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Immediate, Early, and Late Postsurgical Management of Upper-Limb Amputation[a]

J. M. MALONE, M.D.*
L. L. FLEMING, M.D.**
J. ROBERSON, M.D.**
T. E. WHITESIDES, Jr., M.D.
J. M. LEAL, C.P.*
J. U. POOLE, O.T.R.*
R. STERNSTEIN GRODIN, O.T.R.**

* Section of Vascular Surgery
Tucson VA Medical Center and
University of Arizona

** Department of Orthopedic Surgery
Atlanta VA Medical Center and
Emory University, Atlanta

Abstract—This series is composed of 47 patients who underwent immediate, early, or late postoperative prosthetic fitting after upper-limb amputation. The purpose of this review was to analyze the impact of rapid postoperative fitting on upper-limb amputation, and to assess general prosthetic prescription and guidelines for upper-limb amputees. It would appear that in adult amputations there is a "Golden Period" of fitting for upper-limb prosthetic devices and this period appears to be within the first month after amputation. There appears to be no difference in ultimate prosthetic acceptance rate or use patterns as a function of the type of prosthesis initially provided. Based upon this combined review between the Tucson and Atlanta VA Medical Centers, the authors would suggest that all upper-limb amputees be fitted as rapidly as possible (within 30 days) with conventional prosthetic devices, and when they have shown motivation and skill in the use of conventional devices, then to re-evaluate them for appropriate externally powered prosthetic components.

INTRODUCTION

Immediate fitting of a prosthesis at the time of amputation is a relatively recent trend. The first immediate-fit prosthesis for lower-limb amputation was reported by Berlemont in 1958 (1). The technique did not catch on until several years later, after a report by Weiss (37). In 1965, Burgess et al achieved accelerated rehabilitation, increased acceptance of the prosthesis, and less psychological trauma associated with loss of limb when immediate fitting was performed (4). Little has been written about immediate fitting of upper-limb amputees, even though the technique is probably better suited to these patients than to lower-limb amputees.

Based upon previous statistical reports, it can be estimated that there are approximately 400,000 amputees in the United States (13,16,21–23). Each year 30,000 to 40,000 new amputations are performed and approximately 15 percent (6,000) are major upper-limb amputations (10–13, 15, 21–23, 32). In general, the success rate for adult rehabilitation after upper-limb amputation is 50 percent or less (3,5,8,10,14,15,26).

Limb replantation after upper-limb amputation has become well established in many major medical centers. However, only 10–15 percent of all upper-limb amputees are, in reality, good candidates for major limb replantation (proximal to the wrist)

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NOTE: Address correspondence to Dr. James M. Malone, M.D., Chief, Vascular Surgery (112), VA Medical Center, Tucson, Arizona 85723.

and, in general, the success rate declines rapidly as the level of amputation moves proximally up the arm (2,9,24,28). Success after replantation should not be defined as merely limb replant survival, but rather integration of replanted parts into normal use patterns and activities of daily living. The decision for replantation or amputation should be based on consideration of whether a prosthesis or a replanted limb will permit the patient to function best, and not the technical satisfaction to be gained from replantation. In centers specializing in limb replantation, the reported percentages of limb survival and extremity function range from 50 to 92 percent and from 60 to 78 percent respectively (2,9,24,25,28). The incidence of partial success, (for example, salvage of an elbow with hand loss in an above-elbow injury) is impossible to ascertain due to limited reports. It is entirely appropriate, therefore, that new emphasis be placed on upper-limb prosthetics and rehabilitation after upper-limb amputation.

The purpose of this report is to review the literature on immediate and early postsurgical fitting of prostheses to upper-limb amputees, and to review the authors' experience with upper-limb immediate, early, and late postsurgical prosthetic fittings utilizing conventional, electric, and myoelectric components. This report represents the combined results from two separate institutions which have comparable programs for the treatment of upper-limb amputees: the Tucson VA Medical Center /University of Arizona, and the Atlanta VA Medical Center/Emory University.

MATERIALS AND METHODS

Definitions

"Prosthetic use" is defined as percentage use of any type of prosthesis: 100 percent use represents 12 hours of wearing time per day, 7 days per week (84 hr/wk).

