A POWERED CABLE DRIVE FOR PROSTHETIC-ORTHOTIC SYSTEMS

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Summary

A versatile "cable-puller" which can be used to activate the major joints and terminal devices of a variety of upper limb appliances had been developed and is under continuing evaluation in patients with a wide range of amputation levels.

A single low speed, direct drive, torque motor is used with minimal gearing to provide high forces and velocities with minimum weight and space. The system has been used with all components mounted inside the prostheses of elbow and shoulder disarticulation amputees and with the components belt-mounted on peripheral level amputees. The belt-mount has also been used for for elbow paralysis.

For easy operation by the patient, the system is designed for sequential joint action using one non proportional control-input signal to unlock each joint and one proportional control-input signal to move all unlocked joints. The proportional control-input signal is obtained from amputees with different types of stumps by either of two unique types of signal acquisition units. One is a single site non-adherent myoelectric sensor. The other is a skin scar motion detector. The latter has proved especially useful with acquired shoulder disarticulations. The former has served well with all other amputational levels.

Introduction

For many years the force to move the joints of upper limb prostheses has been obtained by harnessing the shoulders. Usually this force is transmitted by a single cable. The cable is routed to cause the prosthesis joint of terminal device to move in one direction while an elastic, a spring, or gravity are used to cause motion in the other. The cable can be routed to move more than one joint. Isolation of motion at a specific joint can be achieved by locking the others. The joints can be moved in any sequence, but not simultaneously. The torque applied to any joint is proportional to the force applied to the cable. If this force can be delivered by a motor of suitable physical characteristics, the shoulders can be relieved both of the effort of imparting force to the cable and of the discomfort of the associated harness. For comparable function there must also be an appropriate control mechanism for the motor.

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Equipment Arrangement

In this study External Power and Control units (EXPACS) were fabricated and attached to otherwise conventional cable-driven prostheses on a series of amputees with a wide range of amputational levels. Each EXPAC consists of a motor and an electronic control module which are currently packaged as a single small unit. The control signal sensor and battery pack are packaged as a separate unit. The EXPACS are arranged in two basically different equipment configurations, an Above elbow (A) configuration, Figure 1, and a Below elbow (B) configuration, Figure 2. Type A is characterized by motor location within the prosthesis. Type B is characterized by motor location remote from the prosthesis, e.g. on the amputee's belt. Whereas the A configuration is appropriate for amputations through or preferably proximal to the elbow joint, Type B is appropriate for amputations through or distal to the elbow joint; however, Type B can be used for amputations at any level as well as for powered braces. Both configurations can be connected to provide either terminal device function or elbow flexion or both. A single Type A unit has been connected to provide both of these functions on both sides of a bilateral upper limb amputee as well as wrist rotation on one side. Presumably it can also be connected to provide shoulder flexion.

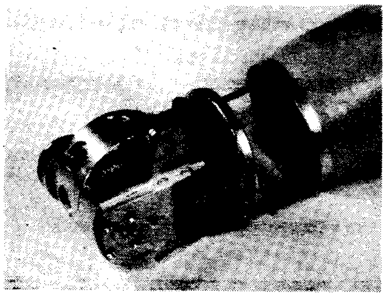

Fig. 1. **EXPAC Type A elbow mounted motor/control unit**

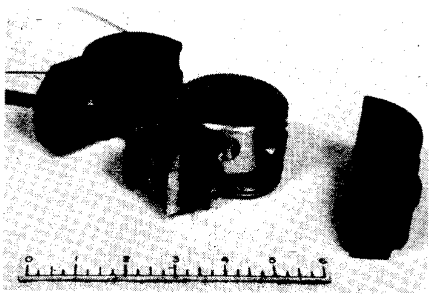

Fig. 2. **EXPAC Type B belt mounted motor/control unit**

Sensors

The primary control input for the power unit is received either by a single site myoelectric sensor /1/ or by a skin displacement sensor. The latter has been found especially useful in Shoulder Disarticulation prostheses. It may have additional usefulness in other situations characterized by an inadequate myoelectric signal. The myoelectric sensor is attached to the wall of the prosthesis and is not separately applied to the stump.

The skin displacement sensor has not been previously described. It was originally developed to utilize the motion of the surgical scar commonly found following scapulo-humeral amputation. It has since been found useful with congential scapulo-humeral amputees, and it may have other applications. This transducer utilizes a movable magnet and stationary semiconductor flux sensitive elements. Approximately three eights inch of motion of the small string emerging from the front of the shoulder of the prosthesis controls the arm and terminal device. When the prosthesis is applied, the string is attached to a button which is separately attached to the skin with double sided adhesive tape (Fig. 3).

