

# Some Experience with Prosthetic Problems of Upper-Extremity Amputees

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THE history of the upper-extremity prosthetics program up to 1954 has been outlined in a previous article in this journal (7). From 1950 to the present, the upper-extremity research group established in the Department of Engineering, University of California at Los Angeles, has processed some 300 arm amputees: 72 during the Case Study Program (3), an overlapping 250 during the 12 schools at the Prosthetics Training Center (1), a small group of adult research amputees, and 104 children seen at the Child Amputee Prosthetics Project (4) prior to July 1, 1956. From the adult cases we have selected 23 of special interest to summarize in this article.

First presented are five cases that responded well to standard methods, the purpose being to

establish a baseline for comparison with the problem cases. Cases aided by the development of special equipment and by training in its use are grouped in one section because of the interrelationship between fitting, correct equipment, and amputee training. Under the heading of special equipment come the prototypes of several devices now standard in the armamentarium and also some modifications that remain unique to the individual wearer.<sup>5</sup> Cases aided by medical and biomechanical treatment are grouped together, again because of the interrelationship involved.

Although some three fourths of all arm amputees encountered in the program have become consistent users of functional prostheses, we have chosen to present unsolved problems in nearly half of the case histories given here. The reason, obviously, is to draw attention to the areas of need. Apart from some unilateral wrist-disarticulation and long-below-elbow amputees who operate easily and efficiently without prostheses (whom we do not consider to be problem cases), arm amputees who have the opportunity to be fitted properly, but who fail to use their prostheses, most often fall into one of three classes:

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1. Women of limited strength who object to the weight of forearm and terminal device.

2. Persons with severe biomechanical limitations, such as forequarter amputees.

3. Individuals suffering from disabling pain,

<sup>5</sup> Since these case histories are drawn from the UCLA experience, the devices presented as solving problems are those designed by this particular project. We

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Just to show that arm amputees are no exception to the general orneriness of mankind, the closing section covers cases presenting unsolved psychosocial problems.

It will be clear that several of the case histories might have been classified under some of the other headings. For example, in view of the drastic effects that the patient's postamputation decrease in earnings had on his family life, Case 9, discussed from the viewpoint of special equipment, could as reasonably have been classified under psychosocial problems. Case 13, discussed under biomechanical treatment, represents also an achievement in equipment modification. And so forth.

The expression "man-machine combination" is a well-worn phrase in contemporary biotechnical research. In limb prosthetics, one might say, there is a "man-equipment-training combination" in which the man may be modified by medicine, by surgery, by physical or occupational therapy, by developments in the psychosocial realm, or by training in control and use of the prosthesis. The equipment must be compatible with all these and may have to be modified by redesign or special fitting to overcome the man's biomechanical limitations. Training may be either of negligible importance, as in Case 12, or crucial, as in Cases 7 and 11. Its usual importance tends to be somewhere between the two extremes.

Finally, it may be noted that the standards, procedures, and techniques employed in fitting, fabrication, and training are all described in detail in the *Manual of Upper Extremity Prosthetics*, 2nd Edition (8). Similarly, all materials and most of the components mentioned are listed in the *Manual*, together with sources and characteristics. Of the components not otherwise referenced directly, all have already been described in previous issues of ARTIFICIAL LIMBS, in the collaboration by Klopsteg, Wilson, *et al.* (5), in manufacturers' catalogs, or in the general literature of the field. A number of the special components are described in recent reports of the Engineering Artificial Limbs Project at UCLA.

were in no position to present the stories behind valuable components which emerged from other laboratories and limbshops.

## CASES RESPONDING WELL TO STANDARD METHODS

## CASE 1, FOREQUARTER

*History*

Case 1, male, a 30-year-old medical photographer, was first seen in the Case Study in February 1951, eight years postoperative. His left forequarter amputation, in which the left scapula and two thirds of the clavicle had been removed, followed injury in wartime Naval service. The Navy had provided him with a Navy-Fitch (2) arm (double-coupled-flexion type with wooden forearm, leather socket, catgut cords, and double chest-strap harness) but had not trained him to use it. Because of socket discomfort, he had worn no prosthesis for the preceding five years and was unable to operate his Navy-Fitch arm at all for testing purposes. He was able to fulfill all his functional needs satisfactorily with one hand, did not believe that any functional prosthesis for his level of amputation was available, and sought only a cosmetic replacement.

*Examination and Evaluation*

The patient was 6 ft. 4 in. tall, weighed 195 lb., was well muscled, and had good posture considering the extent of his loss (Fig. 1). The operative scar on the left shoulder girdle was well healed and not tender, but the area of the axilla was hypersensitive to touch. The subject was able to move the end of the remaining third of the clavicle only very slightly in flexion-extension but was judged to have a good range of motion in elevation-depression.

*Treatment*

The patient's unusually good conformation enabled him to be fitted with a modified shoulder-disarticulation prosthesis rather than with the usual forequarter type. Accordingly, a sectional type of shoulder prosthesis was prescribed, with emphasis on the cosmetic shaping of the shoulder cap. It included (Fig. 2) a chest-strap harness with four attachment points on the shoulder cap, an opposite-shoulder loop for dual control of terminal-device operation and forearm flexion, and nudge control of the elbow lock since the patient had no desire for an actively operated

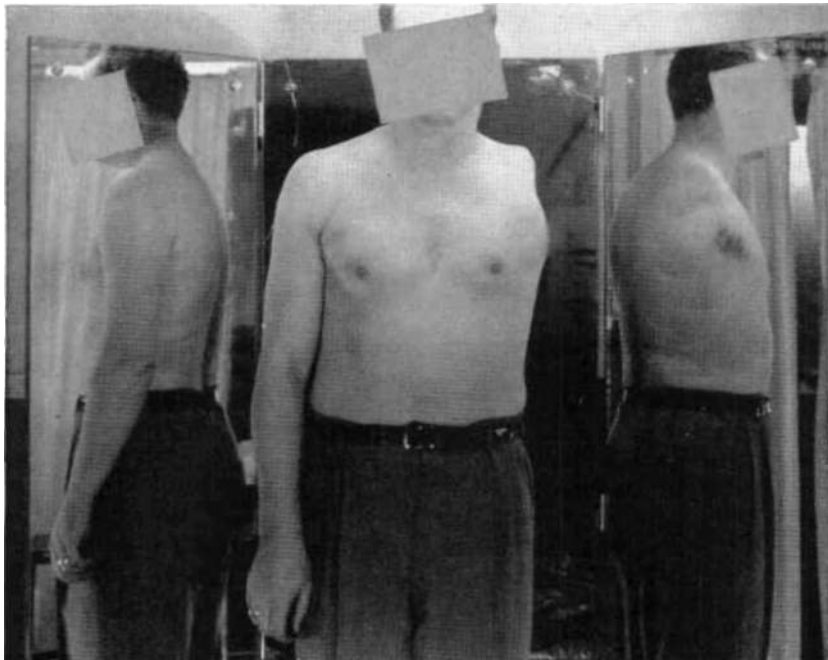


Fig. 1. Case 1. Patient as seen on referral.

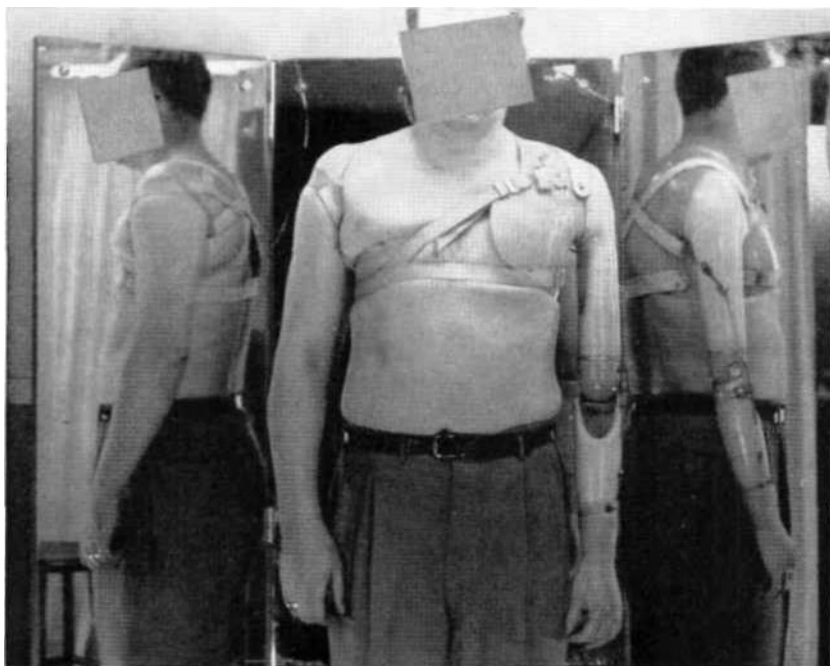


Fig. 2. Case 1. Prosthesis provided at UCLA. The unusually good physical conformation and range of motion of this forequarter amputee enabled him to be fitted successfully with a modified shoulder disarticulation type of prosthesis rather than with the full forequarter socket. There was more functional regain than usual considering the patient's level of amputation. Compare with Cases 15 and 16.

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elbow. The nudge control failed mechanically several times, a circumstance which led to a satisfactory redesign. Originally provided with a Dorrance hook, the patient later requested and received an APRL hand and hook. The pressure-control feature of the APRL hook proved "invaluable" in his darkroom work.

Training in use of the prosthesis was aided by the patient's wife, who was an occupational therapist. After training, the amputee passed nine out of ten activity tests and was judged to perform with extreme smoothness and remarkable ease and dexterity considering his level of amputation. When followed up a year later, the subject reported that he wore his prosthesis during most of his waking hours, sometimes as much as 120 hours a week, using the hand for most of his picture-taking and public-contact work and the hook in developing negatives and making prints.

#### *Summary*

In this case, better results were obtained than might reasonably have been expected. A unilateral forequarter amputee, the patient was interested only in a cosmetic replacement, did not seek functional regain, and did not believe that it was possible. Yet by proper fitting, followed by good training, he became an excellent prosthesis user.

#### CASE 2, WRIST DISARTICULATION

##### *History*

Case 2, male, a 38-year-old machine operator and assembler of tools and outdoor furniture, was first seen by the Case Study in June 1952, seven years after amputation. His left hand had been lost by a shrapnel injury to the wrist while he was serving in a Polish-French tank combat crew in Berlin. He had been fitted with a plastic socket with interchangeable Dorrance No. 8 hook and Becker wooden hand but had not worn the prosthesis for the preceding five months because the socket was broken. Prior to the breakdown, the patient had used the wooden hand 10 hours a day.

##### *Examination and Evaluation*

Examination showed a screwdriver-shaped stump with the styloids intact (Fig. 3). Physical condition was good, although forearm

rotation was somewhat limited. The amputee had never received any physical therapy or prosthetic training.

##### *Treatment*

There is available no wrist cap that matches the elliptical cross-section of the human wrist, and the wrist-disarticulation socket must therefore be faired out to meet the round wrist caps used. In this case, an attempt was made to develop a manually operated wrist unit of elliptical cross-section using rubber O-rings to supply the friction necessary for resistance to rotation. But the resulting appearance was not satisfactory, the added length (1.3 in.) was too great, and frictional characteristics were not as desired. Rather than devote the time and effort necessary to redesigning the unit, the practical solution was adopted of using a Sierra Model C wrist cap instead and fairing out the socket accordingly (Fig. 4). Use of the Model C wrist cap decreased the length by half an inch and improved the functional characteristics.

In accordance with the patient's desire, he was supplied with an APRL hook. He preferred it because of the selective prehension and "better mechanism" and because he felt that exposed rubber bands, as in the Dorrance models, would accumulate grease in his work. But the hook required weekly servicing because of dirt accumulation, and when the patient ripped the stud off he requested a Dorrance No. 5 hook instead. After experience with the Dorrance hook, however, he reported that it tended to scratch the furniture he polished on the job. At the patient's insistence, an auxiliary prosthesis was constructed for use with the old Becker hand, which he considered ideal for the polishing operation. The patient's one remaining objection to his prosthetic equipment was that, with his limited pronation-supination, the hook could not be positioned fast enough, but the length of his stump contraindicated use of a step-up rotation prosthesis. At last report, the patient was wearing a prosthesis 10 hours a day, 70 hours a week.

##### *Summary*

Case 2 was a relatively uncomplicated case that responded well to standard methods of

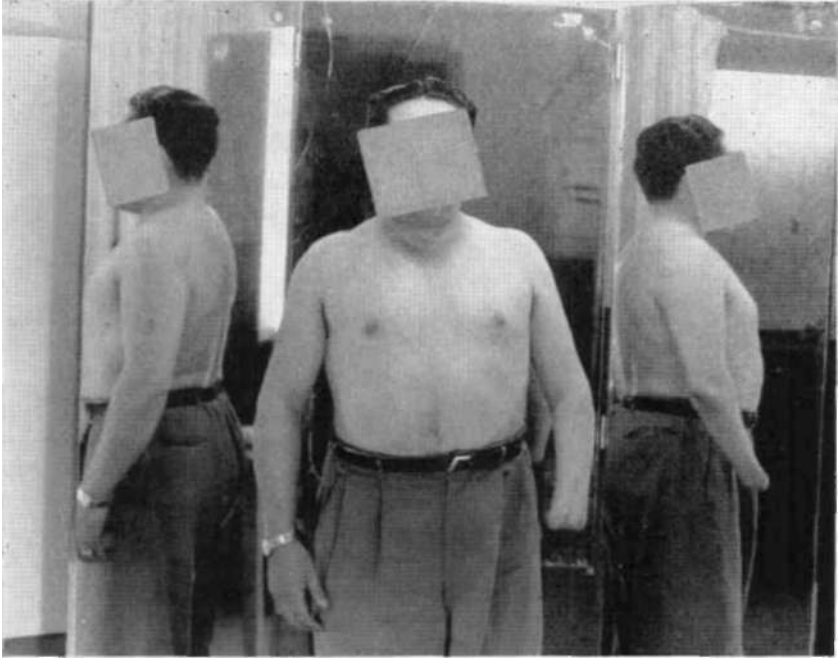


Fig 3 Case 2. Patient as seen on referral.

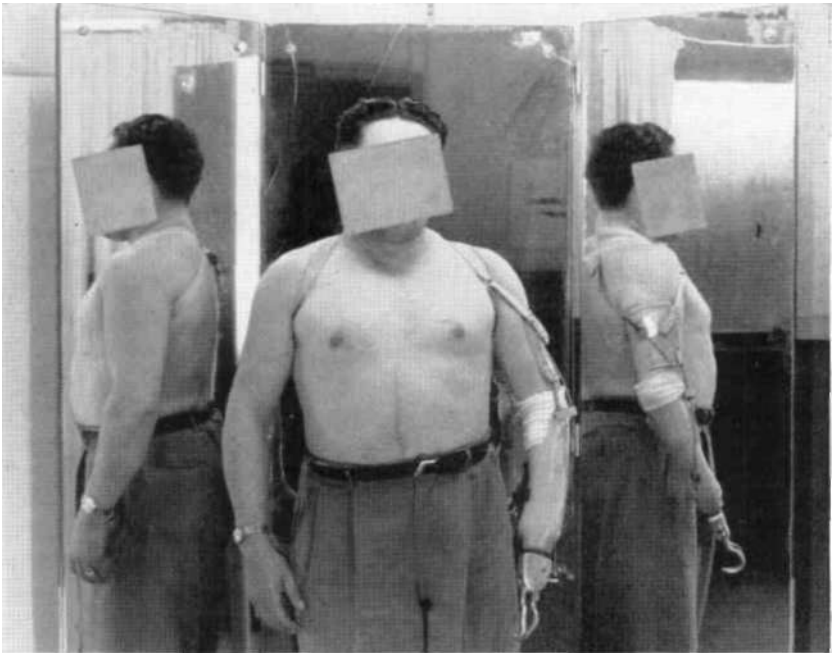


Fig. 4. Case 2. Prosthesis provided at UCLA. Because of required weekly cleaning and relative breakability in heavy work, the APRL hook shown here was later given up in favor of a Dorrance No. 5.