The time of prosthetic fitting will be divided into four categories as follows:

1. "Immediate postsurgical fitting (IPOP)," in which the prosthesis is applied at the time of surgery;
2. "Early prosthetic fitting" in which the prosthesis is applied any time up to 7 days after surgery;
3. "Intermediate prosthetic fitting" in which the prosthesis is applied 8–30 days after surgery; and
4. "Late prosthetic fitting" in which the prosthesis is applied more than 30 days after surgery.

"Rehabilitation" is defined as patient return to job/work or pre-amputation activities. "Rehabilitation time," therefore, refers to the time interval between injury and rehabilitation (as defined).

Success, failure, and rejection are defined as follows: "Success" constitutes use of a prosthesis in the patient's pre-amputation job or activities, "failure" indicates no prosthesis use, and "rejection" represents voluntary prosthesis disuse in a patient who had previously learned to use a prothesis.

Patient Data

The series is composed of 47 patients who underwent immediate, early, or late postoperative prosthetic fittings. The age range was 4–82 years and the mean age was 31 years. There were 21 right and 26 left upper-limb amputations. The level and etiology of amputation, prior occupation, and the time of postsurgical prosthetic fitting are shown in Tables 1–3.

SURGICAL TECHNIQUES

In general, maximum limb length was preserved. The proximal limitation for salvage of a below-elbow amputation was the distal insertion of the biceps tendon on the proximal radius. No effort was made to salvage elbow disarticulation levels, and a limb which could not be salvaged at the specified below-elbow level was converted to an above-elbow amputation, with approximately 2 inches of shortening from the tip of the olecranon in order to allow for the cosmetic placement of a prosthetic elbow unit.

Muscle fixation was used in all amputations and included myoplasty (46) or myodesis (1). All nerves were gently pulled into the amputation wound, transected, and allowed to retract out of the wound. The nerves were managed with either circumferential ligature (26) or electrocautery to the cut nerve end (21). All traumatic injuries were closed primarily and were drained using a closed suction system. In order to decrease skin tension, the subdermal fascia was approximated with absorbable suture and the skin was approximated with metal skin staples.

PROSTHETIC TECHNIQUES

Immediate Postsurgical Prosthetic Fitting (IPOP)

Standard immediate postoperative prosthetic techniques, as utilized for lower-limb amputation, formed the basis for immediate, early or intermediate upper-limb prosthetic fittings (17,18,23). Owen's silk was used as a skin separating agent. Lamb's wool (26) or Dacron waste (21) was used for distal stump padding prior to application of a spandex stump sock. Felt pads were used for bony-prominence relief. The prosthetic shell was

constructed with an inner layer of elastic plaster (Orthoflex ®) (Johnson & Johnson) and an outer layer of Scotchcast™ (3M). The combination of Orthoflex® and Scotchcast™ provided a lightweight but durable prosthesis.

The prosthetic devices utilized in this study included the following components: Otto Bock 6-volt hand; Otto Bock 6-volt myoelectric "Greifer;" Liberty Mutual myoelectric "Boston" elbow (switch or myoelectric control) with adaptation for hook or hand as a terminal device; the VANU/Fidelity Electronics[b] 8-volt hand/elbow combination; VANU/Fidelity Electronics 12-volt switch-control hand; VANU/Fidelity Electronics 12-volt myoelectric control hand; Dorrance 5X hook; and Pope conventional internal-lock elbow with lift assist. There was no uniform pattern of fitting; however, most below-elbow amputees at the Atlanta VA/Emory University were fitted with the VANU/Fidelity Electronics 12-volt myoelectric hand, while amputees at the Tucson VA/University of Arizona received varieties of the prosthetic components listed above, depending on amputation level and job skills.

Early, Intermediate and Late Prosthetic Fitting

Once wound-healing was achieved, all upper-limb prostheses were constructed using standard prosthetic fabrication techniques. In general, early and intermediate prostheses were constructed using the United States Manufacturing Co. (USMC) Aqualite™ kit, and the Scotchcast™ socket was replaced as required to maintain good prosthetic fit. Adaptions in prosthetic technique for most temporary prostheses were as discussed for immediate postoperative postsurgical fitting. Late prosthetic fitting was usually accomplished using either standard double socket lamination techniques or modification of the USMC Aqualite™ kit for construction of a permanent prosthesis.