Motor

The motors used in these EXPACS are direct drive DC torque motors. They provide high torque when stalled and when operating at slow speeds. Their high mechanical power output capability makes possible fast actuation (less than 1 second) at high levels (up to 13.6 kg cable force) with a simple two stage gear reduction system. With this low gear ratio, the system is so quiet that it can scarcely be heard. The power units have no clutches, brakes, or mechanical stops, and are very reliable. There have been no malfunctions or mechanical failures of any of the motor drive units. They can be stalled as full power with no internal damage of any kind. Hence no current limiting circuits are required, and battery power consumption is minimized.

Electronic Control Unit

The control signal, whether originating from myoelectric activity or skin motion, is amplified to provide an appropriate command signal to the power servo. In order to minimize electrical power consumption, particularly when the control voltage is not commanding the motor to pull the control cable, a pulse-width modulation system is used to control the motor output torque. The output of a 25.0 kHz triangle wave generator and the output of the servo-amplifier stage are combined to provide a pulse-width modulated signal which controls motor current. The motor is driven in one direction only. If the error signal (which corresponds to the difference between control signal amplitude and the position of the cable drive pulley) is small, motor current flows for a small part of the duration of each cycle of the 25.0 kHz wave form. The "on" time of the pulse is a function of the magnitude of the error signal. By operating the output transistor in the switching mode, relatively little power is dissipated in the electronics package. When the electrodes are not sensing a myoelectric signal or when the flux sensitive elements of the skin motion sensor are not detecting any skin displacement, stand-by power consumption of the servo and sensor electronics is less than 300 milliwatts. No mechanical switches or special power cut-off relays or circuit are required to switch from "standby" to "operate" condition.

A potentiometer in the power pack assembly provides a position signal to the servo amplifier. The feedback shaping provides high gain at low frequencies and less gain as the frequency is increased. Such signal processing makes the opening of the terminal device very easy to control at all elbow flexion positions with or without and object in it.

Battery Pack

Each amputee has been provided with two removable battery packs and a charger. Early in the study each battery pack contained 12 rechargeable nickel-cadmium AA size penlight cells with 500 milliampere-hour capacity. A diode was placed across each cell to minimize reverse polarity effects when the cells ran down. These battery packs can be fully recharged in four hours using conventional charging circuits. More recently, in response to amputee recommendations, the battery packs have been reduced to approximately two fifths of their former size and capacity.

The battery packs are now usually placed within the prostheses rather than on the belt. The small size renders the battery pack unobjectionable in either location.

This external power and control system has been used on eleven individuals. The amputees were selected to include a wide range of amputational levels and occupations. Included in this program are one Wrist Disarticulation (WD) amputee, two Below Elbow (BE) amputees, two Elbow Disarticulation (ED) amputees, two Above Elbow (AE) amputees, and three Shoulder Disarticulation (SD) amputees. The system has also been used to power a brace on a patient with bilateral shoulder and elbow flexor muscle parlysis.

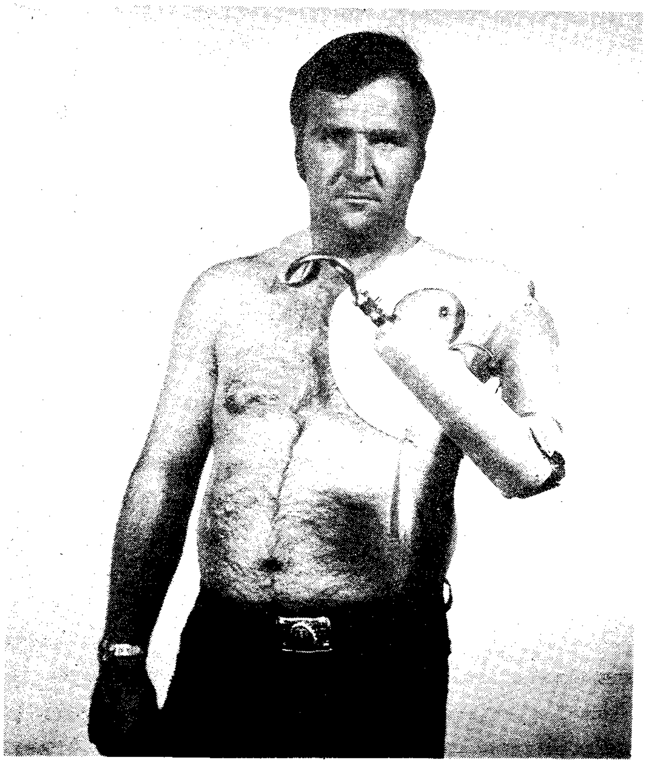

Fig. 3. TH - Shoulder disarticulation prosthesis. Motion of skin adherent button by pectoralis controls elbow mounted EXPAC powering elbow and terminal device. Elbow lock control strap runs to trousers. Battery in forearm.