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fitting and prescription. This particular case points up the unavailability of certain desirable equipment for the wrist-disarticulation amputee and the importance of considering all the occupational requirements in prescribing a terminal device.

## CASE 3, MEDIUM BELOW-ELBOW

*History*

Case 3, male, a 48-year-old butcher specializing in breaking and boning fore-quarters of beef, was first seen in the Case Study in July 1951, nine months after amputation of his left arm below the elbow and one month after prosthetic fitting. He wore his new prosthesis at work but not otherwise, and he complained of stump soreness and pressure, a shoulder saddle that tended to slip under load, and awkward placement of the thumb of the Dorrance No. 1 hook. He had received no training in the use of his prosthesis.

*Examination and Evaluation*

Examination showed a screwdriver-shaped stump, 7.8 in. from epicondyle to tip, exceptionally firm and well muscled, with the radius approximately half an inch longer than the ulna (Fig. 5). The forearm flexors were markedly hypertrophied, and forearm flexion was limited to 120 deg.

*Treatment*

Because of the patient's heavy work, a heavy-duty short-below-elbow type of prosthesis was prescribed (Fig. 6). The amputee specified modification in harness which called for replacing the leather shoulder saddle by one of washable webbing. In view of the patient's desire for selective prehension force, an APRL hook was prescribed experimentally, but it was badly damaged in the course of the patient's work and was therefore replaced by a Dorrance No. 1 hook. An F-M disconnect was tried. But after the patient's hard use broke the gear teeth of the disconnect three times, a threaded type of disconnect was prescribed instead. The first three sockets fabricated proved unsatisfactory—the first because it interfered with circulation, the next two

because of rubbing against the distal end of the radius and the ulna when the patient rotated his forearm. The fourth socket proved satisfactory, but the cables continued to fray with use and had to be replaced every few weeks.

*Summary*

This case emphasizes the importance of rugged equipment for heavy work in the manual trades and the shortcomings in this respect of many available components. The amputee made a contribution to limb prosthetics in initiating the washable webbing shoulder saddle. His experience with cable wear and frequent replacement indicates the problem which has since been very largely solved by swaged fittings and by the nylon cable-housing liner.

## CASE 4, BELOW-ELBOW BICEPS CINEPLASTY

*History*

Case 4, male, a husky 18-year-old student, first entered the Case Study in December 1951, six years after a right below-elbow amputation that followed an explosion in a chemistry experiment in his home. About six months after the accident, he had been fitted with a laced leather socket and wooden hand, but he abandoned the device because he continued to break the fingers in the course of surf-casting and other outdoor activities. About a year later, the patient obtained his second prosthesis, with a David work hook, and wore it daily until it became inoperable. He had received no prosthetic training.

*Examination and Evaluation*

The stump was 83 percent of forearm length, screwdriver-shaped, and well muscled. The patient had a complete range of motion except for forearm rotation, which was limited to 30 deg. of pronation, no supination.

*Treatment*

Classified as a long-below-elbow type, the amputee was fitted with the standard prosthesis for his level of amputation, with an APRL hand and APRL hook. Operation of the voluntary-closing device was learned readily, and the patient was judged an excellent user.

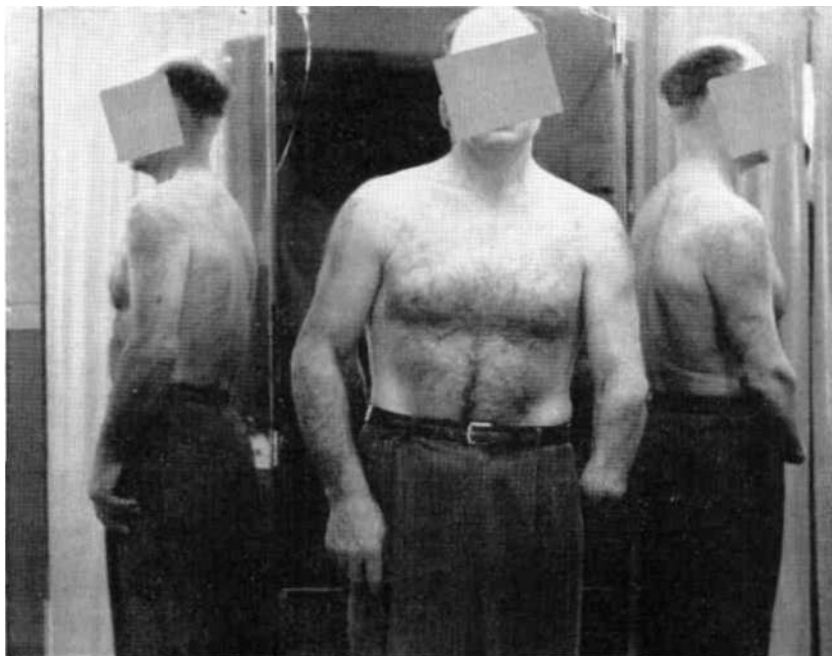


Fig. 5. Case 3. Patient as seen on referral,

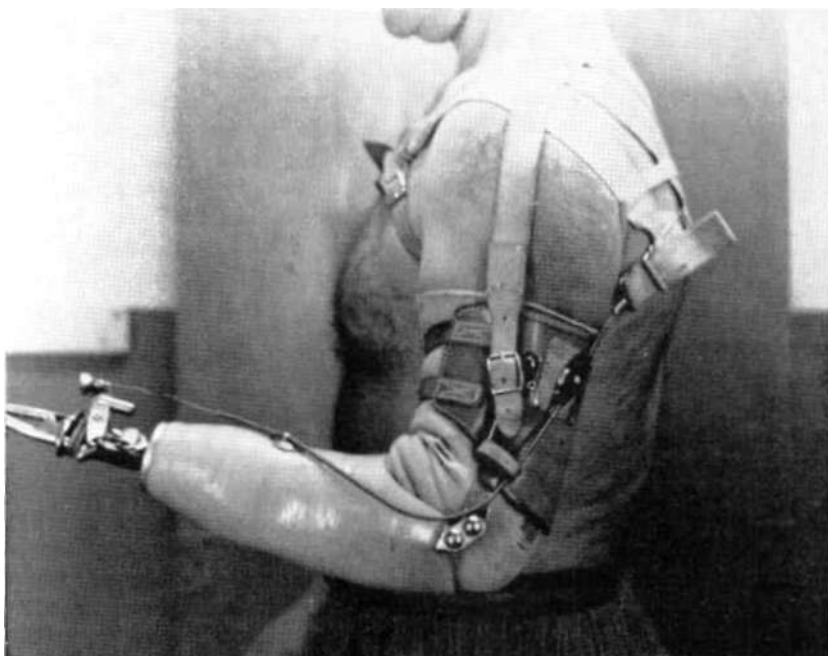


Fig. 6. Case 3. Heavy-duty prosthesis as prescribed for reason of occupation.

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In the trainer's judgment, the wearer's performance of test activities was as good as that of a normal person.

Having heard of the increased range of motion and the freedom from shoulder harness made possible by the cineplastic procedure, the amputee returned to the clinic three months later as a candidate for biceps cineplasty under the experimental program. The operation was prescribed, and the biceps muscle tunnel was constructed in July 1952 without postoperative complications (Fig. 7). Six weeks after surgery, the patient returned to the clinic, where his below-elbow biceps-cineplasty prosthesis was completed (Fig. 8).

After fitting and training, the patient was tested, and his performance was found to be nearly as good as it had been with the harness-controlled prosthesis. At that time, he experienced pain when the load on the tunnel reached 15 lb., but when this problem was overcome he proved to have a tunnel that could develop 105 lb. of pull when under 1 lb. of initial tension and 120 lb. under 10 lb. of initial tension. Two or three years later, the amputee modified his epicondyle clip by cutting it down in size and padding it deeply with foam rubber. Vinyl plastic was tried as a covering material, but the patient proved sensitive to it and went back to leather.

After almost five years, this patient was wearing his prosthesis with APRL hook all of his waking hours. He had no interest in a hand and would not consider a voluntary-opening hook, although he complained of the relative susceptibility of the APRL device to breakage. After several years' experience, he no longer broke his hooks, but the rubber linings wore off the hook fingers and required replacement every few months.

### *Summary*

This case is an example of successful application of the below-elbow biceps cineplasty. Although the amputee was an excellent user of a satisfactory harness-operated prosthesis, he thought the increased range of motion and freedom from shoulder harness worth the surgery. This case also shows the amputee's insistence on using his preferred terminal

device, even for activities for which he knew it was unsuitable.

### CASE 5. ABOVE-ELBOW/HUMERAL-NECK COMBINATION WITH BILATERAL PECTORAL CINEPLASTY

#### *History*

Case 5, male, a 31-year-old Air Force fighter pilot and former all-American football player, entered the project in November 1950 on special leave from a military hospital. He had been under medical treatment since 1947, when the fire that followed a jet crash-landing severely burned his head, the left side of his body, and both arms, resulting in bilateral arm amputation. Both pectoral muscles had been tunneled. The patient had been fitted with Navy-Fitch double-coupled-flexion arms, the cineplastic tunnels being used for prehension control (6). He complained of poor socket fit, restrictive harnessing, rotation of the sockets on the stumps, and the absence of an elbow lock and expressed a desire to learn to perform essential services for himself independently. Except for a six-month program of exercise to strengthen the muscle tunnels, he had never received any training in connection with his amputations.

#### *Examination and Evaluation*

Examination showed a right above-elbow stump and a left humeral-neck amputation, the two sides having the same pattern of scarring over the deltoid and the anterior and posteromedial aspects. There was limitation of humeral motion on the right side and no motion at all on the left. Exercises were prescribed. The patient appeared to be in excellent general condition, physically and psychologically. The right tunnel had a maximum excursion of 3 in. and a maximum force of 51 lb., the left 2.75 in. and 56 lb.

#### *Treatment*

To overcome the rotation of the sockets when the pectoral tunnels were contracted, to enable the amputee to don his prostheses independently, and to avoid the restriction of motion involved in force transmission through



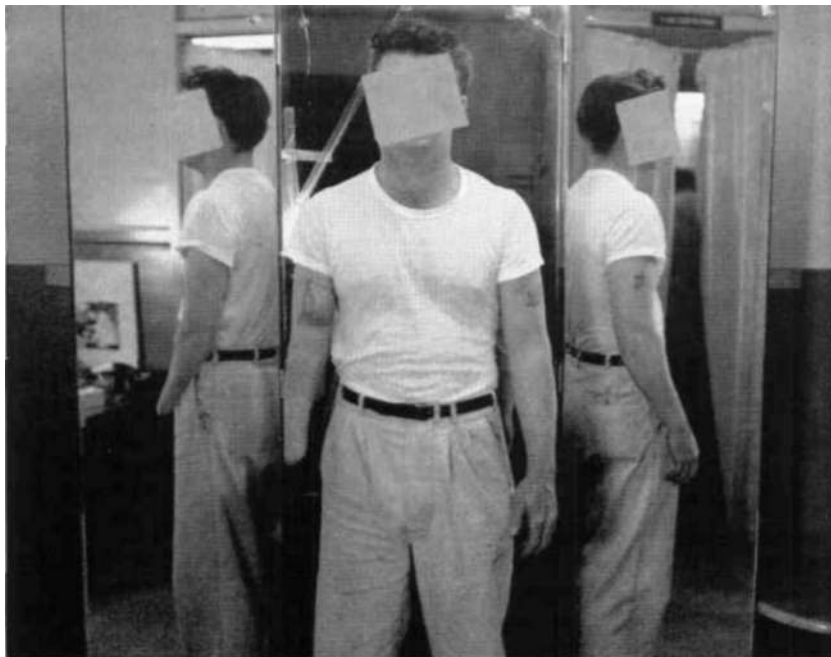


Fig. 7. Case 4. Patient after construction of biceps muscle tunnel.

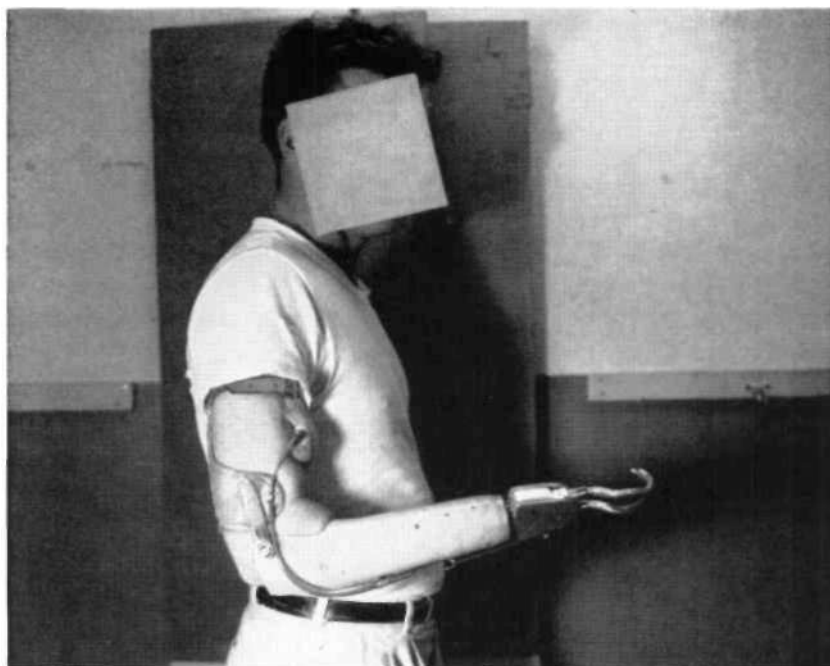


Fig. 8. Case 4. Patient wearing cineplastic prosthesis. Tunnel could develop 120 lb. of pull under 10 lb. of initial tension.

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bilateral pectoral cineplasty, the right side (above-elbow) was fitted and harnessed without use of the pectoral tunnel. The tunnel pin on the left side (humeral-neck) was modified in an effort to improve efficiency of the power-transmission system and to make it possible for the amputee to insert the pin either by means of the opposite prosthesis or by means of the mouth.

Forearm flexion and prehension control were of the standard, harness-operated dual type powered on the right side by humeral flexion and on the left by scapular abduction (Fig. 9), elbow lock on the left being operated by the left pectoral tunnel. After about three hours of



Fig. 9. Case 5. Prostheses provided at UCLA. Use of the pectoral tunnel for elbow lock on the left side was later given up.

training in the control and use of his new prostheses, the amputee was judged proficient.

