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The use of electric elbows in the rehabilitation of children with upper limb deficiencies

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Abstract

For those with levels of loss above the elbow, the normal prescription choice is now considered to be the use of an electric elbow combined with a myoelectric hand using a single site three state control. The lightweight VASI unit controlled by a harness mounted switch is mounted in a prosthesis the socket of which is total contact, and allows improved power transfer.

Introduction

The use of electric elbows in upper limb prosthetics at the Hugh MacMillan Rehabilitation Centre (HMRC) dates back to when it was still known as The Ontario Crippled Children's Centre (OCCC).

In 1964 the staff of the Prosthetic Research and Training Unit (PRTU) at OCCC was charged with providing prosthetic and orthotic care for children referred to the institution's clinic.

Included in the 600 child amputees registered with the institution's clinic were 21 thalidomide children. These children had phocomelic limbs that lacked in reach, grasp and strength. It was the challenge of that group that triggered the team to experiment with externally powered components such as electric elbows, hooks and wrist rotators. A number of these children became adept at operating electric three-jaw-chuck terminal devices and elbows. Using the digits of their flippers to push against switches, some accomplished tasks such as feeding, picking up objects and even flicking on a light switch.

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The experimental devices were primarily functional because it was believed that lack of function would lead to frustration and frustration to rejection. In retrospect, none of these patients became long-term users of their devices. Rejection can be directly attributed to the lack of cosmesis of the devices provided. Indeed, the acceptance and the success of externally powered prostheses began when aesthetically pleasing, functional hands became part of the prosthetist's armamentarium.

Patient selection criteria

In the past, the members of the team would sometimes discuss at length the pros and cons of conventional versus powered fittings. Today electrically powered components, wisely chosen, offer distinct benefits to the amputee. It is known that electric elbows offer more comfort through reduced harnessing and that they provide function to high level amputees when the alternative would be a cosmetic sleeve filler.

In HMRC the selection of patients for the provision of electrically powered prostheses has been reduced to agreeing not "if", but "when". The electrically powered prosthesis has become the conventional prosthesis.

Clinical experience with electric elbows at HMRC

From 1964–1968 several prototype elbows were field-tested on children and teenagers with upper limb deficiencies. The patient group included those with uni- and bilateral above-elbow loss as well as shoulder disarticulation and total arm deficiency.

Different modes of control were tried. These included mercury switches (attitude control), arrangements of push and pull switches, and nudge control. Together with the elbows, various hooks, both cable and electrically powered, were evaluated for their usefulness as terminal devices.

In 1968, the final prototype elbow was passed on to Variety Abilities Systems, Inc. (VASI) for commercial production. To date, 600 of these units have been sold worldwide as the 62-type elbow. Compact and light, (370 gm) the 62-type elbow was found to be a rugged performer which has been used by HMRC in over 150 fittings, on adults as well as on children and teenagers. In some complex fittings involving bilateral, high-level adult patients, this elbow was not only used to provide forearm lift but found equally useful as a powered abductor or humeral rotator. In the case of elbow disarticulation patients, the VASI 62 elbow is the only elbow that can be used in a reversed position with the elbow becoming part of the forearm. Using this approach, the excess length of the humeral segment can be reduced to one inch (25 mm). While the elbow is normally supplied with a 6 volt motor VASI will supply the elbow with a 12 volt armature upon request. This model is about 25% faster but also needs a larger power pack.