Convential Prosthetic Fitting

For the below-elbow patient, conventional prosthetic fitting was accomplished using a USMC Aqualite™ kit. Versions of this kit are available which allow use of a hook, a VANU/Fidelity Electronics 12-volt switch-control hand, or an Otto Bock hand or "Greifer" (switch or myoelectric control) as a terminal device. The forearm of the prosthesis (and cable base plate) are secured to the cast using Elastoplast® tape. A cosmetic-appearing prosthesis can be made by padding the forearm with foam and then covering the prosthesis with

[b] VANU indicates that the device was developed through VA-sponsored research at Northwestern University. In this case the commercial version is a Fidelity Electronics product.

TABLE 1

Level of amputation	Number	Percent
Partial hand	1	(2%)
Below elbow	32	(68%)
Above elbow	13	(28%)
Forequarter	1	(2%)
Total	47	

Etiology of amputation	Number	Percent
Trauma	32	(68%)
Electrical burn	5	(11%)
Neurologic	4	(9%)
Congenital	3	(6%)
Other	2	(4%)
Burn	1	(2%)
Total	47	

TABLE 2
Occupation at time of injury

	Number		Percent	
Non-working		14		(30%)
Student	9		(19%)	
Retired	4		(9%)	
Congenital (< 18yr)	1		(2%)	
Working		33		(70%)
Desk job	10		(21%)	
Manual labor	23		(49%)	
		47		(100%)

TABLE 3
Time of postsurgical prosthetic fitting

Immediate (surgery)	20
Early (0-7 days)	0
Intermediate (8-30 days)	8
Late (> 30 days)	19
Total	47

Coban® (3M). A single axillary harness was used for control of a conventional prosthesis with a hook as terminal device. A switch mounted on the prosthesis, with actuation by a cable from a single axillary harness was used for control of an Otto Bock or VANU/Fidelity Electronics hand. Below-elbow prostheses were constructed to be self-suspending using a modified Münster technique. For patients with very short below-elbow residual limbs, the elbow was initially locked in 90 degrees of flexion in order to obtain a self-suspending prosthesis.

For the above-elbow amputee, a Pope internal-lock elbow was used with lift assist and a standard forearm (which can be precut for length). The immediate-fit group received a hook as the terminal device. Some patients in the early and intermediate prosthetic fitting groups received a hook or a switch-controlled hand (Otto Bock or VANU/-Fidelity Electronics) or both, and a few patients were fitted with a switch-controlled or myoelectric elbow (Liberty Mutual or VANU hand/elbow combination).

Externally Powered Components

When patients were fitted immediately postoperatively with an Otto Bock myoelectric hand or Liberty Mutual myoelectrical elbow, and there was no chance for preoperative myotesting, a "guess" was made about the best flexion/extension control sites. Such choices of myoelectric control sites were much more consistently successful in below-elbow amputees than they were for above-elbow amputees.

It is not advisable to use Orthoflex® plaster for construction of a myoelectric immediate or temporary prosthesis, because both the Otto Bock and Liberty Mutual myoelectric electrodes can be damaged by water. Fabrication techniques are available which allow incorporation of the Otto Bock or Liberty Mutual electrodes in plaster, but these techniques are time-consuming. The authors have found that the simplest approach is to place dummy electrodes over the myoelectric control sites and to construct the initial prosthetic shell with Scotchcast™ rather than plaster. The area over the dummy electrodes was cut out while the prosthetic shell was soft. When the prosthetic shell was dry (in 10–15 minutes), the electrodes were placed over the myocontrol sites and secured to the prosthetic socket with Elastoplast® tape (Beiersdorf, Inc., BDS Plaza, Norwalk, Connecticut) or Scotchcast™.