The unused right pectoral tunnel was removed surgically, and about three years later the patient gave up use of the other tunnel but continued to use the prescribed arms without modification. He had had new prostheses made in 1953 but used them only for gardening and similar activities because he considered the upper portion of the right arm too long. In February 1957, more than six years after fitting, he was still wearing the prescribed arms and the same harness, although he had worn out four Northrop-Sierra two-load hooks and had been interchanging the two Northrop Model C elbows throughout the six years whenever service was required. He used the right prosthesis for most functions, with occasional help from the left. The patient did not bother with his own buttons or cutting his meat for himself, but he was active in the insurance business, took up hunting, and reported: "I write, drive, just like anyone else—only thing, I ain't as pretty."

#### *Summary*

One of many cases in which pectoral tunnels did not work out as planned, this bilateral arm amputee was made independent through standard prosthetic fitting and training. He modified his bilateral prosthetic control system to emphasize unilateral function.

#### CASES AIDED BY SPECIAL EQUIPMENT AND TRAINING

##### CASE 6, SHOULDER DISARTICULATION

#### *History*

Case 6, male, a 23-year-old office worker and preamputation bakery-truck driver-salesman, entered the clinic in September 1952, five months postoperative. His right arm had been disarticulated at the shoulder (Fig. 10) because of a malignant tumor.

#### *Examination and Evaluation*

Examination showed no medical contraindications to prosthetic fitting. Exercises to in-

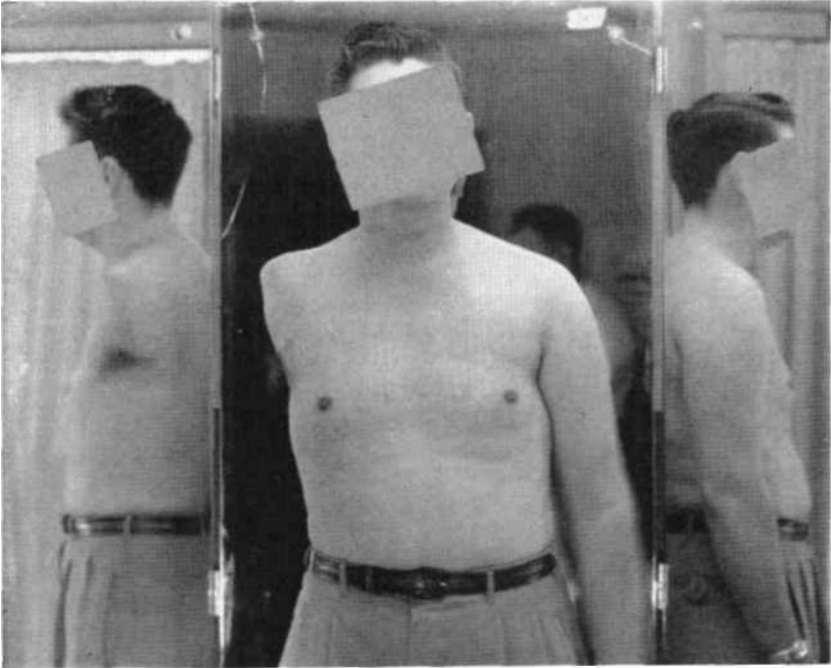


Fig. 10. Case 6. Patient as seen on referral.

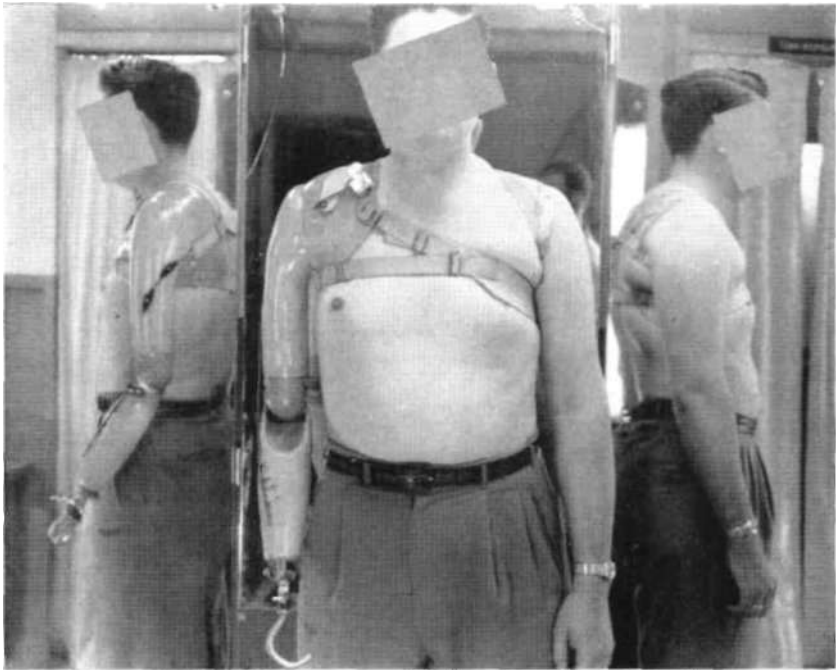


Fig. 11. Case 6. Pioneer fitting of a shoulder disarticulation, including prototype of the UCLA manually controlled, friction-type shoulder joint. The amputee refused to give up the prosthesis even when bodily changes due to illness made it irritating.

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crease the range of motion of the shoulder girdle were prescribed.

#### *Treatment*

At first, a standard, sectional type of shoulder-disarticulation prosthesis was prescribed and fitted, with dual control for forearm flexion and prehension and with nudge control of the elbow lock, a Dorrance No. 555 hook being used to keep weight to a minimum (Fig. 11). Later the patient was given a Northrop-Sierra two-load hook to evaluate; he adopted it enthusiastically.

Since the amputee experienced difficulty in putting on a shirt or coat, he asked for a movable shoulder joint which would allow him to flex his prosthesis in the parasagittal plane. Designed to his satisfaction, this device proved to be the prototype of the UCLA manually controlled, friction-type shoulder joint. At the patient's suggestion also, the nudge control was redesigned to cut down its protrusion and prevent clothing from catching in it. A month later, the subject reported that he wore his prosthesis 12 to 15 hours a day, that it was adequate for the needs of daily living, but that he would prefer a cosmetic hand of some kind for social occasions.

In May 1955, the patient underwent surgery for removal of a large metastatic tumor mass in the right lung, and beginning in September 1956 he received x-ray therapy for an inoperable lesion of the left lung. Loss of weight and atrophy of the shoulder girdle impaired the fit of the prosthesis, but the subject rejected medical advice that he wear only a shoulder cap to decrease the weight. He continued to wear the prosthesis until irritation of the bony prominences of clavicle and scapula necessitated prescription of a new soft-socket liner in February 1957. At that time he was in good general health and working regularly.

#### *Summary*

This pioneer fitting of a shoulder-disarticulation case resulted in devices now standard in the armamentarium. The satisfaction gained by the patient from his prosthesis is indicated by the fact that he insisted on wearing it even when bodily changes made it irritating physi-

#### CASE 7, BILATERAL SHOULDER DISARTICULATION

##### *History*

Case 7, male, a 63-year-old bridge and building-construction foreman with bilateral shoulder disarticulations (Fig. 12), entered the clinic in November 1953, three months after the amputation of his right arm because of osteomyelitis. The left arm had been amputated 15 years earlier as an ultimate aftereffect of trauma in 1923. The patient had never worn a prosthesis. In addition to independence in self-care, he particularly needed to be able to sign his name—the one manual function required in his job.

##### *Examination and Evaluation*

Examination showed a well-healed scar in the left shoulder region but on the right some postoperative edema, encrustation, and weeping. Shoulder motion was limited, and strength was poor.

##### *Treatment*

After an interruption due to an unrelated operation (splenectomy), the amputee was fitted at the Prosthetics Training Center bilaterally and also unilaterally with a right shoulder-disarticulation prosthesis. A year later, in 1955, he reported that he wore either the bilateral set or the unilateral prosthesis all his waking hours, usually the unilateral prosthesis, which had greater force and excursion and did not present the problem of interaction of controls. But he used this prosthesis only for picking up and carrying light objects and for nonprehension activities, such as pushing, pulling, striking, and hooking.

In May and June of 1955, the patient spent seven days at the Prosthetics Laboratory for alterations, experimentation, and training. His shoulder turntable was modified by addition of a Belleville washer in order to maintain constant friction, and nylon cable-housing liners were installed. Several experimental modifications of the elbow unit were tried in an attempt to secure smooth, reliable operation, but the final solution consisted of generous lubrication of the cable with paraffin, plus replacement of the housing by another long enough to allow an in-line entry of the cable into the locking unit.

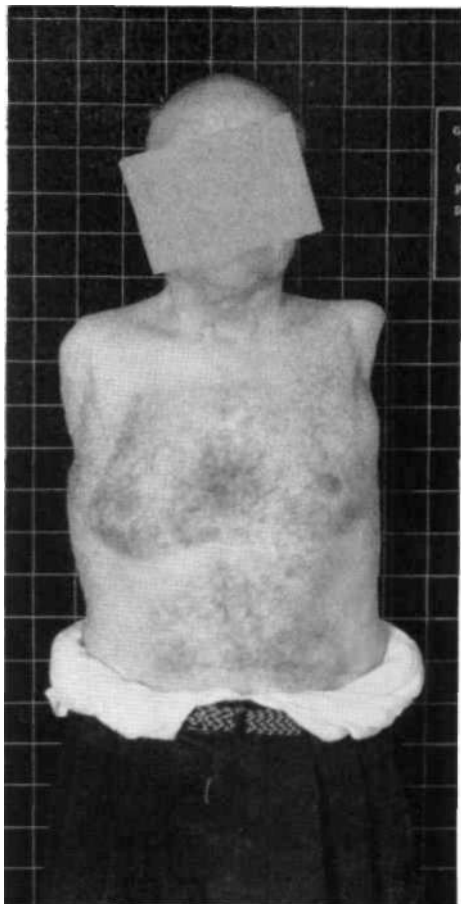


Fig. 12. Case 7. Patient as seen on referral.

The amputee's difficulties with the other components of his prosthesis resulted from lack of understanding of the mode of function, and he was therefore given intensive training. Patterns of activity feasible for this particular patient were worked out, and practice was supervised. Under this guidance, he learned to eat "all shapes and consistencies of food" with a fork, to write legibly, to unzip and zip his trousers (with a 3-in. elkhide thong attached to the zipper pull) for independent urination, to put on and take off a shirt or coat, to turn book and magazine pages, and to perform other activities. The therapist devised special equipment for his use, including

a stand for his electric shaver and a simple trouser belt with a D-ring buckle that he could tighten or loosen with one prosthesis.

In January 1956, it was found that the patient had not been employing these techniques at home because it upset his wife to see him struggle and she preferred to do things for him. In March 1956, he was fitted with a unilateral prosthesis employing the UCLA manually controlled, friction-type shoulder joint, modified arm-rotation turntable, nylon cable-housing liners, and a cable-excursion multiplier (Fig. 13). He was the first of the amputees fitted with this system. Two months later, he wrote that he had leveled a building lot by hand and prepared it for planting, performed household chores, and worked in an office answering the phone, writing down messages, and checking workmen in and out with equipment. In December 1956, the amputee wrote, in his own shaky but legible penmanship, to report the prolonged illness of his wife, during which he had taken care of himself after years of dependence.

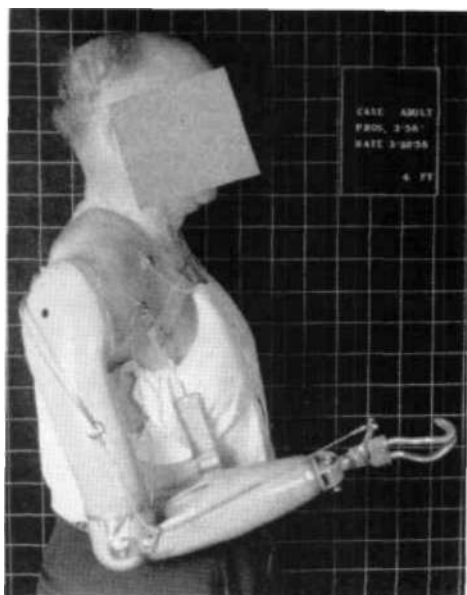


Fig. 13. Case 7. Successful unilateral fitting of the bilateral shoulder-disarticulation case

### Summary

This complex case has been given in some detail because it highlights several different aspects of the problem of the severely handicapped amputee. The interrelationship of equipment and training is pointed up. When the patient was unable to operate his components, the solution resided in modification of some, realignment in one case, and better training in use of the others. The effect of oversolicitous family members in keeping the handicapped person dependent is shown. Given usable prosthetic equipment and training, this elderly bilateral shoulder-disarticulation amputee was able to operate independently when his wife was no longer able to help him. The case meets one of the prevailing standards of rehabilitation—gainful employment at an appropriate task.

### CASE 8, VERY SHORT BELOW-ELBOW

#### History

Case 8, male, a 32-year-old clerk, was first seen in the Case Study in November 1950. His very short below-elbow amputation had resulted from machine-gun fire during service as an Army rifleman in France in September 1944. Except for the insertion of the biceps, the forearm musculature had been lost. Several unsuccessful efforts at prosthetic fitting—unsuccessful because of the limited stump motion—had convinced him that he would have to undergo reamputation above the elbow in order to be fitted with a useful prosthesis. He came to the Case Study as a last resort before reamputation.

#### Examination and Evaluation

Examination revealed a 3.8-in. below-elbow stump. A bony block in the elbow limited forearm motion to between 150 and 165 deg. of extension.

#### Treatment

A very short-below-elbow split-socket prosthesis was prescribed, with an above-elbow type of dual control for forearm flexion and prehension and with a special device which enabled the 15-deg. of stump motion to operate the elbow lock (Fig. 14). This was the proto-

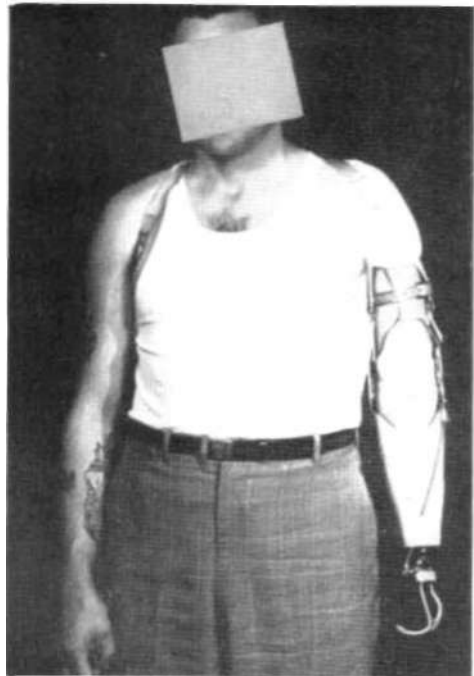
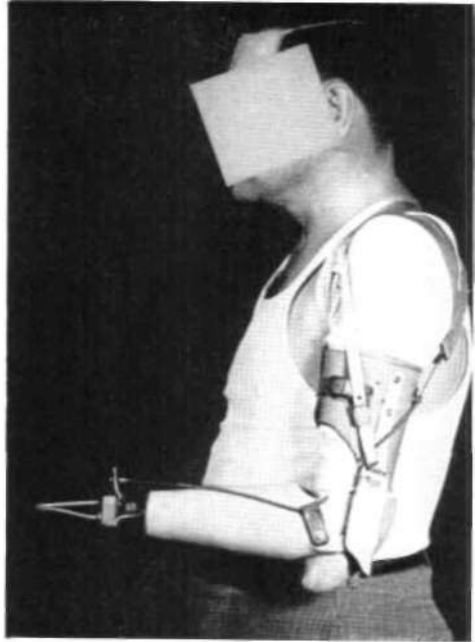


Fig. 14. Case 8. Amputee with very short (3.8-in.) below-elbow amputation fitted with the stump-actuated elbow lock. Reamputation previously considered, was avoided.

type of the stump-actuated elbow lock now-standard in the armamentarium.

