SURGERY AS RELATED TO PROSTHETICS AND ORTHOTICS

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SURGERY AND PROSTHETICS

The single greatest obstacle to progress in amputation surgery has been the surgeon’s lack of prosthetic knowledge. While a small number of surgeons throughout the years have become involved and, in fact, have made significant contributions to prosthetic improvements, the vast majority of amputations continue to be performed by surgeons uninformed in the area of prosthetic rehabilitation. This circumstance does not prevail in other areas of surgery where assistive mechanical devices used to restore function are generally well understood by the attending surgeon.

In the years since World War II, prosthetic engineering and design have improved dramatically. Of late, the prosthettist, as a member of the amputee team, turns hopefully to the surgeon, seeking more functional and physiological stumps. The accepted practice of so often fitting the prosthesis to a difficult, inadequate stump is questioned. This questioning is beneficially influencing surgeons to review and upgrade amputation techniques.

Immediate postsurgical prosthetic fitting has also influenced the amputation surgeon (1). Prosthetic replacement of basic lost function here becomes a part of the surgical procedure. The surgeon can now relate directly to prosthetic rehabilitation beginning at the time of surgical limb loss. The amputation now becomes reconstructive, for not only is the limb removed, but also a terminal, functional end-organ is created to accept and control the substitute part. This surgical approach dictates full conservation of stump tissues and relates directly to prosthetic use. The amputation must respect the gentleness and technical finesse associated with reconstructive surgery of the hand or foot.

Coincident with these changing attitudes, the amputation has now moved into the main stream of surgical interest and research. The last authoritative atlas of amputations in English was published by Slocum
In 1949. When one considers the vast volume of surgical literature, including monographs and textbooks since that date, amputations have commanded a small part of these communications. A review of recent literature, however, confirms the upswing in interest and progress in the field.

Amputation stumps in the lower limb, designed to use current prosthetic substitutes, totally contact the prosthetic socket and, whenever possible, provide some degree of end-bearing capacity. This includes diaphysial amputations as well as those through joints and metaphysical bone. Sectioned muscles are stabilized whenever possible at or near the end of the amputation site. Nerves are sectioned high and allowed to retract into soft tissues which cushion them from socket pressure. Bone is carefully contoured in a smooth manner to minimize skin sensitivity and soft tissue breakdown under pressure and shear stress. Tibial-fibular synostosis will improve stump strength and stability in certain specialized below-knee amputations. Skin management and scar placement will be dictated by the physical circumstances present, specifically, the nature of the skin and its blood supply. The goal is a nonadherent and nontender scar. Long accepted and relatively dictatorial skin flap and scar placement directives have to a large degree been abandoned or modified. As the surgeon amputates, he continually thinks of the resulting stump-socket interface of the prosthetic replacement.

Specifically in the lower limbs, the Syme (Fig. 1) and below-knee (Fig. 2) levels are by far the most statistically important. Both forefoot and Syme amputations are being performed in increasing numbers. Two-stage techniques, particularly at the Syme level, are gaining increasing favor, especially in the diabetic.

Most below-knee amputations now utilize a longer posterior skin and fascial flap. The advantages of this type of amputation have been

**Figure 1.**—Postoperative Syme amputation demonstrating proper contour and shape.

**Figure 2.**—Cylindrical, partial end-bearing and muscle stabilized below-knee amputation stump suitable for modern prosthetic fitting.
pointed out. At knee-disarticulation level, recent useful modifications include a minimal removal of condyles with the patella (Fig. 3) and with resuture of the quadriceps mechanism. The center of axis of motion of the knee joint can then be placed in an essentially normal position as related to the opposite knee, allowing the use of intrinsic knee mechanisms in the prosthesis (Fig. 4).

Figure 3.—a. Twenty-one-year-old male with modified PRS low transcondylar knee disarticulation illustrating level of amputation through the knee joint. b. Healed amputation with end-bearing suspension capability of the stump.

Figure 4.—The center of axis of prothetic knee movement can now be approximated to the opposite leg.
Through-thigh amputations require full attention to muscle stabilization since most above-knee prostheses are no longer suspended by a pelvic belt with hinge, and stump muscle power and bulk are critical to full function potential (Fig. 5). Hip disarticulation is an increasingly acceptable level of functional limb ablation because of the advances in prosthetic technology (Fig. 6).

**FIGURE 5.**—a. Stump of 13-year-old male with amputation for osteogenic sarcoma of the proximal tibia. b. The stump is functionally suited to utilize modern prosthetic units.

**FIGURE 6.**—Fifteen-year-old female with osteosarcoma of the femur; this illustrates the amputation site (hip disarticulation) suitable for maximum function with current prosthesis.
New surgical innovations are being made with regard to the placement of the scar in the hemipelvectomy procedure and the design of the amputation area suitable for limb fitting (Fig. 7).

In the upper limb, maximum stump length is preserved, muscle stabilization is routine as surgical circumstances permit, and scar placement follows the general rules of plastic surgery. Wide availability of externally powered upper-limb prostheses directs the surgeon to retain myoelectric signal sources within the stump. Appropriate surgery will also facilitate the use of displacement and other pressure sensor afferent sources in many patients.

We have recently been studying the muscle suspension capabilities of both upper- and lower-limb stumps. Voluntary and involuntary muscle activity within these stumps can substantially aid limb suspension. Retention of muscle size, shape, and power, together with complementary socket design, requires prosthetic-oriented surgery.

**SURGERY AND ORTHOTICS**

The orthopedic surgeon has for decades used a wide variety of operations to eliminate the use of orthoses or to limit their scope and need. This surgery developed as a result of the thousands of patients crippled by poliomyelitis, tuberculosis, osteomyelitis, septic arthritis,
FIGURE 8.—a. Photo depicts bipolar electrode placement around the common peroneal nerve at knee level for neuromuscular assist device in a 70-year-old male with CVA. b. Stimulation at surgery indicating receiver site and response of dorsiflexors of the ankle and foot.
trauma, tumors, and congenital anomalies. Joint arthrodesis, osteotomies, tendon transfers, tenodesis, limb discrepancy correction, and other deformity correcting and motion restraining surgery made up the major volume of the older orthopedic surgeons' work. Many of these crippling diseases have largely disappeared. Nonetheless, our rich heritage of experience is still applicable to currently encountered functional limb and spine deficits requiring orthoses.

More recently, surgical techniques have been developed to utilize sources of external power, i.e., electricity, compressed gas, spring mechanisms, etc., to facilitate orthotic substitution or to eliminate the use of orthoses. An example would be the neuromuscular assist electrodes placed on the peroneal nerve where brain damage and/or upper motor neuron involvement results in drop foot (Fig. 8). Further reinforcement surgery of this type is in the future.

**CONCLUSIONS**

Amputation surgery as never before is being directed toward prosthetic rehabilitation. This trend can be expected to continue and accelerate. Most surgeons performing amputations are unaware of the bioengineering implications incident to the surgery itself. Education at the clinical level needs top priority. Prosthetic and orthotic rehabilitation could be greatly improved if present improved surgical techniques were more widely used. In no field of surgery is bioengineering more relevant; the much discussed man-machine interface joins here. Its union will be successful only to the degree that the surgeon recognizes his role and responsibility.

**REFERENCES**