For the patient fitted immediately with the VANU/Fidelity Electronics myoelectric hand, specific adaptations were made to allow immediate fitting of electrodes without water problems. Electrode pins were made from ¾ inch aluminum ledger screws which had flow-form 3/16 inch plastic heat-shrunk tubing insulation applied to the pins. The pins were placed through the spandex stump sock directly over control sites on the forearm and incorporated in the cast. Electrodes were anchored in the below-elbow cast using elastic plaster. The myoelectric terminal device was then attached to the socket and the electrodes were connected to the pins.

RESULTS

This review covers a time period from 1966 to 1982. The range, and mean patient followup time, are shown in Table 4.

All traumatic wounds closed primarily healed without complication (0/20). There was no injury to the wound or amputation residual limb due to casting techniques and/or immediate fitting of a prosthesis (0/20). There were no postoperative deaths and no morbidity in the surgical group (0/20). One patient who sustained a traumatic above-elbow amputation required late revision (1 year) for ectopic bone formation which involved his median and ulnar nerves (1/20:5 percent).

The time from injury to prosthetic function, injury to rehabilitation, and percentage of successful rehabilitation are shown in Table 5. There was no significant difference in injury-to-function, injury-to-rehabilitation, or in rate of rehabilitation, between immediate and intermediate postsurgical fitting. The difference in successful rehabilitation between those patients who were fitted within 30 days of surgery (immediate and intermediate) and those patients fitted more than 30 days after surgery (late) was significant (26/28 = 93 percent vs 8/19 = 42 percent) ($P < 0.001$) (Chi Square, Yates Correction).

For patients fitted with a prosthetic device within 1 month of surgery, the mean time from-injury-to-work is 6 months and for time-at-work, 17 months. Of the patients who were injured on the job and treated with prosthetic fitting within 30 days of surgery, 100 percent (13/13) returned to work, while only 15 percent of patients (3/20) injured on the job and referred for prosthetic fitting more than 1 month after surgery returned to work ($P \ll 0.001$) (Chi Square, Yates Correction).

Of the group of 13 patients who were fitted with a prosthetic device within 30 days of surgery and who all returned to work, 6 of the 13 (46 percent) returned to the same manual job, 1 of the 13 (8 percent) returned to a manual job of increased difficulty, 4 of the 13 (31 percent) returned to

TABLE 4
Time of prosthesis use

	Number of patients	Followup (months)	
		Range	Mean
Immediate (surgery)	20	1–120	32
Early (0–7 days)	0	—	—
Intermediate (8–30 days)	8	1–35	13
Late (> 30 days)	19	1–108	24

TABLE 5
Fit, function and rehabilitation

	IPOP*	Intermediate*	Late*
Number of patients	20	8	19
Injury to function	1 wk	2 wks	1 yr
Injury to rehabilitation	4 mos	4 mos	1 yr
Successful rehabilitation	18/20	8/8	8/19

IPOP & Intermediate (26/28) versus Late (8/19):P < 0.001

*Mean time in weeks or months

manual jobs of decreased difficulty, and 2 patients (15 percent) went from manual jobs to desk jobs.

Prosthetic use patterns as a function of length of time of prosthetic fitting after surgery were reviewed. When each postsurgical prosthetic fitting category (immediate, intermediate, and late) was subdivided into two groups based upon the type of initial prosthetic component provided (conventional body-powered or externally powered) there was no significant correlation between ultimate use of conventional body-powered or externally powered prostheses and the type of prosthesis with which a patient had been initially fitted—in the immediate and intermediate postsurgical groups. All of these patients who returned to work developed use patterns for both their conventional and externally powered prostheses which were based upon the particular job skills needed by each amputee. But amputees who had been fitted more than 30 days after surgery (late group) almost exclusively used their externally powered prosthetic components in preference to their conventional body-powered prosthetic devices, irrespective of the type of prosthesis that was first provided for them.

All of the patients had phantom paresthesias, but none of the surgical patients who received immediate or intermediate prosthetic fitting reported painful phantom syndromes. A significant portion of the patients transferred sensory feelings from their phantom limb to their prosthetic components, and it was not uncommon for these patients to complain that their prosthetic hand or arm itched or was cold. This "sensory transformation" of the phantom sensation was seen only in those patients fitted with prosthetic devices within 1 month of amputation and was not seen in patients who were fitted more than 30 days after amputation. In addition, painful phantom symptoms were common in patients fitted with a prosthesis more than 1 month after amputation.