Case LR

This prosthesis was fitted to a left WD amputee in February 1970 (Fig. 4). It has a plastic laminate forearm socket suspended only by a supracondylar strap. The motor, electronic control unit, and battery pack are worn on the waist. The myoelectric sensor was built into the wall of the socket in a floating arrangement whereby it rests on the skin over the proximal end of the long extensor muscles of the forearm. Proportional opening of the terminal device is controlled by varying the myoelectric signal.

Fig. 4. LR - Wrist disarticulation prosthesis. Myoelectric sensor on socket. Early model of bulky belt mounted battery and motor/control components.

After wearing the unit for one year, the amputee reported the following: For delicate work his Body Powered (BP) prosthesis is superior to his Externally Powered (EP) one owing to shoulder muscle feedback, the capability of setting the shoulders for steady force, lack of lag, and higher speed. Beacause of the time lag and lower velocity, he is inclined to use his EP prosthesis primarily in a "bang bang" mode. He dislikes the bulk and weight of the battery and motor, especially at the end of the day. He has reported that the EP prosthesis is ideal for working above his head or within closely restricted space, such as when lubricating head or within closely restricted space, such as when lubricating the underside of his automobile, or for conditions which render shoulder motion undesirable or difficult such as when propped up to read in bed. The absence of the shoulder harness and lack of compression force on the end of the amputation stump are definite advantages of the EP system when the end of the amputation stump happens to be tender. This amputee has been able to use a snugger socket with the EP system than with the BP system beacause of this feature. He has had no sensor site skin sensitivity problems dispite a known sensitivity to nickel, the metal rivets in his lower limb prosthetic socket, and his wrist watch. The net result of all these factors is that he likes to have his EP system for special uses and for relief from his BP prosthesis, especially in hot weather. Now two and a half years after delivery his appraisal remains unchanged. His average EP use continues to be one or two days a week.

Case JC

This system was fitted to a right, mid BE amputee during October 1970. His power unit and battery were initially designed to be clipped on to the belt with the power being transmitted to the prosthesis by a Bowden cable. A more permanent type of belt mounting with the battery and motor securely attached on opposite sides was subsequently found to be much more comfortable and less obstructive. Prior to the fitting with his EP prosthesis he had one year of expirience with his BP limb. Initially he reported that he was using his EP limb "most of the time". Approximately 5 months later he reported that he used his limb "almost every day". At that time, this amputee said that a significant reason for not wearing his EP prosthesis more frequently was that it was built more snuggly than his original prosthesis and that although this gave him greater control, it required too much extra time for application. After he had the limb for about 18 months, he reported that he was using it only occasionally as a backup prosthesis. He reprted that this was due to a superior socket fit and better control which he had obtained with a more recently fitted BP prosthesis.

He had a very weak myoelectric signal when first fitted. After the first couple of weeks of wear, his signal improved by a factor of three, necessitating a readjustment in electronic system gain.

Since then his myoelectric output has remained constant and at this high level. This amputee was a piano student (Fig. 5). He has been able to continue his piano lessons and has developed impressive skill in controlling his specially designed terminal device with his myoelectric signal.

Fig. 5. JC - below elbow prosthesis. Terminal device specifically designed for piano playing.

Case JP

This unit was fitted to a short BE amputee who had already learned to use a BP prosthesis with a Muenster socket and APRL hook or hand (Fig. 6). The EP prosthesis also was built with Muenster socket. There is no additional suspension or harness. The power unit and battery are permanently belt mounted but the battery mount permits convenient battery replacement. Force transmission between motor and terminal device is by Bowden cable; hook and hand are of voluntary opening type. Prior to fitting with the EP prosthesis the amputee stated that he was bitterly disappointed with the functional capabilities of his BP prosthesis. Although he usually wore this prosthesis, he did so almost exclusively for appearance and rarely used the hook.

