscle following division low down in the thigh does not appear to be great and may not retreat up the stump more than one centimeter, and this is probably due to its attachment to the lateral intermuscular septum.

When a nerve is divided it inevitably forms a neuroma. If the nerve is divided at the distal end of the stump then a neuroma will form in that situation. If the neuroma gains a secure attachment to distal scar tissue, which in the conventional stump is capable of displacement, often extreme and violent during the gait cycle, then repeated, very unwelcome stimuli will be produced. It seems, therefore, correct to cut the nerve in a place remote from the end scar where it is well covered by muscle. The nerve should, therefore, be cut high. In order to do this it is necessary to pull the nerve down, but excessive tension should be avoided. In atherosclerosis it would seem appropriate to divide the nerve higher than the other tissues in any case, as Smith's (4) work in Aberdeen suggests that ischemia in the nerve trunk may reach much more proximal levels than in other tissues with an increase in disassociated nerve fibers and increased stump and phantom pain. Treatment of the nerve itself has evoked much discussion and often diverse enthusiasms. The nerve has been introduced into the medulla of the bone through windows in the cortex and has been covered in envelopes of different materials but most people would consider that a clean cut of the nerve is what is normally required. It is relevant to note, however, Weiss' (5) technique of clamping the nerve with approximately one centimeter between the clamping points and division immediately below the lower of these two points. His intention in this procedure is to produce as it were, a neuroma within the nerve. A further study will be required to see whether in fact this is a procedure of value. Burgess (6) has revived interest in ligature of the nerve because of his concern in vascular cases where the accompanying artery may be abnormally large and the cause of troublesome bleeding after a high clean cut. So far as I understand no unpleasant sequelae have followed this procedure (Fig. 2). It seems to me that the main requirement is to cut the nerve at a sufficient distance from the end scar.

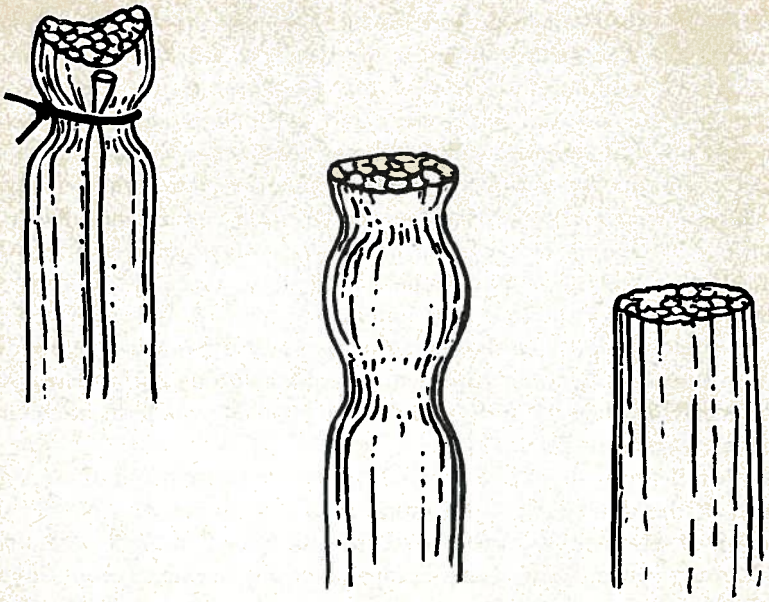

FIGURE 2.—Schematic illustration of treatment of nerve. On the left, a high clean cut; in the middle, the procedure used by Weiss with double crushing of nerve which is divided just distal to lower clamp; and on the right, ligature of the nerve where the accompanying vessel is abnormally large.

The main vessels in the limb should be isolated, ligatured, and divided low in the wound, and in this way valuable tributaries may be retained and optimum blood supply maintained.