Most patients preferred externally powered components for activities of daily living and social occasions. Patients doing heavy manual labor had difficulty with their externally powered components due to component failure and breakage, and most of those patients used their conventional body-powered prosthesis for work. Patients fitted with both the Otto Bock hand and Otto Bock "Greifer" (5) preferred the Otto Bock "Greifer." As might be expected, all patients indicated that they were extremely pleased with the cosmetic value of their electric/myoelectric prostheses compared to standard body-powered prostheses.

DISCUSSION

Rehabilitation after upper-limb amputation is more difficult than after lower-limb amputation (3). In general, the highest success rates are achieved when the patient is fitted as rapidly as possible after surgery (2,3,6,8,12,26,29–35). In most centers, a prosthetic device is not provided for the patient until after complete wound healing and stump maturation (3–6 months), and that approach often results in late fitting of amputees and ultimately poor rehabilitation results. A review of the current literature on upper-limb amputation limited to cases where patients were treated with this "standard approach" suggests that their rate of rehabilitation approximates only 50–60 percent by 6 months after amputation (3, 8,9,13,26). In most settings, by the time amputees are fitted with a prosthetic device (medium prosthesis delivery time is 6 months (10)) they have become skilled at being one-handed individuals and they see very little use for "an assistive prosthetic device" (3,11,25,26).

Multiple factors influence the acceptance and use of a prosthesis by upper-limb amputees. Vitali et al, in 1978, reported a 67 percent rejection rate for standard below-elbow prostheses (36). Significantly better results have been achieved using a

myoelectric hand. Northmore-Ball et al, reported a series of 53 myoelectric fittings with only an 8 percent rejection rate (27). A 10-year review of the English language literature documents that immediate postoperative prosthetic fitting after upper-limb amputation can significantly improve rehabilitation rate and shorten rehabilitation time (Table 6). That review documented 182 reported cases of immediate postsurgical prosthetic fitting for upper-limb amputation for which data on level of amputation and rehabilitation rate and time was available in 142 cases (78 percent). Thirty-five cases (35/142=25%) reported the use of externally powered components, and the rest of the cases involved the use of conventional prosthetic devices. The overall rehabilitation time ranged from 1 to 30 days, but in general was less than 10 days. The fitting time for permanent prostheses ranged from 2 to 30 weeks, but in most cases, was less than 12 weeks; and most importantly, the overall amputee rehabilitation rate was 93 percent (132/142). Our data is consistent with the existing literature; however, there are some significant differences between our data and the literature and for this reason several points need to be emphasized.

We have analyzed successful rehabilitation as a function of the time of postsurgical prosthetic fitting. Our patients were divided into four groups corresponding to the time interval between surgery and prosthetic fitting: immediate postoperative (surgery), early (0–7 days), intermediate (8–30 days), and late (>30 days). The success rate for patients fitted within 1 month of amputation was 93 percent (26/28) and the success rate for those patients fitted after 1 month was only 42 percent (8/19). This difference is statistically significant ($P < 0.001$) (Chi Square, Yates Correction). In general, patients fitted within 1 month of amputation required approximately 1–2 weeks to learn how to use their prosthesis, they became functional in most activities of daily living and job skills within 1 month, and they attained rehabilitation (return to pre-injury activity or work) in 4 months. Perhaps more important was our success rate in returning to work patients who were injured on the job. For patients injured on the job who were fitted within 30 days of surgery, the mean time from injury to work was 4 months, the average time at work was 17 months and the success rate was 100 percent (13/13). In contrast, for such patients fitted with prosthetic devices more than 1 month after surgery, the time from injury to work ranged from 6 months to 2 years and the success rate in returning to work was only 15 percent (3/20).