Although the patient rated the prosthesis as excellent, he felt that more practice was needed in learning to operate the elbow lock with his stump and was found not to be wearing the prosthesis as many hours a week as he had reported. Three years later, however, he was wearing the limb constantly.

### *Summary*

In this clear-cut case, the design of a special device to meet a special situation solved the amputee's problem. The patient was saved from reamputation by the development of a device that is now standard. The history suggests, however, that the solution would have been still more successful, in terms of prosthesis use, had the amputee received more training and perhaps psychological counseling.

CASE 9. VERY SHORT BELOW-ELBOW WITH BICEPS CIXEPLASTY

### *History*

Case 9, male, age 40, was seen as an industry-counseling case in October 1951, two and a half years after an amputation which resulted from an industrial accident while he was working as an elevator and control-system installer. On the patient's return to work, after nearly two years' disability, the elevator company had transferred him to office work at slightly more than half his former salary. On the reduced income, he had been forced to give up his home, his wife suffered a nervous breakdown, and the two children had to live with relatives during a long period of readjustment. He had been provided in 1949 with a cosmetic arm and "Realistic" hand but had never had a functional prosthesis.

### *Examination and Evaluation*

Examination showed a left very short below-elbow stump, badly scarred, with flexion limited to 90 deg. by a bony block in the elbow. Shoulder motion also was limited.

### *Treatment*

The amputee was given a short-below-elbow prosthesis with an APRL hand and with the

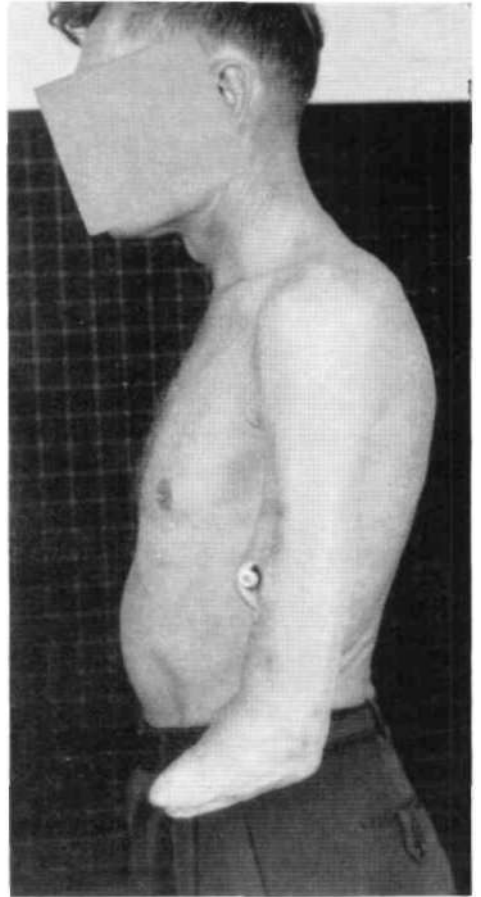


Fig. 15. Case 9. Patient after construction of biceps muscle tunnel.

forearm set in 20 deg. of initial flexion. Five months later he reported himself satisfied with this limb and, although he said he was wearing it 12 hours every day, he desired a step-up hinge to increase forearm flexion. In September 1953, a split-socket prosthesis with variable-ratio step-up hinge was fitted, with both hook and hand as terminal devices. The new prosthesis increased the patient's maximum forearm flexion to 120 deg., and he was judged as being "very adept" with both hand and hook. After acquiring a functional prosthesis, the amputee was able to return to his skilled trade with another employer, although he had to start as an elevator-mechanic's helper.

## SOME ARM CASKS

Fig 16 Case 9 Patient fitted with UCLA below-elbow biceps-cineplasty system using split socket and the 1.5-ratio step-up elbow hinge.

Learning that still greater functional regain (ability to operate the prosthesis above shoulder level) was possible with biceps-cineplasty control, the patient had his left biceps muscle tunneled in August 1954 as an experimental subject in the below-elbow biceps-cineplasty program (Fig. 15). Shortly after the surgery, he was fitted with a below-elbow biceps-cineplasty prosthesis with split socket, variable-ratio step-up hinge, and UCLA control system. In March 1956, an experimental prosthesis was fabricated for him using the new UCLA 1.5-ratio step-up elbow hinge (Fig. 16). With this limb he was able to lift 11 lb., nearly twice his previous maximum. It should be remembered that in this case slump flexion was not aided by the biceps because the biceps tendon had, of course, been severed. The 1.5-ratio hinge gave 5 deg. more forearm flexion than did the variable-ratio hinge. Although this increase in forearm flexion was of no importance to the patient, who had felt that the variable-ratio hinge gave all the forearm flexion he needed in his left arm, he greatly appreciated the ease and smoothness of action of the 1.5-ratio hinge. By 1957 he had advanced to the position of elevator inspector.

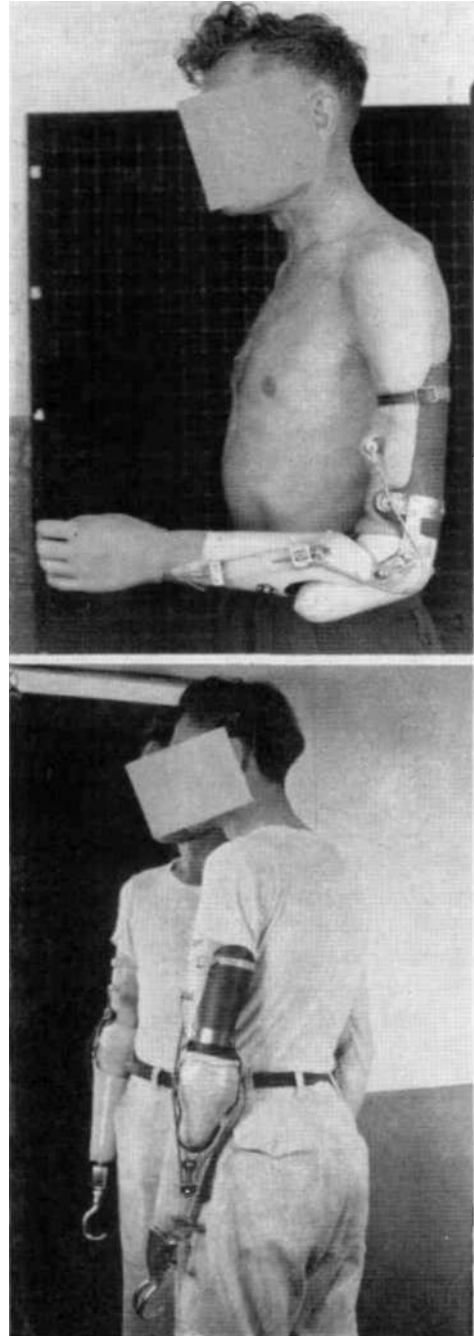
### Summary

This case highlights the contribution of new devices to the welfare of the amputee with a very short below-elbow stump. It also points up the socioeconomic value of a functional prosthesis in the manual trades. When this amputee was prevented from working at his highest level of skill, severe dislocation was experienced by an entire family. Fitting of a suitable prosthesis enabled him to return to gainful employment.

CASK 10, CONGENTINAL BELOW-ELBOW.

### History

Case 10, female, a 37-year-old teaching nun, entered the clinic in January 1955. A congenital left below-elbow amputee, she had worn cosmetic arms since the age of four. She was



wearing a cosmetic appliance 6 hours a day, 5 days a week, but desired more prosthetic function. Her particular desire was to be able



to hold an open book while writing at the blackboard.

#### *Examination and Evaluation*

The patient was of slight build (Fig. 17). Stump length was on the borderline of the very short below-elbow type (3 in. below the epicondyles). Forearm flexion was limited to 90 deg., and strength was also limited. There was pain on pressure at the tip of the stump and along the anterior surface; x-rays showed two bony spurs on the anterior surface of the ulna.

#### *Treatment*

The patient was first fitted with a short-below-elbow prosthesis with Hosmer PC-100 hinges, flexion range being sacrificed for simplicity. Three months later, another prosthesis was made, with outside-locking elbow hinges as commonly used with the elbow-disarticulation type of prosthesis. For greater gripping surface, the Dorrance No. 555 hook was replaced by a Dorrance No. 5X. To help relieve pressure on the stump during forearm flexion, the therapist suggested use of humeral abduction, and the patient found this technique made many activities more comfortable and less awkward.

For further relief from pressure, a polyurethane foam socket liner was made the following July. The seam coincided with a bony prominence, however, so that a new liner was necessary. At the same time, the socket was cut out to free the medial epicondyle.

When nylon cable-housing liner was installed in February 1956, the patient reported that, although it afforded great mechanical advantage, it deprived her of the "vibration feedback" on which she had previously relied for information as to her cable tension and amount of hook opening. The final modification (Fig. 18) was made in July 1956, when a chest strap was added to the harness to prevent it from slipping off the shoulder when the arm was raised in upward and backward motions. Over the period covered, the patient tried several hooks, alternating between her needs for greater gripping surface and for lighter weight. Her final choice was the Dorrance No. 5XA. In February 1957 she was provided with



Fig 17. Case 10 Patient as seen on referral.

three interchangeable socket liners for purposes of cleanliness.

This patient's desire to pass out papers to her classes was met by the technique of holding the stack of papers upright with the right hand and picking off copies with the hook.

#### *Summary*

This case indicates the experimental approach that must be adopted to meet the needs of an amputee with special physical limitations. It also suggests the use of the custom-fitted soft-socket liner when the amputee's stump configuration is too complex and painful to be made comfortable in the conventional plastic socket. The outside-locking elbow hinge provided the needed stability for this short-below-elbow amputee with limited strength.

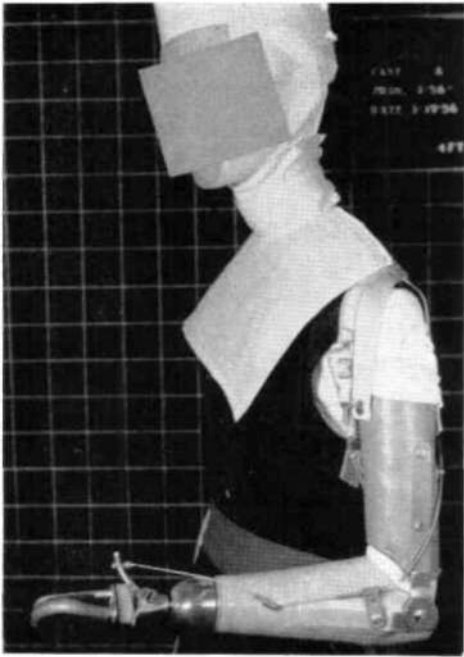


Fig 18 Case 10 Present prosthesis.

#### *Examination and Evaluation*

Examination showed a right stump extending 5.3 in. below the acromion, a left stump 3 in. below the acromion (Fig. 19). The patient was tall and broad-shouldered, with excellent mobility of the shoulder girdles. The right stump required shrinkage, however, and in September 1954 the subject underwent surgery for excision of a neuroma, a spur, and a bursa. Simultaneously, excess fat and skin were trimmed off. About six months later, a fibular bone graft into the left humeral head was performed, but the stump thus produced was not functional, it projected at an awkward angle, and it proved sensitive to socket pressure.

#### *Treatment*

Before the bone graft, the amputee was fitted bilaterally (Fig. 20). She was trained to use each arm effectively, but because of interaction of controls she had great difficulty in coordinated activities and she found that the left arm was in the way in many functions. She was

#### CASE 11, SHORT ABOVE-ELBOW/HUMERAL-NECK COMBINATION

##### *History*

Case 11, female, a 35-year-old health educator and graduate dentist, entered the program in March 1953, 11 years after amputation. With right short above-elbow and left humeral-neck stumps, she had lost her arms as a result of electrical burns in a sailing accident. Before her marriage, she was self-supporting as a teacher and lecturer. After marriage, she was an active housewife and mother of two small sons. She had been fitted with bilateral prostheses of modern type in 1947. Her second and third prostheses were for the above-elbow side only, and the third, fitted in November 1952, was the first to incorporate an elbow lock. The family moved from Michigan to Los Angeles so that the patient could enter the UCLA program. They remained for two and a half years, during which various combinations of prosthetic equipment were tried.



Fig. 19. Case 11. Patient as seen on referral.

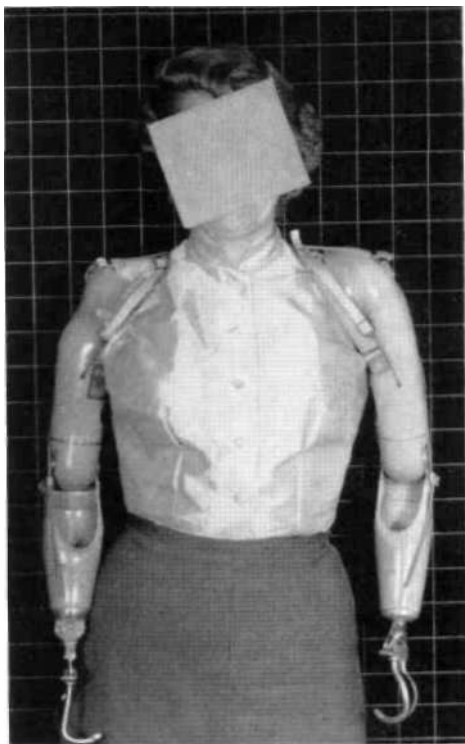
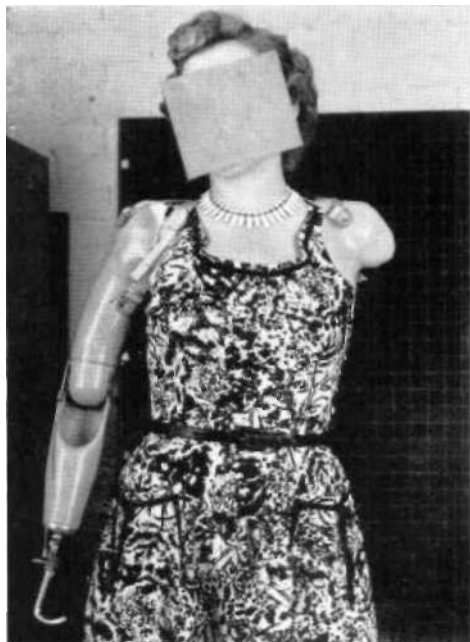


Fig. 20. Case 11. Patient as fitted bilaterally.