There appear to me to be two requirements in the treatment of the bone following division. One is to shape the bone according to the needs of the particular level. In the above-knee procedure anterior smoothing and rounding should be carried out, especially in myoplastic procedures; at below-knee level, very careful sculpturing of the bone end is required to produce a smooth radius in all directions. This of course, applies mainly to the anterior distal end where the object should be to produce a large part of a small radius rather than the converse or an oblique flat plane with three corners. The second requirement is to close off the medulla of the bone, and leaving aside procedures involving the use of implants such as silicone plugs this is best achieved by a periosteal or osteoperiosteal flap. Work performed in Russia by Askalanov and Aronov (7) has contrived to show that with an open bone end the intramedullary pressure drops to zero and that the radiopaque material used in the experiments suffers a reduction in clearing time. Furthermore, the intramedullary sinuses are dilated and tortuous with residual deposits of the material. When the open end of the bone is closed again the hydrostatic situation returned to normal. Therefore, it seems that

a closed system is necessary for normal intramedullary pressure to be maintained in the bone, and a normal pressure system is necessary for normal venous return from the bone. Accordingly, the medullary cavity should be closed as a definitive part of the operation of amputation.

I would wish at this point to return to the subject of the treatment of the muscles. Some of the myoplastic procedures described in the literature attempt to selectively suture agonists and antagonists over the end of the bone, but in the light of the factors already discussed this should properly be done under tension. The resultant muscle "loop" must be secured firmly to the end of the bone to optimize muscle function. If not, then the active muscle "loop" is subject to displacement with distortion of the end of the stump. Furthermore, in two patients bursae form in response to the movement of the muscle "loop" over the bone end and in one of these patients was the cause of severe pain with the development of a cavity which intermittently filled with large quantities of serous fluid (Fig. 3). Both Weiss (8) and Burgess (6) recommend attachment of the various muscle groups to the bone end via drill holes at the end of the bone (Fig. 4). This seems to be a reasonable procedure at both above-knee and below-knee levels. It tends to give a rather cylindrical stump and while I believe it to be the best technique for vascular cases, the technique can be modified and improved in respect to the shape of the functional organ we are seeking to produce. At above-knee level, I suture the adductor group, lateral hamstrings, and the medial hamstrings to the bone end via nonabsorbent sutures in approximately their proper anatomical place. This leaves the anterior half of the bone end undisturbed by drill holes (Fig. 5) and permits the use of an anterior periosteal flap raised prior to division of the bone to be brought forward over the bone end after muscle suture to close off the medulla of the bone. The quadriceps is left as one complete complex shaped at its end, and being longer than the posterior and medial muscles, is drawn over the end of the bone and sutured to these muscles posteriorly (Fig. 6). In this way we

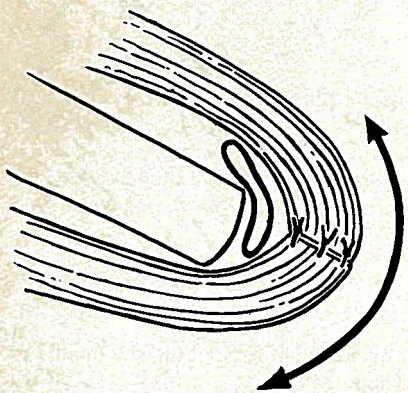

FIGURE 3.—Schematic representation of situation in "myoplasty" where muscle loop is formed and left unsecured to bone end; the anterior edge of the bone has not been rounded and a bursa has formed.

FIGURE 4.—Drawing showing management of muscle groups as in myodesis used by Weiss and Burgess; the medulla remains open.

achieve a very satisfactory stump end with smoothly changing contours (Fig. 7 and 8).

At below-knee level, I prefer to use the osteomyoplasty as described by Ertl (2) and Loon (9) where a bony bridge is formed by the raising of osteoperiosteal flaps from the medial and lateral sides of the tibia which are attached to the periosteum of the fibula thus forming a rather firm osteoperiosteal bridge. The anterior tibial and posterior groups of muscles after