From the many fittings carried out, a clear concept for an above-elbow prosthesis with electric elbow and hand developed. As a model it has remained unchanged to this day. In principle, the available myoelectric potential is reserved for control of the hand. Control of the elbow is kinetic, using extension of the humeral stump to trigger a pull switch. The patient is fitted with a "half-and-half" socket. The completed socket distal to the axilla shelf is made from rigid resin, whilst the shoulder portion is made from flexible silicone rubber laminate. The deltoid area is cut away. Anterior and posterior wings extend past the coracoid and scapular spine respectively. These sockets are almost self-suspending, show excellent rotational stability and most importantly, enable the patient to carry the weight of the prosthesis comfortably all day. These sockets are total contact but not suction sockets as it was found that neither children nor parents have the skill and determination to pull a stump correctly into a negative pressure socket. Suspension is aided by a single one inch (25 mm) wide transverse strap with velcro closure over the chest. The pull switch is mounted on the medial superior quadrant, of the socket's anterior surface so that it is floating and self-aligning and is fastened with a single screw. The cord or dacron strap is carried over the shoulder on the same side and fastened with a buckle to the transverse strap on the back. Thus, extension of the above-elbow stump will activate the switch and, consequently, the elbow. Involuntary activation is avoided because humeral extension is almost an unnatural movement. A single myoelectric control site for the hand can usually be found at the medial head of the biceps. However, especially in short above-elbow stumps, the medial head of biceps is not where it should be, but can be located more posteriorly and deeper into the axilla. In many years of prosthetic practice, only two patients at HMRC have been found to have signals from both biceps and triceps. The myoelectric control system for most above-elbow patients therefore, is a single-site 3-state system. HMRC have used the amplitude-sensitive VASI or UNB systems as well as the rate-sensitive Bock system. For small children, the so called St. Anthony's Circuit (cookie cruncher) has also been used. This is also a single-site system where the EMG signal causes the hand to open. When the patient relaxes, the hand closes automatically.

Unfortunately the batteries needed to drive the actuators and systems have not been designed to accommodate the prosthetist's needs. They are heavy and because of their shape and size, are difficult to place into the artificial limb. The batteries are placed as proximally as possible and if there is no space between elbow and socket, sometimes single button cells are spread on the outside of the socket and, after wiring is done, taped into place. The least satisfactory method is to have the battery pack attached to the harness which leads to endless cable and connector problems. It has also been seen that many patients and parents have problems with charging the batteries because the patient, not unlike a car driver whose gas gauge does not work, must judge the amount of charging needed.

About six years ago HMRC were asked to provide powered prostheses for a two-and-a-half year old girl with bilateral above-elbow amputations who was unable to obtain function

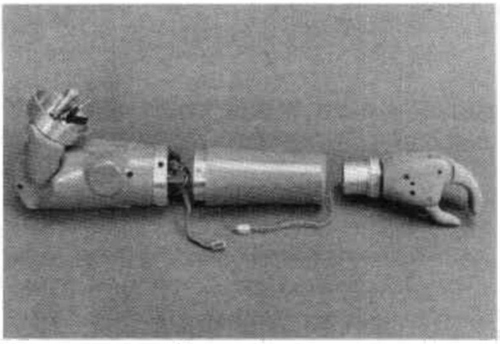

Fig. 1. The HMRC "mini" elbow.

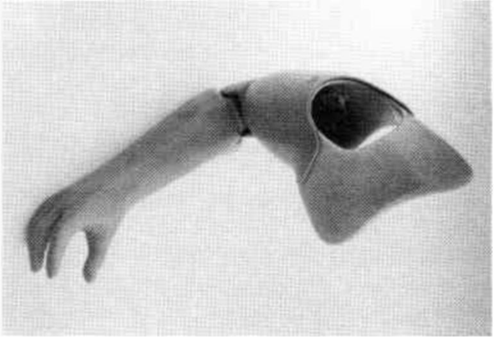

Fig. 2. The HMRC "mini" elbow in prosthesis.

from conventional prostheses. Because the available 62-type elbow would have been too large, a pair of electric elbows were made up from the chassis of Bock 6 ¾ size hands. The thumbs of the hands were mounted on the socket, the index and middle finger became the root of the forearms. The elbows were controlled by switches as described above. As the family insisted on hands, she was given two VASI 2–6 hands which were controlled with 3-state systems. Within a couple of days this girl, not yet 3-years-old, learned to control the elbows and hands and was feeding herself. However, there were maintenance problems with these make-shift elbows and they were replaced later with the first 3–8 "mini" elbows which had been designed by the HMRC mechanical engineering section (Figs. 1 and 2). Today, the girl is a very effective user of her arms showing a remarkable degree of skills at home and in school. She is, however, unique only because she was the youngest patient to be fitted with electric elbows. Equally good results have been observed in children, teenagers and adults with shoulder disarticulation, amelia or forequarter level amputations when using electric elbows and hands.