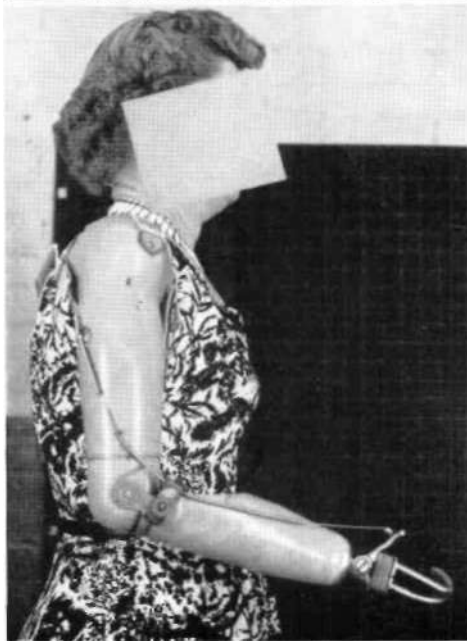
much better without cross-controlling, **but** she stated that bilateral fitting was worth some sacrifices for the sake of body balance and prevention of spasm of the neck and back muscles.



taught to drive an automobile (for the first time) using the driving ring, obtained her driver's license, and from that time continued to drive for herself and to take her turn at the wheel on long trips. She prepared the family meals and washed the dishes but did not feed herself because of limited forearm flexion. Later, with the addition of a wrist-flexion unit and with intensive training, she learned to use a fork effectively but found it an activity too fatiguing for everyday use.

In June 1955, before the grafted slump was ready for fitting, the patient was fitted with a right prosthesis, with only a shoulder reaction cap on the left side (Fig. 21). Function was

Fig. 21. Case 11. Patient as fitted unilaterally with opposite-shoulder reaction cap. Properly aligned unilateral prosthesis gave body balance without counterweighing.



The disadvantages mentioned were found to be due to subtle misalignment of the single arm and were corrected by fabrication of a unilateral prosthesis correctly aligned.

In a final attempt to achieve successful bilateral fitting, the patient suggested a perineal strap. This change in harnessing, tried in January 1956, succeeded in separating the control motions but at the cost of limiting motion and preventing the wearer from putting on her prostheses independently. After this, the subject concluded that unilateral fitting without perineal harnessing gave her the maximum of function, especially with the aluminum Dorrance 5XA hook and a slightly shortened forearm. Several months after the family moved away, the amputee sent word that her final prosthesis was the lightest and most comfortable of all and reported that she fed herself quite nicely with the swivel "spork" (combination of spoon and fork).

#### Summary

The maximum comfort and function attained by this bilateral high-level amputee was obtained with unilateral equipment. Even body balance was restored by careful alignment without further counterweighting of the opposite side. Intensive training, plus high motivation on the amputee's part, resulted in regain of many functions and the learning of some new ones (*e.g.*, driving a car). The attempt to lengthen the humeral-neck stump by a bone graft, while successful from a surgical viewpoint, was of no prosthetic value because of the angle of the resulting stump.

#### CASES AIDED BY MEDICAL AND BIOMECHANICAL TREATMENT

##### CASE 12, SHOULDER DISARTICULATION WITH WEAK PECTORAL TUNNEL

#### History

Case 12, male, a 22-year-old beekeeper, entered the program as an industry-counseling case in February 1952, 18 months after the loss of his right arm in a mortar barrage during the Korean War. The small cineplastic pectoral tunnel that had been constructed was intended to operate the elbow lock of the

shoulder-disarticulation prosthesis with which he had been fitted. But when the patient was seen at UCLA, he was operating the elbow lock manually with the opposite hand because the tunnel pin excoriated his muscle tunnel and also because operation of the elbow required more excursion than he could produce (because of stretching of the nylon control cord).

#### Examination and Evaluation

Examination showed the pectoral tunnel to be unusually narrow and superficially placed (Fig. 22). The maximum force developed during testing was 8 lb., less than one sixth the force normally available from a pectoral tunnel. Although the two shoulders were at the same height, the patient had developed a thoracic curve with compensating lumbar curve.

#### Treatment

Prescribed physical therapy included posture instruction and practice, exercises to develop the left arm and right shoulder girdle, and DeLorme progressive pulley exercises for the muscle tunnel. After 20 half hours of super-

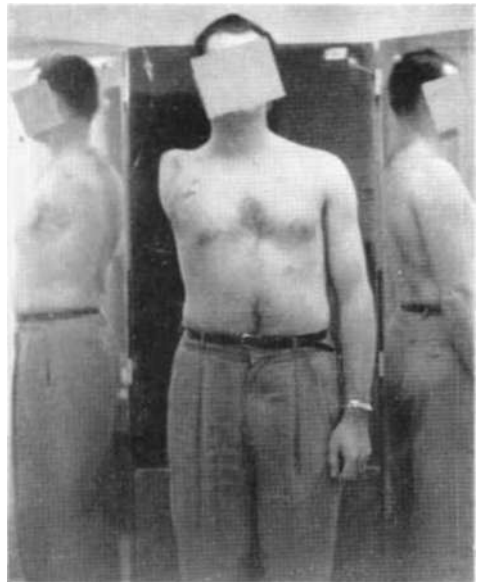


Fig. 22. Case 12. Patient as seen on referral.

vised practice and eight hours of massage and irradiation, the maximum force available from the pectoral tunnel had more than doubled to 19 lb., still about a third of the normal amount

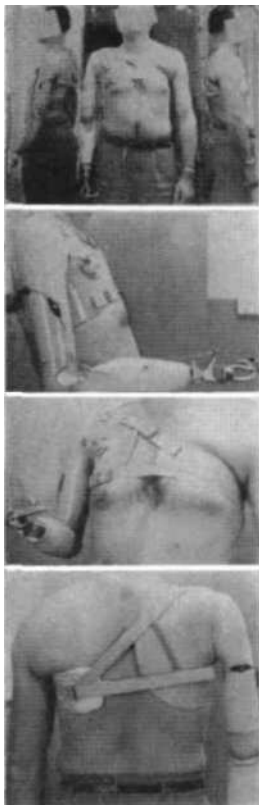


Fig. 23. Case 12. Present prosthesis. By physical therapy and suitable adaptation of equipment, a weak, superficial pectoral tunnel was reclaimed for elbow-lock operation

but more than enough to operate the prescribed elbow lock. The tremor which had been evident on contraction had disappeared.

A question-mark muscle pin was prescribed to overcome the rubbing and pressure-pain experienced with the straight muscle pin, and an adjustment turnbuckle was included. A larger shoulder cap (with circular cut-out for the muscle tunnel) provided stability, and the modern cable transmission system lessened friction and increased efficiency (Fig. 23). Instead of the hinge joint which had allowed the patient to abduct his prosthesis by bending his body to the right, the prescribed prosthesis included the new UCLA manually controlled friction-type shoulder joint,

which allowed him to flex the humeral section.

Training results cannot be reported because the subject left for his home state as soon as his new prosthesis was checked out. The physical therapist, however, reported that the patient was "quite adept without instruction."

### Summary

This amputee represents a case of a surgically inadequate pectoral tunnel which, by

physical therapy and proper adaptation of equipment, was reclaimed for elbow-lock operation.

### CASE 13, FEMALE CONGENITAL BELOW-ELBOW WITH WEAK BICEPS TUNNEL

#### History

Case 13, a 25-year-old office worker first seen in March 1951, is the only female cineplasty case in the UCLA experience. A congenital left below-elbow amputee, she had been fitted with her first prosthesis in October 1949 after biceps cineplasty and had never received any training. The patient reported that since graduation from high school she had been employed in secretarial work, bookkeeping, filing, sorting, operating "Mimeograph," running an "Addressograph," manning a PBX switchboard, and typing and that her amputation had not affected her earning power. She stated that her cineplastic Huffner prosthesis with magnesium forearm and metal hand was too heavy, fitted poorly, rubbed at the elbow joint, and caused damage to clothing. The tunnel pin was observed to slip to one side during operation, and the prosthesis rotated accordingly so as to require readjustment every 15 minutes.

#### Examination and Evaluation

Examination showed a firm stump with a full range of forearm flexion. Curvature of the bones limited extension of the forearm to about 150 deg. The muscle tunnel showed a usable excursion of approximately 2.5 in. and a rest-length force of 13 lb.

#### Treatment

Resistive exercises were prescribed to be performed at home, and tunnel exercise pins of increasing diameter up to 1/3 in. were given successively. Work on the prescribed prosthesis was started during the fifth week of exercise. Although there was a temporary gain of 1 in., tunnel excursion did not increase permanently as a result of exercise, but the force more than doubled to approximately 30 lb. While this value is markedly less than normal biceps-cineplasty tunnel force in a

## SOME ARM CASES

male amputee, lack of comparative data on female cases prevents a judgment as to whether this relative weakness of the biceps is normal for the patient's sex.

In any event, the tunnel was not adequate to operate the desired terminal device, the APRL hand. Accordingly the mechanical advantage of the lever system of an APRL hand was doubled, thereby reducing the force requirements by one half but doubling the excursion requirements. The problem of slipping of the tunnel pin was eliminated by the development of the UCLA equalizing yoke, which also increased the available force by maintaining the tunnel in a slightly prestretched position (now the standard procedure). The

new prosthesis (Fig. 24) enabled the patient to obtain 5 lb. of prehension force at 1 in. of opening, as contrasted to the 1 lb she was able to obtain with her old equipment

Unfortunately, family reasons required the patient's return to Chicago immediately after checkout, without any training. During the next two years she wore the prosthesis little. After two years, referral to Dr. Clinton L. Compere in Chicago resulted in the fitting of a new prosthesis, with proper training in its use, after which the amputee became a satisfied and consistent user. When followed up three years later, she continued to express satisfaction with her prosthesis and recommended cineplasty to other female amputees.

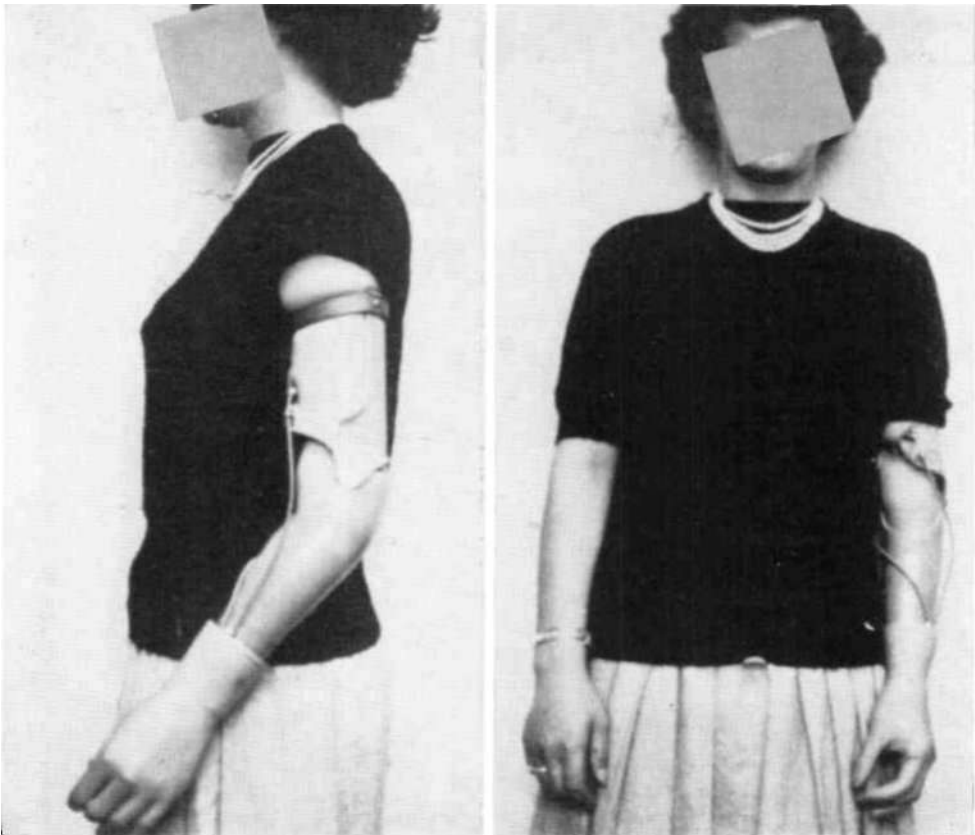


Fig 24. Case 13, Patient with new prosthesis. Physical therapy, modification of equipment, and special training made useful an otherwise surgically inadequate biceps tunnel.

### Summary

This case points up the interrelationship between considerations of surgery, physical therapy, engineering, and training. An essentially inadequate muscle tunnel (a surgical problem) was rendered useful by exercise, special individual modifications of equipment, and development of components which benefit all below-elbow biceps-cineplasty amputees. The results of physical therapy and engineering design were negated by lack of prosthetic training. When training became available, the amputee was changed from a virtual non-wearer to an enthusiastic user.

#### CASE 14, SHOULDER DISARTICULATION

### History

Case 14, male, a 27-year-old purchasing liaison representative with a paralyzed right arm, first appeared at the project in June 1952. A brachial plexus traction injury six years earlier had resulted in loss of arm control and virtual loss of forearm control.

### Examination and Evaluation

A few intrinsic muscles remained in the hand, the forearm could be flexed very slightly, and a low level of sensation remained, but all the major arm and scapular musculature had atrophied. The patient was exceedingly anxious to have the flail arm removed so that he could wear a functional prosthesis. He said that the flail arm was useless and in the way. He was experiencing marital difficulties during this period, and the clinic psychologist suspected that the desire for amputation might be an emo-

tional reaction to the home situation. The clinic strongly recommended against amputation until functional bracing had been tried. It prescribed such bracing. But this advice was not followed, and the arm was amputated.

### Treatment

In August 1952, the patient reappeared at the clinic, a month postoperative, for fitting as a shoulder-disarticulation amputee (Fig. 25). He was instructed in how to correct posture and was given shoulder exercises to do. Fitting and training in the use of a standard shoulder-disarticulation prosthesis resulted in excellent use (Fig. 26). The amputee continued to serve the schools of the Prosthetics Training Center and the UCLA research program as an amputee subject, was considered an excellent user of his prosthesis, and stated three years after amputation that he had never regretted his decision. As far as the staff can judge, his emotional difficulties appear to have been resolved by the amputation and successful prosthetic fitting.