There were two rehabilitation failures in patients fitted within 30 days of surgery (2/28=7 percent); however, these patients represent rejection of their prosthetic components, not rehabilitation failures. Prosthetic rejection in the early postoperative period appears to be dependent upon patient age (6 years and 82 years), patient motivation, and our ability to provide longterm prosthetic followup and occupational therapy. Failures in the late group (11/19=58 percent) appear to be primarily due to poor patient motivation and lack of need for "assistive prosthetic devices" on the part of patients who have become one-handed. It is impossible to know the role of financial coverage in the success or failure of utilization of prosthetic components, but the authors' review suggests that there may be a correlation between non-patient-dependent financial coverage (i.e., insurance, workman's compensation, etc.) for prosthetic devices and the ultimate success of prosthetic use.

Analysis of prosthetic use patterns, as a function of time of prosthesis fitting after surgery and of the type of prosthesis, suggests that ultimate patient prosthetic use (of either conventional or myoelectric components) is not based upon the type of component with which a patient is initially fitted, but rather is based upon the individual requirements of each patient with respect to his work or home activities. In other words, there is no "standard" prosthetic prescription for upper limb amputees.

It must also be emphasized that the aggressive approach employed in this series for the primary closure of traumatic wounds is unconventional. The lack of a significant difference in rehabilitation rates between immediate postoperative fittings and early-and-intermediate postoperative fitting suggests that early secondary closure is an acceptable alternative to primary closure, if a question of wound toilet exists.

We believe that, compared to upper-residual-limb wrapping after amputation (conventional prosthetics), there are multiple advantages to early postoperative prosthetic fitting (within 30 days of surgery) and they include decreased edema, decreased postoperative pain and phantom pain, accelerated wound healing, improved patient rehabilitation, decreased length of hospital stay (and perhaps of hospital costs), increased prosthetic use, maintenance of some continuous type of proprioceptive input through the residual limb, and improved patient psychological adaptation to amputation.

It would appear that, in adult amputations, there is a "Golden Period" of fitting for upper-limb pros-

TABLE 6
Upper limb immediate postsurgical fitting

	Type of amputation**					Rehab time (days)	Rehab rate	Permanent prosthesis (weeks)
	WD	BE	ED	AE	S/D			
Fleming LL et al (12) (1980) Beneficial*	—	15	—	1	—	rapid	15/16*	—
Tooms RE (37) (1972) Beneficial no data	—	—	—	—	—	—	—	—
Loughlin E et al (20) (1969)	—	2	—	—	—	3-5	2/2*	4
Robinson KP et al (31) (1975)	—	1	—	2	—	3	3/3	4–6
Burkhalter WE et al (3) (1976)	14	38	6	29	9	—	87/96	2–16
Jacobs RE et al (14) (1975) (10 other cases no data)	1	1	—	2	—	6–9	4/4	4–30
Sarmiento A et al (33) (1969)	2	1	—	1	—	1–30	4/4	3–8
Reyburn TV (30) (1971) (30 cases no data)	—	—	—	—	—	—	—	—
Malone JM (23) (1981)	—	4	—	7	1	2–14	12/12*	4–6
Childress DS et al (16) (1969)	2	—	—	—	—	1	2/2*	4
Childress DS (1) (1970)	1	2	—	—	—	1	3/3*	4
TOTAL CASES	20	64	6	42	10			
	(182 cases; 142 with data)							

REHABILITATION TIME
1–30 days (most < 10 days)
REHABILITATION RATE
132/142 (93%)
TIME TO FIT PERMANENT PROTHESIS
2-30 weeks (most < 12 wks)

* Externally powered (35/142 = 25%)
**Amputation types: WD = wrist disarticulation; BE = below elbow; ED = elbow disarticulation
AE = above elbow; S/D = shoulder disarticulation + forequarter amputation

thetic devices and this "Golden Period" appears to be within the first month after amputation. There appears to be no difference in ultimate prosthetic acceptance rate or use patterns as a function of the type of prosthesis initially provided (conventional or externally powered). The authors' current philosophy is to fit all patients as rapidly as possible (within 30 days) with conventional prosthetic devices, and when they have shown motivation and skill in use of the conventional device, then to re-evaluate them for an appropriate externally powered prosthetic component. A plea for immediate, early, or intermediate prosthetic application is stressed by the authors, to whom prosthetic fitting within 30 days of amputation appears to be the most important aspect in the treatment process which ultimately leads to successful upper-limb amputation rehabilitation■

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