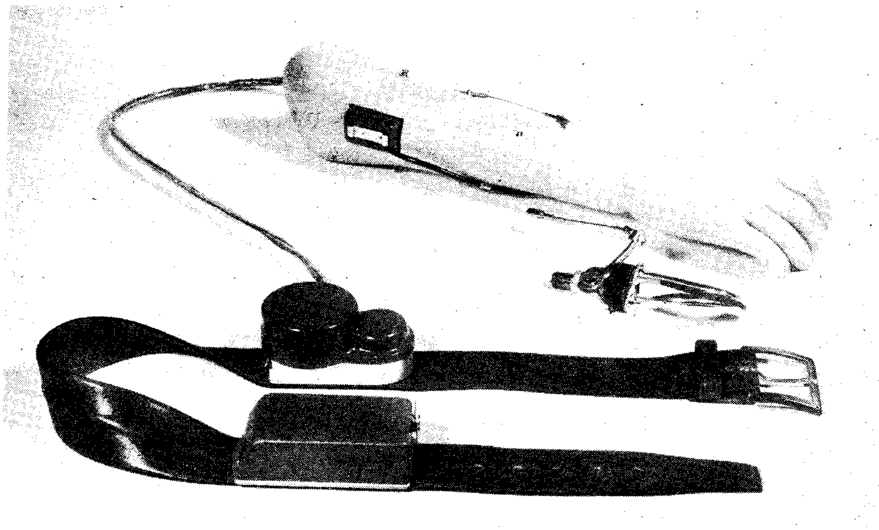

Fig. 6. JP - below elbow prosthesis. Belt mounted battery and motor/control components. Myoelectric sensor in socket wall.

This amputee adapted immediately to the EP prosthesis without special training. Since delivery of this system he has used it exclusively, full-time every day except on two occasions when he removed it for a few hours because of some skin irritation at the socket sensor port. It was felt that this problem was due at least in part to overzealous wetting of the skin in this area at the time of application of the prosthesis and to excessive pressure of the sensor. The condition improved with corrective action and no longer interfers with the use of the prosthesis. It became evident that this amputee was cycling his EP prosthesis more frequently than he formerly cycled his BP prosthesis. He reports that his 500 milliampere-hour battery lasts him about 9 hours, and, in order to permit continuing function of his limb, he carries and extra battery with him when away from the house for the whole day. He is a part-time farmer and mechanic. He likes to use the prosthetic hand in a work glove when working with farm tools. He prefers the hook when working with smaller metal objects. He reports that although the belt mounted components seemed annoying at first, he is no longer aware of them. When sitting he rotates his belt slightly, thereby bringing the motor around to his side where it does not press against his back. He has felt that the speed of operation is satisfactory, but he would prefer a little greater speed. His recommendations have been carried out in later models. There have been no equipment breakdowns or malfunctions with this amputee´s equipment. He denies having any trouble with inadvertent openings but says that occasionally when applying high force to an object he switches off his battery to maintain grip. He states that it will be terrible for him when the system is retreived when the evaluation is completed and he complains that he does not know how he will get along when he no longer has this prosthesis.

Case US

This unit was fitted to a right ED amputee who had only two months expirience with his BP prosthesis prior to being fitted with the EP unit (Fig. 7). A conventional Hosmer internal locking elbow was used, the lock being activated in the traditional manner by force being transmitted from the shoulder through an external cable connected to the elbow lock control strap. The power unit and battery are permanently mounted on the belt. The battery mount is designed to permit convenient battery replacement. Force transmission between motor and terminal device is by Bowden cable. The terminal device is of voluntary opening type. The limb was delivered in December 1970

This amputee´s original injury was incurred at work while operating machinery used for processing soap. In January 1971 he returned to the same full-time job with the same employer. He uses his EP prosthesis from the time he gets up in the morning at least until he returns from work in the afternoon. Usually he takes the limb off at home but he puts it back on for any bimanual activities or to go out in the evening. He has worn the limb continuously as long as fourteen hours. Since delivery of his EP prosthesis, the only times he has worn his BP prosthesis were while a broken battery case was being replaced and on two other occasions when his EP prosthesis was in the laboratory for checkout. The case was replaced with one of more durable material after he dropped and broke it. No further brekage has occured. He has reported inadvertent openings of the terminal device in the washroom when trying to hold toweling in order to wash and dry his remaining hand. In this situation he has resorted to switching off his battery in order to maintain a grip on the toweling. The sensor case was modified to improve electrode contact. He's had no other malfunction or mechanical or electrical breakdown. In reply to inquiry about speed he said that ideally he would like to have it a little faster. In reply to inquiry about weight of his prosthesis he stated, "No problem. I guess I am used to it". Regarding the components on his belt he answered, "A little bulky but they don't bother me." He stated "The arm is working beautifully. It will do anything you try to do with it.