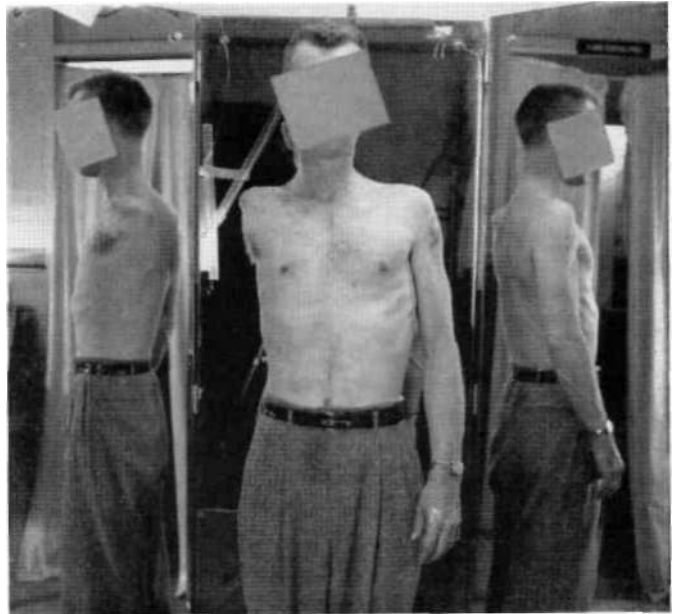


Fig. 25. Case 14. Patient as seen one month after voluntary disarticulation of a flail arm against clinic advice.

### Summary

It is difficult to prescribe the removal of an extremity that retains some sensation and some function, with a view toward replacing it with a mechanism. This patient knew what he wanted, obtained it against the advice of the clinic, and is apparently well satisfied with the results.

### CASES PRESENTING UNSOLVED PROBLEMS OF BIOMECHANICAL LIMITATION

The chief unsolved problem of biomechanical limitation in upper-extremity prosthetics is the case of the forequarter (interscapulothoracic) amputee, whose entire scapula and clavicle have been removed. In the UCLA experience to date, there has been no congenital forequarter amputee and only one caused by injury.<sup>6</sup> All the rest had undergone amputation because of malignancies. With the possible exception of one traumatic child case, which is still in question, within the knowledge of the staff no true forequarter amputee has become a successful user of a prosthesis.

<sup>6</sup> Case 1, although classified as a forequarter, is excluded from this discussion because he retained most of the clavicle, which had a good range of motion.

In forequarter cases, any functional regain is achieved at the cost of great effort because so little excursion is available by way of body control motions and because so much area must be covered by the socket for stability—virtually the entire thorax and back to the mid-line on the side of amputation plus a curved lobe that hooks around the neck onto the opposite shoulder. So far, none of our forequarter cases have considered the effort and discomfort worthwhile. Their attitudes may be influenced by a conscious or unconscious fear of stirring up malignancies, for the mortality rate among these cases has been high.

### CASE 15, FOREQUARTER

Case 15, a 30-year-old housewife, entered the project in June 1955, seven months after amputation for a recurrence of rhabdomyosarcoma. She was intelligent and anxious to cooperate. After a three-month period of training and practice in use of the prescribed prosthesis, she doubted whether the functional regain was worth the effort and discomfort. Later, word of her death reached the clinic.

### CASE 16, FOREQUARTER

Case 16, a 31-year-old housewife, was seen in July 1955, about four months after amputation for a malignant synovial tumor. After prescription, fitting, and instruction, she was unable to operate the prosthesis enough to check it out for mechanical functioning. Because she was able to manage adequately with one hand all of her activities except sewing and knitting, and because she found the prosthesis hot, heavy, uncomfortable, and difficult to operate, she withdrew from the program and was referred to a maker of cosmetic restorations.

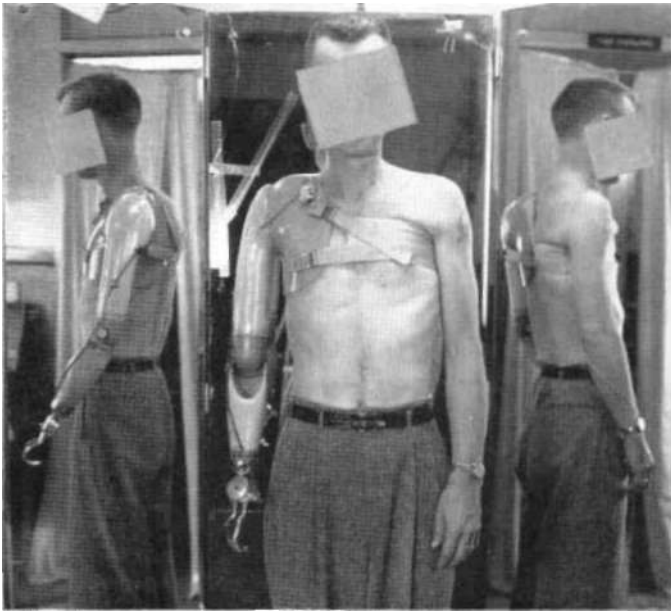


Fig 26 Case 14. Successful shoulder disarticulation prosthesis.



## CASE 17, CONGENITAL QUADRILATERAL

*History*

Case 17, male, a 27-year-old congenital quadrilateral amputee 29 in. tall, entered the clinic early in 1951. Born without legs (bilateral hip disarticulations), he managed locomotion at home by hopping on his pelvic musculature. Away from home he was dependent on others for transportation; he could maneuver his wheelchair into the street but not across curbs. On the right was a below-elbow stump, while the left stump was above-elbow (Fig. 27).

The patient operated a 24-hour telephone-answering service at home with the help of his wife and one part-time employee. He often worked the switchboard for eight hours without relief, writing down messages by means of a pencil inserted in a leather band worn on the below-elbow stump. He also ran a baby-sitting agency and from time to time recruited and managed telephone sales crews for special sales campaigns. His regular working day was 10 hours. His businesses were growing, but he felt handicapped by his inability to visit prospective clients. He had been fitted with

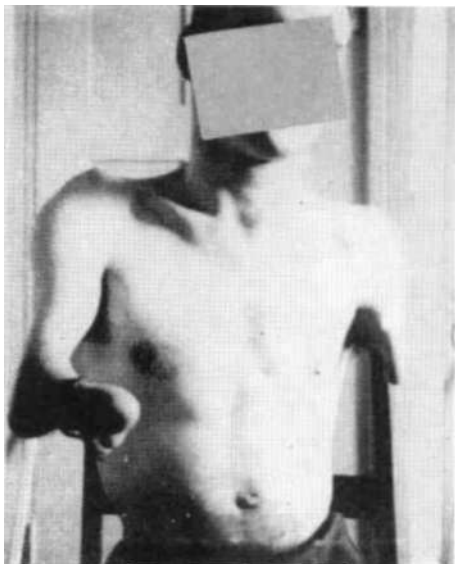


Fig. 27 Case 17. Upper extremities of patient as seen on referral.

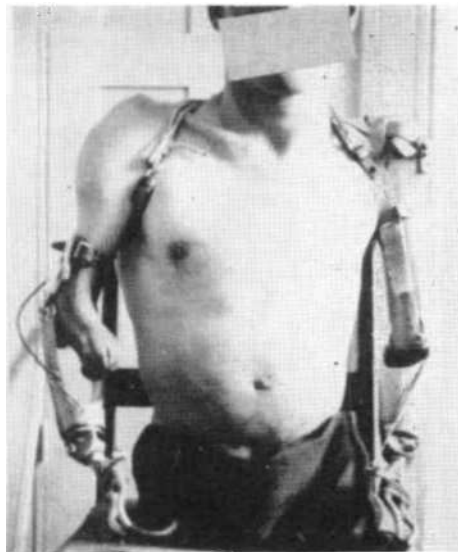


Fig 28. Case 17 Prostheses provided Right prosthesis is cut out to accommodate characteristics of the below-elbow stump.

artificial arms at the age of 21, but he found them in the way for the quick motions necessary in his work. Except for a wooden ladder used to reach chairs, toilets, and so on, he took care of all his vocational, avocational, and personal-hygiene activities without the use of prostheses or special facilities.

*Examination and Evaluation*

Examination showed the above-elbow stump to be limited to 70 deg. of abduction, 95 deg. of flexion, and 5 deg. of extension, with no rotation at all. The arm on the below-elbow side was limited to 80 deg. of abduction, 120 deg. of flexion, 15 deg. of extension, and 10 deg. of rotation, the elbow being fused at approximately 90 deg. The patient had never had physical therapy, and none was prescribed because his strength was satisfactory and it was felt that, in view of the fact that he was a congenital amputee, the muscles could not be stretched without severe pain.

*Treatment*

The new prostheses fitted to the patient (Fig. 28) were evaluated by him and shown by

test to be excellent in relation to his old pair. But 20 hours of training led to the conclusion that interference with old habit patterns was insurmountable, especially because the subject wore the prostheses only six hours a week and was too busy to practice. At no time did his performance of test activities with the prostheses approach his performance with bare stumps. But he found the limbs useful for social occasions. His evaluation remained the same after a year of wearing the prostheses six hours a week.

One benefit the patient received from his participation in the UCLA program was the design of a special pigeonhole device which served his filing needs far better than did the notebook system he had been employing. A specially designed prosthesis holder enabled him to put his arms on without help.

#### Summary

In the case of an amputee who combines severe limitations (by ordinary standards) with well-established habit patterns that enable him to function quickly and efficiently without prostheses, training in the use of prostheses may be futile. This amputee, who in his vocation operated far better without prostheses than with, nevertheless appreciated prostheses for wear on social occasions.

#### CASES PRESENTING UNSOLVED MEDICAL PROBLEMS

##### CASE 18, FOREQUARTER

Case 18, a 68-year-old housewife, was seen in November 1953, seven months after her right forequarter amputation. The medical report obtained from her physician indicated that she had undergone a simple mastectomy of the right breast in October 1944, x-ray-therapy of the axillary areas in 1945 and 1947, and a left radical mastectomy for metastasis to the contralateral breast and axilla in 1950. Paralysis of the right arm had developed in 1952, and forequarter amputation was performed in March 1953.

In view of the advanced age and history of malignancy, the clinic agreed that a functional prosthesis was contraindicated. A soft cosmetic shoulder cap was prescribed to meet the

amputee's need for body balance and symmetrical appearance.

##### CASE 19, SHOULDER DISARTICULATION/SHORT ABOVE-ELBOW COMBINATIONS

#### History

Case 19, male, a 60-year-old railroad pensioner, entered the clinic in November 1951. Ten years earlier, he had been run over by a boxcar. Shoulder disarticulation of the right arm, amputation of the left arm about 3 in. below the acromion, and application of a tibial graft to the above-elbow stump had followed (Fig. 29). The stumps proved too sensitive to

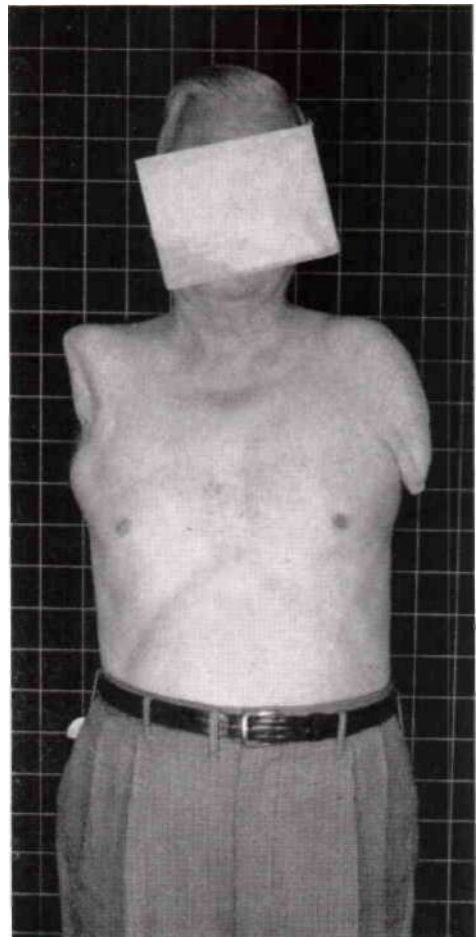


Fig. 29 Case 19 Patient as seen on referral.

be fitted with prostheses, and the patient had been unemployed ever since, living on his railroad pension and dependent on others for his daily needs. Throughout that time, he had had intense sensation of phantom hands, with the "fingers" painfully pinched together and somewhat overlapped.

### *Examination and Evaluation*

In May 1952, the patient underwent with good results a partial resection of the pectoralis major tendon for the purpose of lengthening the above-elbow stump. At the same time, three supposed neuromata, which turned out to be tender masses of scar tissue, were removed from the most sensitive areas. The operation was of some help, but the pain remained in the scar areas and in the distal 3 in. of the anterior aspect of the bone graft and prevented the amputee from sleeping and from wearing the prosthesis prescribed and fitted to him.

Later in 1952, the patient was hospitalized for two weeks at the Pain Clinic at the University of California Medical Center in San Francisco. Under relatively mild sedation of phenobarbital and Seconal, he slept well and required only a few grains of codeine. Indefinite continuation of the mild sedation was recommended. The phantom pain disappeared after injections of sodium amyral, but the tender areas of the stump were not eliminated. Efoaine was ineffective, and treatment with a strong vibrator was not well tolerated. The intraspinal injection of sodium chloride solution as a counterirritant caused the trigger points to disappear only temporarily. Finally, in view of the patient's improved frame of mind, it was decided that minor pressure, such as would be exerted by the prosthesis, might be tolerated.

### *Treatment*

Although pairs of prostheses of modern design were prescribed and fitted to the patient during the schools at the Prosthetics Training Center, his stump pain remained an unsolved problem. In April 1956, when the subject was 65 years of age, intensive research began on the case. The decision was made to fit the shoulder-

disarticulation side only and to make a reaction-cap socket for the above-elbow side rather than to make further attempts at bilateral fitting. Sectional plates were modified to form the UCLA manually controlled, friction-type shoulder joint and skewed 20 deg. to the sagittal plane so as to enable passive flexion and abduction of the humeral segment. The arm-rotation turntable was modified by addition of a Belleville washer for finer adjustment of tension, and a cable-excursion multiplier was added. The use of nylon cable-housing liners, which had been adopted as standard procedure at UCLA, greatly decreased cable friction and increased smoothness.

Mechanically, the prosthesis enabled the patient to perform simple grooming and eating manipulations for himself. But pain under the left reaction cap intensified with the use of the prosthesis. Investigation showed that this problem was due partly to inadequate training. In addition to left shoulder flexion to stabilize the reaction cap, the amputee was employing flexion of the above-elbow stump. Although training in the correct motion was given, it was not expected that the patient would overcome his faulty habit patterns, and a mechanical solution was sought.

After several unsuccessful trials, a reaction cap was made from a wrap taken with the humeral segment snug against the body but with the distal end of the stump projecting slightly (Fig. 30). This expedient transferred the undesirable pressure to the anterior portion of the stump. To alleviate the pressure there, a cutout was made and margined with foam-rubber padding.

Staff evaluation was that, while the mechanical results were very good, the potential functional regain would be somewhat limited by the patient's outlook and by his habits of dependence. It should be mentioned, perhaps, that this amputee supplemented his meager pension by earnings in part-time employment at a men's club. With his prosthesis he carried a specially built tray for holding several drinks.