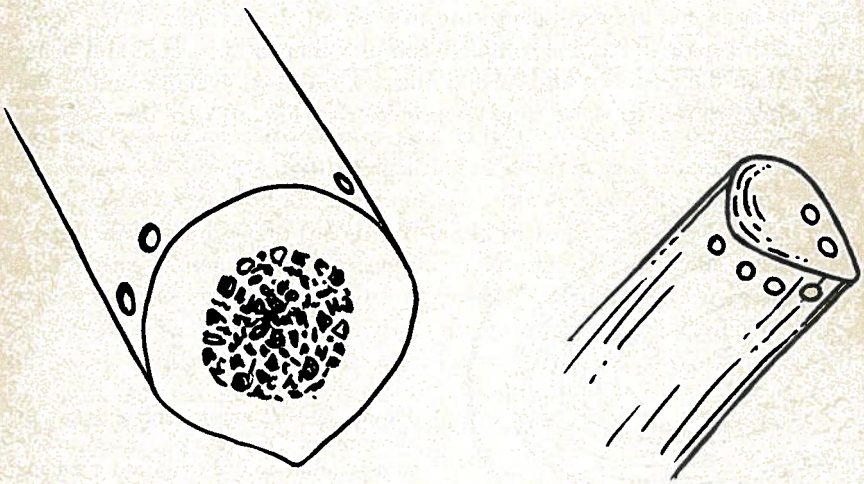

FIGURE 5.—Schematic illustration of drill holes in cut end of femur. Anterior quadrant left free of holes to permit elevation of periosteal flap.

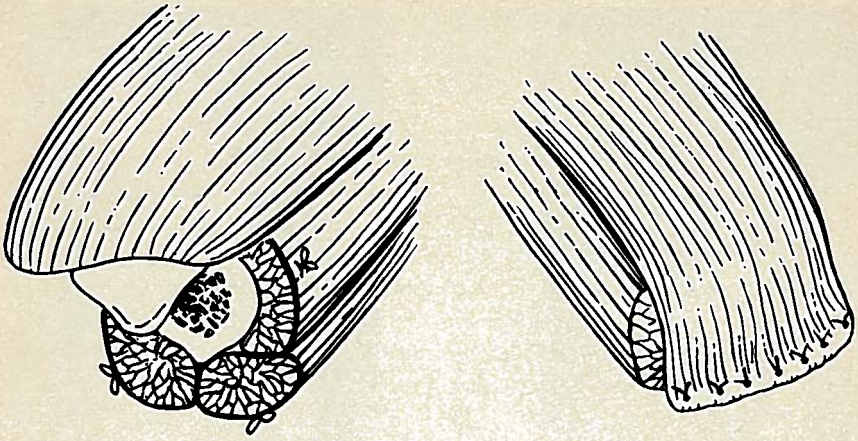

FIGURE 6.—Schematic illustration of procedure advised by author. Lateral and medial hamstrings and adductors sutured under tension to bone via drill holes and cut flush with bone end. Medulla closed with anterior periosteal flap. Quadriceps left long and drawn over stump end to be sutured under tension to posterior muscles.

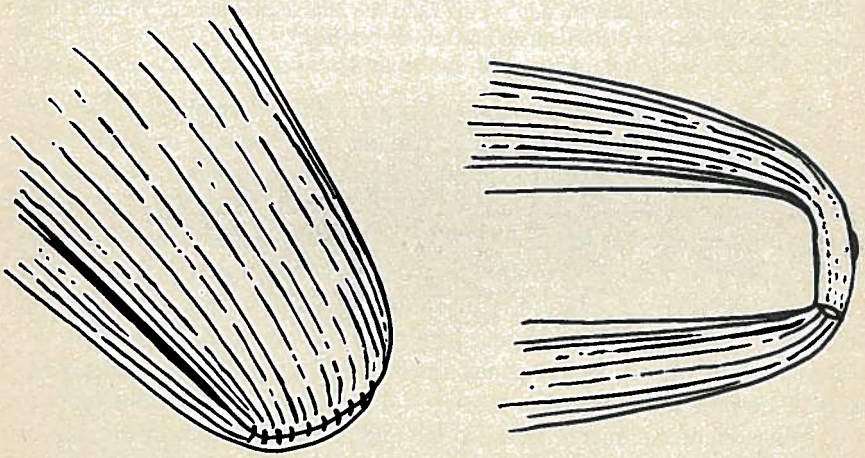

FIGURE 7.—Drawing of "ideal" situation at stump end. The posterior muscles are securely fixed to bone end. The bone is rounded; the medulla closed and the anterior muscle, e.g., quadriceps, further covers the bone and is secured to the posterior muscle groups, e.g., hamstrings. Thus an adequate but not excessive "pad" is formed at bone end, partly fibrous tissue but mostly viable functioning muscle.

trimming and possible excision of the soleus are drawn together over the bridge and sutured together. Here too, it is vital to secure the muscle loop firmly to the periosteum of the tibia and to the base of the osteoperiosteal bridge.