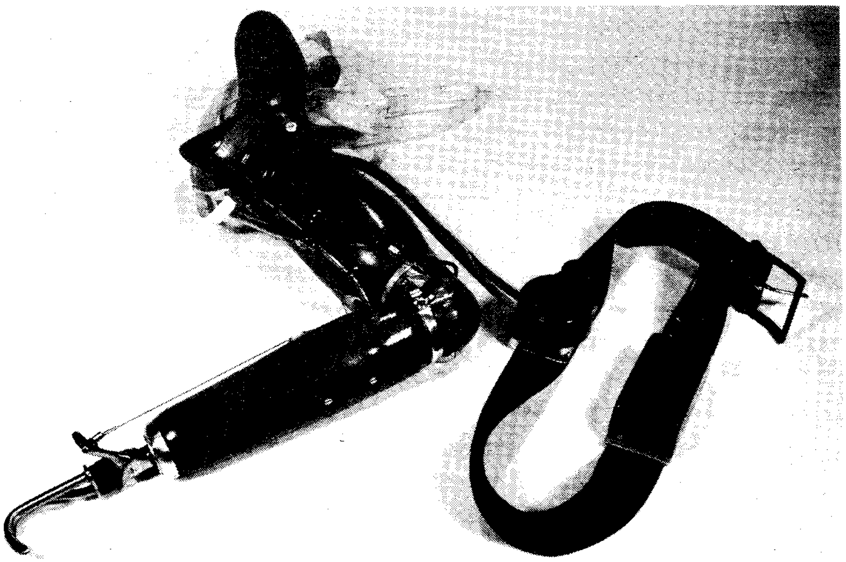

Fig. 7. US - elbow disarticulation prosthesis.
~~Belt mounted battery and motor.~~
Myoelectric sensor in socket wall.
Hosmer internal locking elbow.

Case HT

This unit was fitted to a 57 year old left ED amputee about one week after delivery of his first BP prosthesis and the nine months after his amputation. The original injury to his left upper limb also resulted in severe permanent limitation of motion in his left shoulder. Due to the limited muscle power and excursion of the shoulder, the harness selected for the BP prosthesis consists of a shoulder saddle and cross-chest strap for suspension and a separate axillary loop for transmission of force from the right shoulder to the main cable. This loop was designed to exploit right side shoulder motion to obtain maximum cable excursion. In spite of these special considerations and daily training efforts, the amputee had great difficulty developing any useful function with his BP prosthesis.

The EP unit has a socket, forearm, wrist unit and voluntary opening terminal device which are identical to those of the BP unit (Fig. 8). An identical shoulder saddle and cross chest strap are used but the axillary loop was omitted. The main cable is routed around a pulley in the forearm unit. The power unit and battery are mounted on the belt.

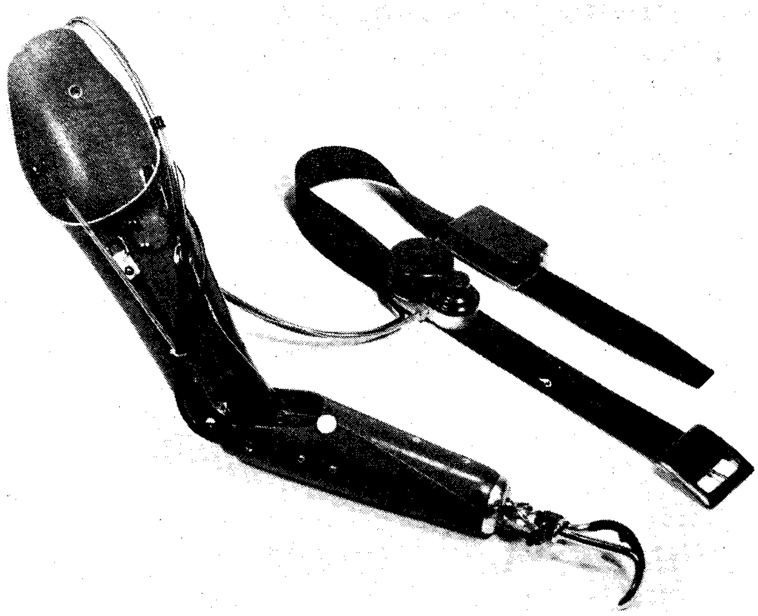

Fig. 8. HT - elbow disarticulation prosthesis.
Belt mounted battery and motor.
Myoelectric sensor in socket wall.
Outside locking elbow hinges.