### *Summary*

Here was a very complicated case in which intense phantom pain of 11 years' standing was eliminated but in which stump pain per-

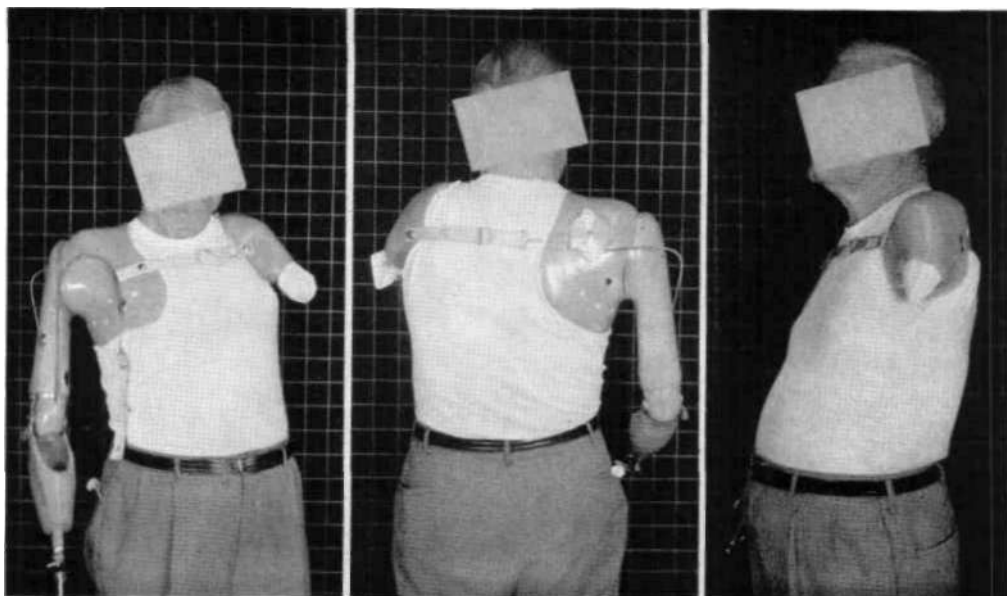


Fig. 30. Case 19. Patient as fitted unilaterally with specially designed opposite-shoulder reaction cap.

sisted. Mechanical problems were solved by the UCLA unilateral equipment for bilateral shoulder cases, but the amputee's habits and motivations limited full prosthetic effectiveness. At least this patient was enabled to earn some money for the first time in 15 years.

#### CASE 20, SHOULDER DISARTICULATION

##### *History*

Case 20, male, a 26-year-old Polish-born Israeli plumber, well driller, and, after amputation, clerk, entered the project in August 1951. During the Arab-Israeli War of 1948, when a jeep in which he was riding struck a land mine, he had suffered a crush injury to the left arm, which resulted in shoulder disarticulation. Afterward, the patient experienced intense and continuing phantom pain in the missing hand, in the distal third of the phantom forearm, and occasionally in the entire phantom arm. Usually the phantom hand was localized in the normal position, but sometimes it was perceived as telescoped to the phantom elbow.

Paravertebral punctures had been employed, but the relief lasted only until the anesthetic

wore off. Sympathectomy of the thoracic chain had no effect, nor did eight electric-shock treatments administered by a psychiatrist. The patient was then sent by the Israeli Government to California for treatment.

##### *Examination and Evaluation*

Examination showed marked scoliosis (the left shoulder carried 1.5 in. higher than the right), an extreme anterior protrusion of the thorax, and lateral curvature of the spine (Fig. 31). The patient had never received physical therapy, and the left shoulder girdle was atrophied.

##### *Treatment*

Exercises to correct scoliosis and to increase range of motion were prescribed, the Sayre head sling was used to stretch tight neck musculature, and self-corrective mirror instruction in posture was given. When last seen in May 1952, the subject was still performing his exercises, and his posture and shoulder mobility had improved markedly.

Case 20 was fitted with a standard shoulder-disarticulation prosthesis (Fig. 32), which he

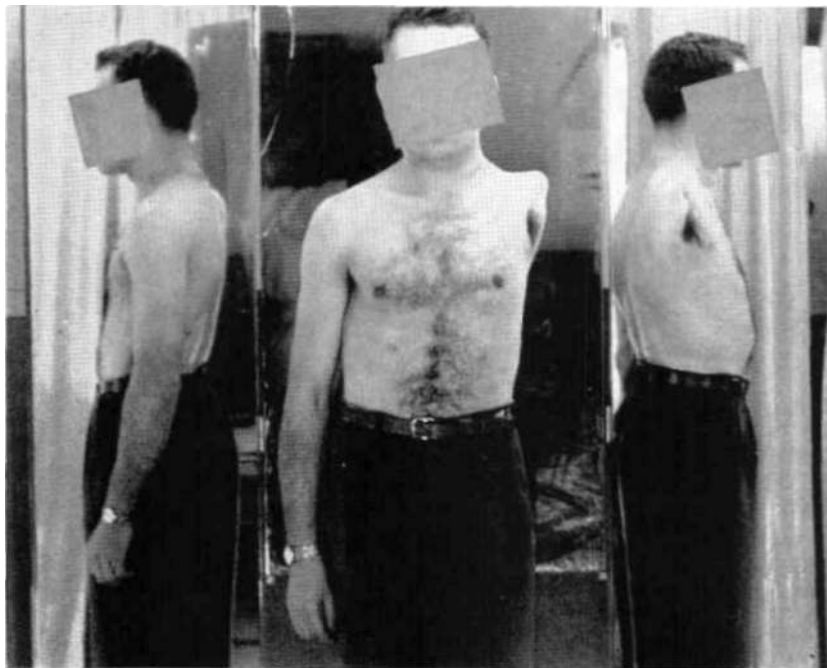


Fig. 31. Case 20. Patient as seen on referral.

valued highly and which he wore all of his waking hours despite the discomfort of a perineal strap, which, because of unhealed operative wounds, he preferred to an opposite-shoulder loop. But his phantom pain continued to be disabling. Two stellate-ganglion blocks were attempted but failed. In October 1951, a neuroma of the left brachial plexus was removed, and a marked fibrotic scalenus anticus muscle was cut and allowed to retract. The patient was pain-free for 10 days during the next month, but thereafter the pain returned with even greater intensity. In December 1951, therefore, he was referred to the Pain Clinic at the University of California Medical School in San Francisco.

On examination, the staff of the Pain Clinic found a strip of complete anesthesia below the left clavicle (thought to be related to the scalenectomy) and generally poor sensation on the left side of the entire body, with reduction of urinary and sexual function. These deficiencies were gradually eliminated during the weeks of the patient's treatment at the Pain

Clinic. But no relief whatever of the phantom pain was obtained by counterirritant injection of sodium chloride into the intraspinal ligaments, by injection of sodium amyral into the trigger point in the neck, by vibration treatment, or by intravenous injection of pontocaine. The amputee was enabled to sleep, however, by the use of phenobarbital, plus almost daily intravenous injections of 10-percent sodium amyral to the point of slight drowsiness. The latter did not eliminate the pain but seemed to relax the phantom hand and lower the pain to tolerable levels. On the clinic's recommendation, these injections were continued, but within a few weeks the patient proved refractory to the sodium amyral. When he left Los Angeles in May 1952, he was resigned to living with his phantom pain and hoped only to keep busy enough to keep his mind from it.

#### *Summary*

This case was a success prosthetically but a complete failure from the standpoint of re-

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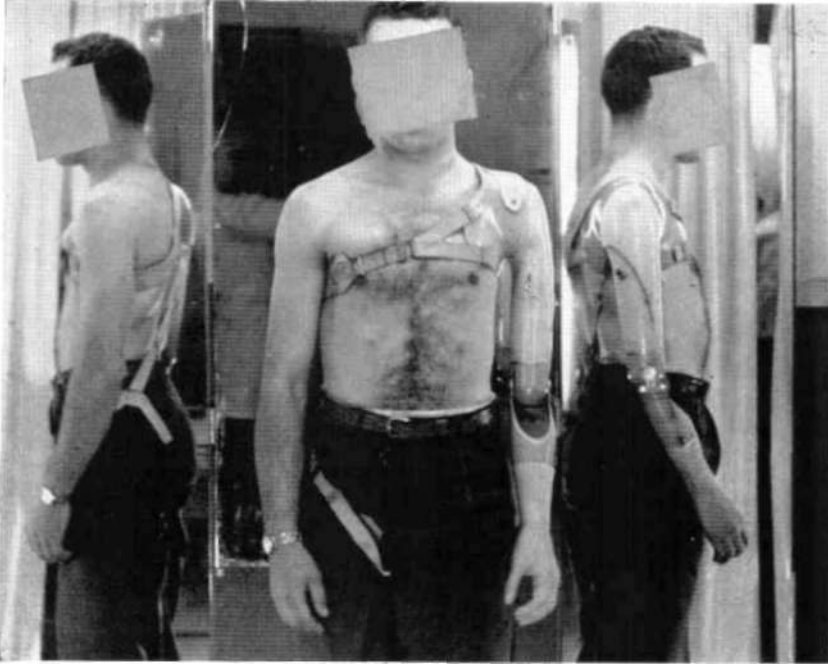


Fig. 32 Case 20 Standard shoulder-disarticulation prosthesis supplied to patient,

lieving the amputee's phantom pain. Neurosurgery, drug therapy, and psychiatry were equally fruitless; the first resulted only in the additional pain of multiple operative wounds.

#### CASKS PRESENTING UNSOLVED PSYCHOSOCIAL PROBLEMS<sup>7</sup>

##### CASE 21, VERY SHORT BELOW-ELBOW

###### *History*

Case 21, male, age 52, entered the clinic in October 1951, five years after the explosion of an enemy mine resulted in the very short below-elbow amputation of his right arm. A revision had been performed five months after the amputation. Before his wartime service as a captain and major, the patient had worked for a railroad for 20 years, his civilian occupation

<sup>7</sup> Two of the three problem cases included in this section are clear-cut. That Case 21 is placed in the category of psychosocial problems represents a judgment on the part of the staff and of officials of the Veterans Administration; from Case 21's viewpoint, his problem related to inadequate fitting and alignment.

being given as trainmaster. Since his amputation, he had been unemployed much of the time, living on rental income and Federal pension benefits.

While in an Army hospital in 1946, the patient had been fitted with a modern prosthesis with polycentric hinges. He was wearing it five years later and at that time stated that he wore it 12 hours a day. But he was not satisfied with the limb. During the four years between 1947 and the time of the patient's appearance at the clinic, the VA paid for three additional prostheses and also for an extensive series of modifications. Finally, in January 1951, convinced that the amputee was not wearing any prosthesis regularly, and under pressure from him for a satisfactory prosthesis, the VA representative referred him to the UCLA Case Study.

###### *Examination and Evaluation*

Examination showed a stump 3-5/8 in. long measured from the medial epicondyle to the end (Fig. 33), the distal area of the stump being

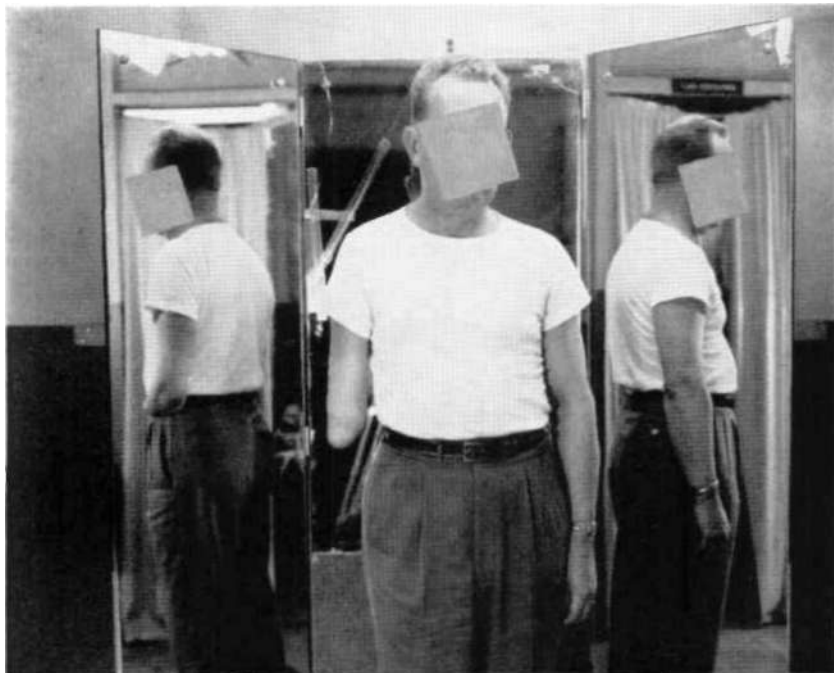


Fig. 33. Case 21. Patient as seen on referral.

sensitive to pressure. The amputee had received physical and occupational therapy and prosthesis-use training, all of which he evaluated as excellent. Strength and range of motion were good, and no exercises were prescribed.

#### *Treatment*

After the patient's first UCLA prosthesis (Fig. 34) had been fitted, revised several times, and worn for a short period, and after the amputee had complained of the same pressure pain as before, a special study of his forearm flexion was made. Thereafter the clinic prescribed a prosthesis with flexible insert hinges, thus sacrificing flexion step-up in order to provide a comfortable fit. To obtain a useful range of flexion, the socket was so formed and the hinges so aligned as to place the forearm in 20 deg. of initial flexion. After wearing the second arm a short time, the amputee rejected it with the complaint that the outer wall of the socket was bent laterally about 15 deg. from the normal plane of flexion, thus preventing

him from using it in driving a car. He complained also that the prosthesis lacked a stop to prevent him from hurting his stump on full extension. The staff was unable to relate these complaints to any objective measurements, and no stump soreness or discoloration was found.

Investigation of the patient's Army and VA records revealed no personality disturbance that might explain a hypercritical attitude toward prostheses. The UCLA staff psychologist examined all of the amputee's previous prostheses (which, except for the first, were in nearly new condition) and obtained the patient's relative ranking of each. It was found that the amputee's rankings were consistently related to the degree of misalignment between the epicondylar axis and the elbow axis of the prosthesis.