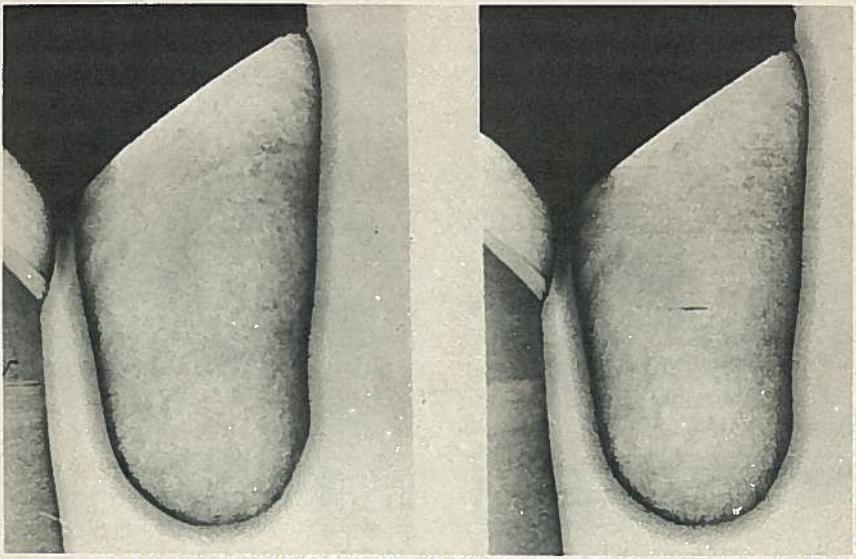

FIGURE 8.—Myoplasty amputation. Muscles secured under tension to bone end. On the left the muscles are relaxed and on the right the muscles are tensed. There is little change in shape, no scar distortion, and no muscle "retreat."

In some patients the bridge may be formed with periosteal flaps alone but this gives a rather soft saddle of tissue making muscle suture unsatisfactory. Maurer (10) employs a short section of the fibula to bridge the two bones securing fixation by an intramedullary screw. Bridging between the tibia and fibula is desirable as it stabilizes the fibula, provides better "keying" of the socket, and gives the opportunity for a degree of end bearing. In vascular cases the bridging procedures are of doubtful validity as the elaboration in tissue treatment may well prejudice healing of the wound. In these cases the technique of tension myodesis appears to be most apposite to the situation as there is no muscle or periosteal tissue left distal to the level of bone section.

Further reference must be made to the tension of the muscle at the time of suture, whether it be muscle to muscle or muscle to bone. The muscle should be sutured to the end of the stump so that the muscle is marginally shorter than it would be at rest length. Weiss (11) recommends from 0.4 to 0.8 centimeters in the case of the thigh muscles—a counsel of perfection but indicative of the thought and care being applied to these techniques. Estimation of the level of muscle division with respect to bone length can be achieved in various ways, e.g., marking sutures on the surface of the muscles and transfixion pins acting as markers or traction implements. The position of the patient at operation is of some importance. Normally this position is chosen to provide easy access for the surgeon. It is well to remember that the position chosen for operation may not be appropriate for muscle suture—in

the below-knee procedure with the patient prone and the knee flexed, the limb is presented in a manner permitting convenient surgical access but full extension of the knee is required if the muscle groups are to be properly tensioned at the time of suture. I prefer to have the patient supine to insure full knee extension. In the above-knee amputation with the patient supine, a sandbag beneath the buttock on the affected side is necessary to gain sufficient hip extension for proper muscle suture. Perhaps the best position for the patient is lying on the unaffected side enabling anterior or posterior approaches and the opportunity for adequate extension of the hip.

Amputation is a procedure which has unique implications. One aspect concerns the operative exposure itself and unlike other operations it is possible to be destructive in the exposure provided this refers to the tissues distal to the ultimate level of section. The tissues remaining in the stump should be handled gently especially where nutrition is marginal, and the criteria of the procedure should be concerned with the state and relationship of the various tissues in the completed stump and not with details of exposure. In my view it is of little consequence whether the above-knee amputation is performed from the front or behind or even from the medial aspect. Equally, the below-knee procedure can be performed through an anterior approach or from the lateral aspect as advocated by Weiss (11). Our proper purpose should be to provide the best functional organ of locomotion possible in the circumstances.

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