The subject was able to function both the elbow and terminal device with good control immediately after delivery of the limb and without special training. No adjustments were required. He stopped using his BP limb, he wore his EP limb full-time, and he reported over the ensuing twelve months until lost to follow-up that he was delighted with all aspects of the limb.

Case LC

This unit was fitted to an AE amputee who lost his left upper limb in an industrial accident about six years previously and has been using a BP prosthesis for approximately five years. He is a full-time employee of an industrial contracting company where he works as a high-pressure boiler welder. He is also a private horse farmer. His BP prosthesis is of heavy duty construction and has an internal locking elbow and farmer's hook. He is very skillful with his BP prosthesis, subjects it to heavy use, and has been wearing it full time all the time.

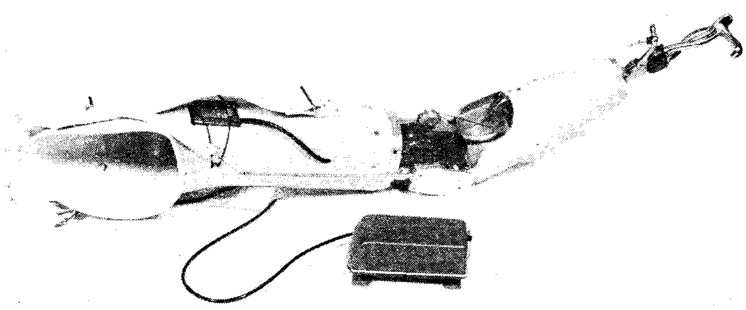

Fig. 9. LC - above elbow prosthesis. Motor in elbow. Battery clips to belt. Myoelectric sensor in socket wall.

Since he depends heavily on the humeral rotation turntable in his work and since his stump is fairly long, a special turntable was designed and constructed to occupy minimal longitudinal space and still permit placing the motor in the elbow region without lowering of the elbow center unnecessarily (Fig. 9). The sensor was placed in a socket port over the biceps muscle; the remaining electronic components were placed in the forearm unit and the battery attached to the belt. One week after the EP limb was delivered the amputee reported that the above elbow figure 8 harness was uncomfortable due to the increased weight of his prosthesis.

The harness was then converted to a shoulder saddle with chest-cross strap. The patient then reported that his new harness system was more comfortable. He also reported that his work required him to be standing or walking almost all of the time and that he found that under these circumstances the EP prosthesis was too tiring to permit him to continue working for an uninterrupted period exceeding five hours. He reported that he achieved adequate relief if he was able to sit down and that he thought that the prosthesis would be ideal for an amputee whose work would permit him to rest the weight of the limb occasionally on a supporting surface such as a desk top or in his lap. He believed that part of his fatigue might be due to unaccustomed use of the biceps muscle. He had no malfunctions or breakdowns and denied inadvertent openings. A fresh battery pack lasted him 5 hours of work time. He stated that the response of the limb was good and he hoped to develop an increased fatigue tolerance. He noted that an advantage of his EP prosthesis was the ability to reach higher. In January 1972 it was evident that the patient had stopped using his EP prosthesis and showed a clear preference for his BP prosthesis. The unit was therefore recalled.

Case LB

This unit was fitted to a right AE amputee in August 1970. One year prior to this time he had been fitted with a BP AE prosthesis with internal locking elbow, AE figure 8 harness, dual control quick disconnect wrist, voluntary opening hook and an Army Prosthetics Research Laboratory (APRL) hand. He developed moderate facility with this equipment but never used the hand. The EP power unit is located in the elbow space and controls either the terminal device (voluntary opening function) or elbow flexion. A routine external locking cable and strap to the shoulder saddle are used in order to select terminal device vs. elbow function (Fig. 10). The battery for this system is located on the belt. The single site myoelectric sensor is mounted in the wall of the stump socket over the biceps muscle.

The amputee clearly prefers the EP prosthesis to his BP system and uses it all the time. Harness adjustments, repair of the elbow locking cable attachment, and replacement of broken rubber bands (which close the hook) have been necessary, but these were unrelated to the powered system. There have been no breakdown or adjustment in the actual EP system except for replacement of the stainless steel cable which broke in the vicinity of the forearm bracket assembly.