When, in 1952, the prosthesis last prescribed was fitted, the relationship of the prosthetic elbow center to the epicondylar axis was measured as a function of forearm flexion, and the

## SOME ARM CASES

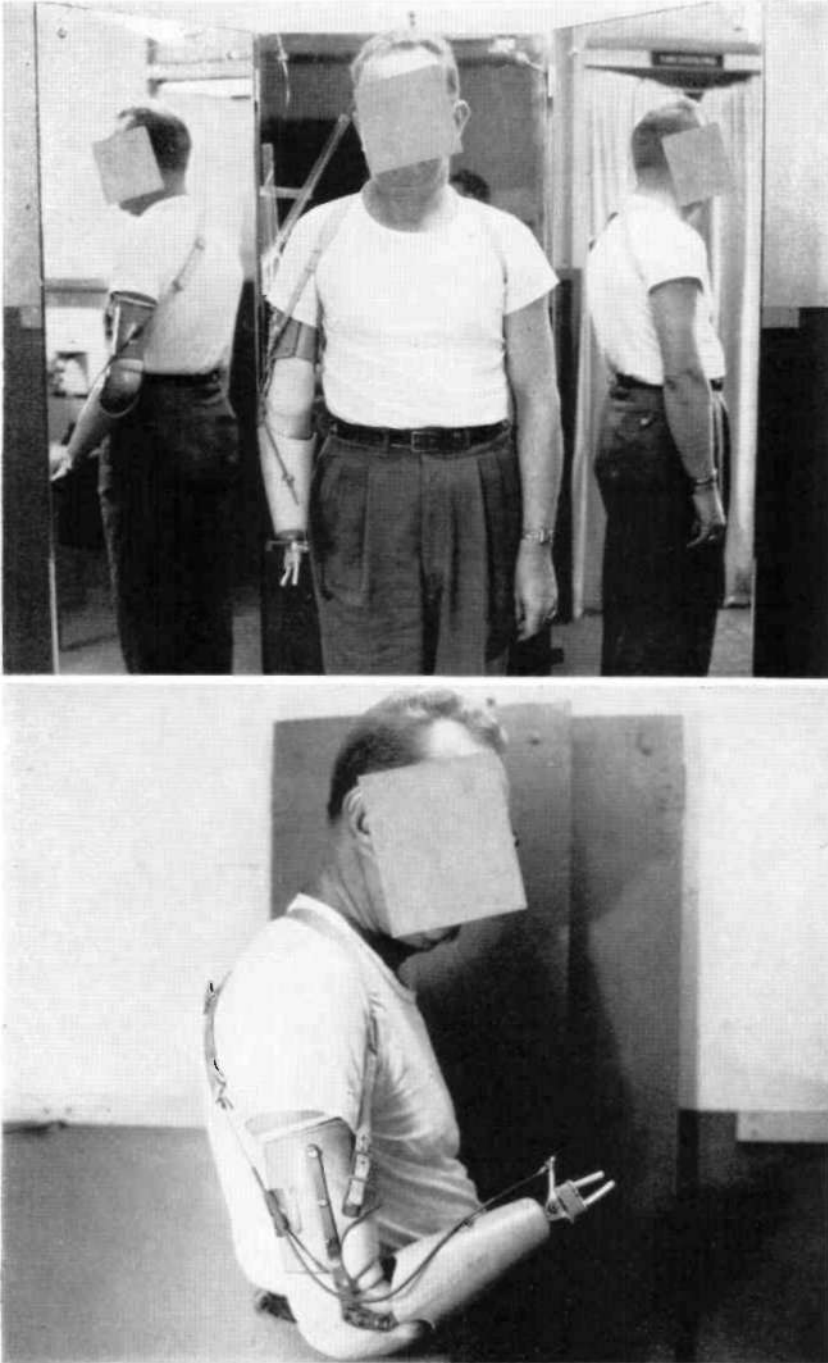


Fig. 34. Case 21 First prosthesis provided at UCLA, using split socket and variable-ratio step-up hinges to increase forearm flexion. Because the patient complained of pressure pain upon flexion, the step-up hinges were later abandoned in favor of flexible insert hinges.



greatest discrepancy was found to be 1 in. with the forearm fully flexed. It was explained that this degree of misalignment was within the unavoidable error of the best techniques then available. As before, the prosthesis passed all checkout tests, was taken home, and returned with little evidence of wear. The amputee complained of the same pressure pain as before. Since the staff's resources had been exhausted, the case was closed. The staff psychologist was of the opinion that the patient was unconsciously rejecting a satisfactory prosthesis to retain a disabled state that absolved him from the necessity of working at a lower level of prestige and authority than characterized his preamputation history as safety engineer, trainmaster, and field officer.

#### *Summary*

Case 21 was a frustrating case for everybody concerned. It raised many questions and provided no answers.

#### CASE 22, BELOW-ELBOW WITH BICEPS CINEPLASTY

##### *History*

Case 22, male, a 30-year-old unemployed right below-elbow amputee, appeared before the cooperating VA hospital clinic in October 1954 requesting a cineplasty operation, although he had never had personal contact with any cineplasty case. His amputation three years earlier had resulted from an automobile accident, and there had been a reamputation six weeks later. The patient had never had a prosthesis and stated that he could not get a job without one. His previous employment record was poor.

##### *Examination and Evaluation*

Examination showed a man 6 ft. 2-1/2 in. tall, weighing 155 lb., with a normal range of motion and no conditions requiring medical or physical therapy (Fig. 35).

##### *Treatment*

The patient was referred to the Prosthetics Training Center to observe cineplasty wearers. There he served as an amputee subject, was fitted satisfactorily with a conventional below-

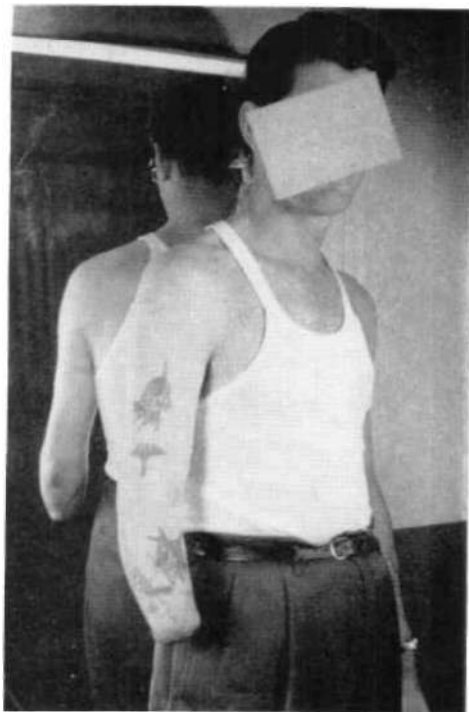


Fig. 35. Case 22. Patient as seen on referral,

elbow prosthesis (Fig. 36), and impressed the staff favorably by his cooperative attitude. He returned to the VA hospital with even greater enthusiasm for cineplasty, and with some misgivings a biceps tunnel was prescribed and constructed in November 1954. Postoperative convalescence was uneventful but was marked by a multitude of vague complaints with no assignable physical foundation, a demand for attention, and unwillingness to leave the hospital until forced to do so. The amputee returned to the next prosthetics course, where a cineplasty prosthesis was fabricated about seven weeks postoperative. During training, it became evident that his attention span was poor; disassociation of elbow flexion from biceps contraction was slow, and he was an inept student.

About three months after his operation, while in the laboratory, the subject induced an episode of hyperventilation during which he seemed to be choking. He was removed by ambulance to the Los Angeles County General

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Hospital, where a tracheotomy was performed, but he signed out on discovering that he was scheduled for a laryngoscopy. On his return, he informed all the laboratory staff that his tracheotomy was necessitated by cancer of the larynx. Thereafter he delighted in wheezing through his tracheotomy tube on every possible occasion until the tube was removed.

It had previously been noted that the patient delighted in wearing short-sleeved shirts and exposing his muscle tunnel to everyone with whom he came in contact. He also revealed himself as an inveterate fabricator, and psychiatric consultation disclosed him to be a dependent and insecure individual. About two months after the hyperventilation episode, he was admitted to the hospital with chest pain and unexplained fever. The hyperventilation was noted again in the hospital. His "fever" was explained when he was observed putting the thermometer on the radiator. Upon discharge, the patient disappeared.



Fig. 36. Case 22. Conventional below-elbow prosthesis first fitted to patient.

### Summary

The results of prosthetic fitting, which were in the main successful, were largely negated in this case by the extreme maladjustment of the amputee. Again the principle of careful selection in a cineplasty program was emphatically illustrated.

### CASK 23. BILATERAL BELOW-ELBOW

#### History

Case 23, male, an unemployed 31-year-old bilateral below-elbow amputee, was referred by the California State Department of Rehabilitation in October 1951. He had lost his hands in August 1949 in a punch-press accident while learning to be a tool and die maker. He gave his previous work as coil-spring winder and crane operator. He had been fitted with below-elbow rotation prostheses (APRL-Sierra) on both sides but with no wrist-flexion device. He reported that he wore his prostheses 15 hours a day but that he found them inadequate for all but the simplest personal tasks and could not return to the trade he had been learning. He was anxious to dress himself, eat independently, drive a car, and so on.

#### Examination and Evaluation

Examination showed no postural abnormalities. The patient was well muscled and had a good range of motion. His right stump was 84 percent of estimated forearm length, his left 73 percent (Fig. 37).

#### Treatment

Although the length of the left forearm placed the patient in the medium-below-elbow class, long-below-elbow prostheses were prescribed for both arms because both retained forearm rotation (160 deg. in the right, 110 deg. in the left). Wrist-flexion units and Dorrance No. 5 hooks with rubber-lined fingers were prescribed for both prostheses (Fig. 38). In mechanical tests, the new prostheses and the original pair made approximately the same scores.

Although the amputee had had no prosthetic-use training and was inadequate in the use of his original prostheses, after about four hours of training in the use of the prescribed

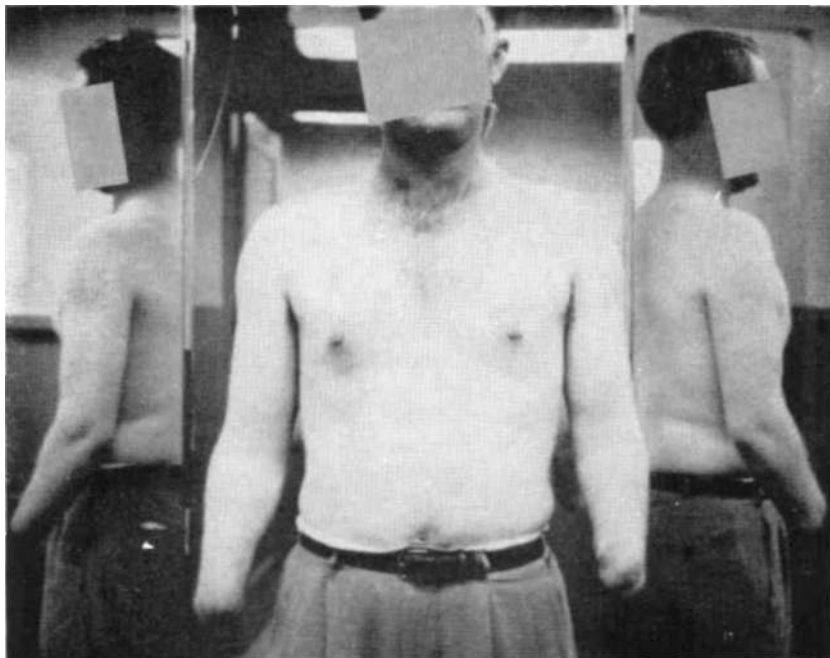


Fig. 37 Case 23 Patient as seen on referral.

prostheses he was judged proficient. His level of performance with either side was regarded by the trainer as excellent.

Because the patient desired independence, much practice was given in opening doors and similar activities. When training was completed in October 1951, the subject stated that he felt independent and that he was going to move out of his parents' home and seek employment. After two weeks, he reported that he was totally independent and required no help in his everyday activities. He gave much of the credit to the wrist-flexion units, with which he accomplished many activities formerly impossible for him.

The day after the patient's discharge from the project in November, his picture was in the local newspapers under such headlines as **NAB HANDLESS BANDIT IN MARKET ROBBERY**. The stories revealed that he had had a brief notoriety as the "Paper-Bag Bandit" in 1945, when a series of seven bank robberies in four months netted him approximately \$10,000 and a 5-year-to-life term at Folsom Prison. There he

had lost his hands in a license-plate pressing machine. He had been on parole when referred to the clinic. To the humiliation of the UCLA amputee trainer, the subject was captured in the market parking lot as he struggled to open the door of the stolen stale vehicle he was using as his getaway car. The clinic staff which had discharged the patient with new prostheses one day earlier was surprised also to read his statement that he had turned to robbery because he "needed money fast to replace a broken pull wire and a couple of rubber tips."

#### *Summary*

Does rehabilitation mean returning the patient to his former occupational status?

#### CONCLUSION

From the case histories given here, certain facts emerge. A primary feature is the individual nature of the problem, in which rules are only general guides. The amount of functional regain cannot always be predicted. Compare, for example, the results obtained with

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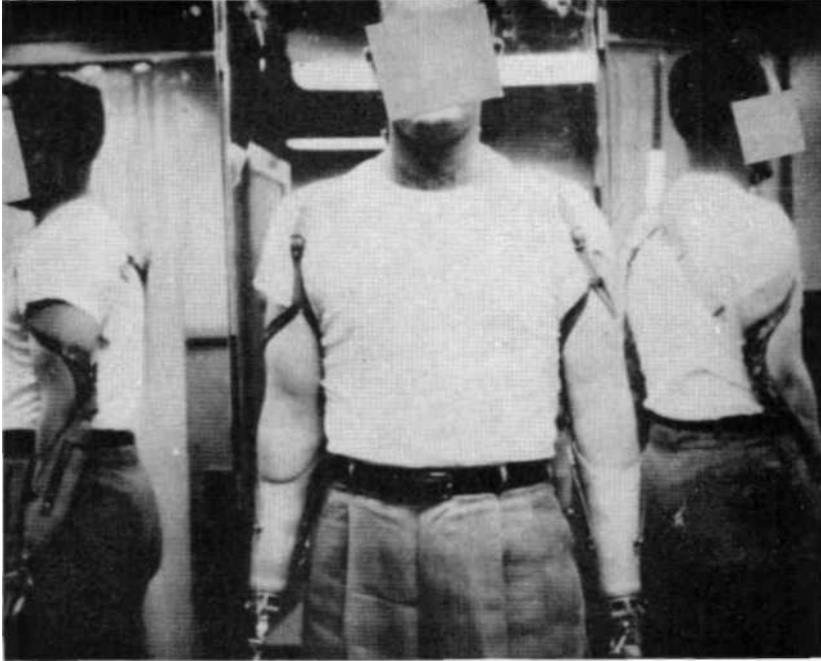


Fig. 38. Case 23. Bilateral prostheses as fitted at UCLA.

three of the forequarter amputees (Cases 1, 15, and 16). Even in the abbreviated histories here, and far more in the actual case records, it is clear that the fitting of an arm amputee is a custom job usually involving a certain amount of experimentation and successive approximation before satisfaction is achieved.

It is now obvious that by far the majority of arm amputees can be satisfactorily and usefully fitted with prostheses. The exceptions, as of this writing, are those amputees with long arm stumps who have so much residual function that they may not feel the need for mechanical assistance and, at the other extreme, amputees who are so handicapped that it is difficult to provide enough stability and body control motions. During the course of the UCLA study thus far, the fitting of the shoulder amputee was raised from a marginal to a truly worthwhile procedure, as was the fitting of the bilateral high-level amputee. The forequarter amputee remains, in most cases, an unsolved problem.

At this time, it appears that unilateral fitting

of the bilateral high-level amputee (shoulder and very short above-elbow types) provides greater function than does bilateral fitting. A bilateral shoulder amputee can achieve considerable independence if equipped with the UCLA manually controlled, friction-type shoulder joint, cable-excursion multiplier, arm-rotation turntable modified for constant tension by addition of a Belleville washer, and swaged cable fittings with nylon cable-housing liner. The latter two apply to all arm amputees.

Some cases of phantom pain are refractory to every therapeutic measure. Yet painful pressure-sensitive areas on the stump may often be dealt with by careful fitting techniques. In general, below-elbow, biceps-cineplasty cases were successful while other types involving cineplasty were not. The stories behind the development of now-standard armamentarium components are drawn from the UCLA experience, and such background is therefore necessarily given only for UCLA-developed items and not for the valuable developments of other agencies such as Northrop

Aircraft, the Army Prosthetics Research Laboratory, and the commercial limb industry.

#### ACKNOWLEDGMENTS

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