Fig. 10. LB - above elbow prosthesis motor in elbow. Battery clips to belt. Myoelectric sensor in socket wall over biceps.

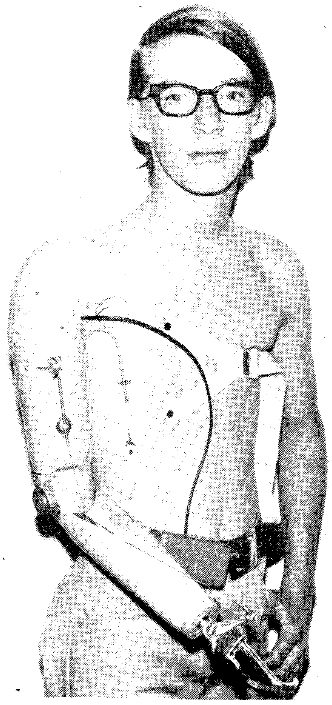

Fig. 11. TL - shoulder disarticulation prosthesis.Motion of skin adherent button by pectoralis controls motor in upper arm space. Elbow lock control strap runs to trousers. Early model of bulky belt mounted battery.

Although he states that he actually prefers the additional weight of his EP prosthesis compared with his BP one, he also states that the weight becomes ojectionable if his activities require him to be standing or walking and without additional support for his prosthesis for durations of time exceeding 3 hours. For this reason he feels that his type of limb might be tiresome for some types of outdoor employment. On the other hand, if he is able to sit down and thereby rest the prosthesis in his lap or on a table for a few minutes every couple of hours, the EP prosthesis causes him less fatigue than the BP one; therefore, he feels that the limb is especially suited to persons doing office work or to persons whose work activities entail periods of sitting, as in driving a motor vehicle.

Experience with his EP system also indicates that its advantages include ease of operation and a substantially enlarged work envelope.

Case TL

This prosthesis was fitted to an 18 year old right SD amputee to replace the limb lost in a traumatic amputation secondary to a corn picker accident (Fig. 11). The amputee was fitted with a conventional BP prosthesis approximately three and a half moths after the amputation. This device produced negligible function and he wore it only for appearance on special occasions. Prior to being fitted with the EP prosthesis he had, for all practical purposes, totally rejected the conventional system.

No myoelectric signals suitable for control of the prosthesis were found when a through examination was made of the muscles of the inj injured side of the amputee's body. However, more than two centimeters of transverse motion of the scar results when the pectoralis muscle is contracted. The patient has excellent voluntary control of this motion.

A special transducer was developed to utilize this skin motion. This transducer utilizes a movable magnet and stationary semiconductor elements which respond to changes in magnet field strength.

After using this prosthesis for approximately one month, the amputee reported that he was using it 50 to 75% of the time. His use rate his remained approximately the same since that time (18 months). He uses it for bimanual operations and for tasks such as carrying empty buckets, but he does not use it when he can do his work without it. The adhesive attachment to the skin has remained intact for more than two weeks without coming loose, and appears to be satisfactory for this purpose. The battery is providing up to 9 hours of operation on a single charge. The amputee has expressed a need for a "reach" capability (scapulo-humeral) and is of the opinion that this would make the prosthesis much more useful.

Case TH

This unit was fitted to a 43 year old left SD amputee to replace the limb lost in an injury thirteen years prior to this fitting.

The amputee was fitted with a conventional BP prosthesis following his amputation but abandoned it due to discomfort associated with weight, heat and inadequate function. This amputee's EP prosthesis is one of the most recent fittings in this series and embodies modifications recommended by our other amputees (Fig. 3). The most recent model of Type A EXPAC was used. This power and control unit is located in the elbow space. Except for one half inch greater length, it is dimensionally equivalent to the non powered internal locking Hosmer elbow unit. The primary control input is from motion of the skin scar over the remanent of the pectoralis major muscle and utilizes the new flux sensitive skin motion sensor. An Otto Boch Type of shoulder hinge permits passive abduction and flexion with friction control. The elbow lock control mechanism is an inherent part of the Type A EXPAC and is activated by elevating the shoulder. The primary control cable exits anteriorly from the EXPAC just above the elbow joint, travels in front of the rotational axis of the elbow, through a set of pulleys in the forearm unit and continues down to the attachment point on the voluntary opening terminal device. The removable, rechargeable battery pack is of reduced size and located in the proximal end of the forearm unit. This patient requested a plastic laminate cervical horn to secure the prosthesis to his trunk in preference to cross chest straps; therefore, the entire unit is self contained without straps and without components mounted elsewhere on the body. The entire prosthesis weights 2,95 kilograms. This amputee is a landscape manager and competition horseman. He intends to use his prosthesis in his work. He seems quite pleased with it but at the time of this reporting he has not had the prosthesis long enough for a useful evaluation.

Case VP

This is a bilateral upper limb prosthesis which was fitted to a 21 year old female congential bilateral Shoulder Disarticulation (SD) amputee.

For most of her life she has had bilateral shoulder disarticulation BP prostheses powered by motion of her left thigh utilizing a separate plastic laminate thigh cuff attached to a

Bowden cable. The elbows were locked by chin nudge controls. This device provided negligible function and was worn rarely and for appearance only. The EP bilateral SD prosthesis uses a single recent model Type A EXPAC in the left elbow space. The cable from this unit is routed to power both elbows, both terminal devices, and wrist rotation on one side. This amputee's equipment was originally arranged to use two primary proportional control inputs (one for each limb) derived on each side from a particular motion of the tip of the ipsilateral acromial process. The flux sensitive skin motion sensor was used on each side. After the appliance was fitted, it was found that the patient had better voluntary control of one acromial process than the other and, furthermore, was able to concentrate on controlling only one prosthesis joint at a time. The equipment was therefore recovered and altered to use a single primary proportional control input from one acromial process. An additional non proportional control input was used to lock or release all but one joint. Since a single power cable is routed through a series of pulleys to move all joints, and since one joint has the greatest resistance to motion, it operates only when all others are locked. Thus the system is organized for operation of the various joints in a sequential rather than a simultaneous mode and with the actual sequence being determined by the operator. It is believed by the investigators that this arrangement facilitates the most precise control of the motion of the appliance. The release of each of the locks is solenoid-actuated and controlled by a specific shoulder motion. Locking occurs automatically after a preset time adequate to bring the particular joint into the desired position. If the amputee fails to bring the joint into the desired position before it locks, she can unlock the joint and try again.

This appliance has been returned to the amputee only recently, and an adequate interval for further clinical evaluation has not passed.

Case JM

This 50 year old man is not amputee but has acquired extensive bilateral shoulder muscle weakness and elbow flexor paralysis. Although the muscle power to his right wrist and hand is fairly good, he has only a trace of biceps function and cannot lift his forearm or hold it up against gravity. He is able to swing his hand up into a functional position only by vigorously rotating his trunk and shoulders.

A Type B EXPAC was attached to an orthosis designed to accept and transfer torque to the right elbow joint (Fig. 12). The unit was attached to power flexion, relying on gravity and some active triceps muscle function for extension. Despite the weakness of the elbow flexor muscles, the biceps myoelectric activity was adequate for a control signal. The sensor was placed over the biceps muscle, the motor and battery were mounted on the belt, and the cable was routed across his back under his shirt.

Fig. 12. JM - Orthosis for elbow flexor paralysis. Biceps myoelectric sensor controls belt mounted EXPAC powering elbow flexion.

In spite of the fact that, with the exception of the control input sensor, none of the power components are located on his upper limb, the patient finds that the weight and bulk of his orthosis offsets its usefulness after a couple of hours. He believes that this is due largely to his shoulder muscle weakness and the fact that the orthosis was not designed to provide active shoulder (scapulo-humeral) flexion.

The system does permit him to lift objects in his hand weighing up to about 0.9 kilograms and to shake hands and reach objects at waist height without gross body motions. The EXPAC functions smoothly and reliably in this application. Further efforts are being directed at reducing the bulk and weight of the orthosis.

Conclusion

The application of a cable-pulling type of External Power and Control unit to various traditional types of upper limb prostheses and an upper limb orthosis has been presented. The system is designed to deliver torque under proportional control to a series of joints via a suitably routed cable from an appropriate motor and to permit sečective isolation of motion to specific joints sequentially by non-proportional control inputs. Additional physical and mechanical features of the system and its components are described.

A new type of skin motion sensor is presented.

Functional experience with these units on a series of ten amputees and one paralytic representing a wide range of amputation levels and disabilities is given and compared with the functional experience with traditional body powered appliances on the same individuals. The majority of the amputees in this series favored their externally powered prostheses. Reasons for their preferences and appropriate equpment modifications are identified.

References

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