4. MYOELECTRIC PROSTHESSES FOR INFANTS

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PREFACE

Ashok S. Muzumdar
Series Editor

The question, what is the best age for fitting very young children with myoelectric prostheses, has stimulated considerable debate in the past. Essentially, the two sides have argued either in favour of fitting at a very early preschool age versus advocating the philosophy of delaying such fittings until perhaps preadolescence.

The collection of articles presented in this monograph, the fourth in the U N B. series on myoelectric prostheses, provides evidence of both pioneering work done in this subject area as well as, for the most part, long term experience gained in some of the major and well recognized centres in the western world.

It is not our intention to influence the readers by favouring one or the other side of the debate but rather to have them review the material herein and then arrive at an informed decision.

A word of caution: since these articles originate from various centres in Canada, Sweden, the United Kingdom and the United States where certain differences do exist in the provision of health care delivery, including the source of funding, logically one could surmise that such differences in both the practice and philosophy of dealing with young children with myoelectric prostheses would introduce elements of variability. Notwithstanding this fact, I do feel that the similarities of practice far outweigh any dissimilarities.

I trust that this monograph will provide a useful insight for clinicians and other professionals working with small children requiring myoelectric control systems.
INTRODUCTION

R.N. Scott

Over the past few years it has been evident that there is a lack of consensus on the age at which myoelectric prostheses should be prescribed for children with congenital upper limb deficiency. We receive frequent inquiries from parents, clinicians and third party payers, all of whom desire a definitive answer to this question. We have no such answer.

To contribute to the development of some consensus on this topic, we invited a number of persons with clinical experience and diverse views to contribute papers for this Monograph.

The Monograph is not a position paper supporting any specific answer to the question. What we hope that it does is to present in one place a summary of the present views of a number of outstanding clinicians, based upon their experience with more than 800 amputees fitted with myoelectric prostheses in four countries, over as much as 20 years. As with most research, the result poses more questions than it answers.

One of the fundamental questions is whether the objective of fitting a myoelectric prosthesis is that the amputee should use it all day every day, anything less being an indication of failure on our part or that of the amputee. The paper by Lyttle and Ringdén assesses utilization in a novel way, and highlights the fact that "users" do not come close to this target.

Lyttle and Ringdén also identify an interesting aspect of data on acceptance vs. age at fitting, wherein the period around 8 years of age shows particularly low acceptance probability relative to data for younger or older children. This trend also is

evident in the two year follow up data presented by Jacobs.

It is interesting to compare the data from Störbye and Hermandson with that from Day, both representing large populations dealt with in the same period with similar devices. Is it possible that the radically different long term acceptance and utilization data are the result of differences in the amount of follow up attention which the respective clinics have been able to provide? If so, is there a possibility that a significant number of amputees continue to use their prostheses partly in an attempt to avoid disappointing the clinic team?

We are pleased that the concept of Limb Banking was mentioned by Brenner, because this seems the most effective solution to high costs, and the Detroit group has long experience in its implementation. Designers of new myoelectric systems are under pressure to provide better performance, greater versatility, smaller size, lighter weight and increased reliability in systems which are easier to fit; they are not apt to be able to reduce costs significantly in the face of these conflicting demands.

One of the problems which becomes particularly clear in this Monograph is the need for some agreement on standards for data collection, so that information from many groups can be pooled for analysis. The Association of Children's Prosthetic and Orthotic Clinics is working toward that objective, and any progress will make subsequent attempts to obtain an overview of a topic such as this more feasible.

Meanwhile, we hope that this Monograph will prove helpful by collecting a variety of clinical experiences "under one roof".

FOREWARD

Yoshio Setoguchi

The development of the myoelectric prosthesis has added a new dimension to upper extremity amputees. As the systems improve, it is only a matter of time before the fitting of more infants and young children becomes a reality. The question is not whether young children should receive myoelectric prostheses. The question is whether criteria should be established so that clinics which treat children with limb deficiencies/amputations can provide these more expensive prostheses in an equitable manner. Although many physicians would like to provide these "hi-tech" systems to all of their appropriate patients, funding is a major problem or issue. The initial cost of the myoelectric prosthesis is high and like the standard prosthesis it must be replaced as the child grows.

Based upon the realities of today's concerns with the ever dwindling funding of medical care, it becomes imperative that the medical professional, embodied with the responsibility of prescribing prosthetic systems, try to develop some criteria to provide these expensive systems to those who would benefit the most.

This monograph is a beginning step toward this objective as clinics which have the most experience to date on myoelectric fittings for infants and children report their findings. Hopefully the information will provide insights into fitting criteria, evaluation protocols used to analyze the effectiveness of this fitting technique and the results of the prosthetic acceptance in the various groups of children.

The following historical information provides the reader with some background on the research and development of externally powered prostheses. The concept of the use of external power to assist in the control and operation of prostheses for both upper and lower extremity amputations/limb deficiencies is not new. One could consider the powered wheelchair as one example of a successful application.

The development of external power to upper extremity prosthetics began with the thalidomide tragedy some 30 years ago. At that time, research into powered systems was focussed on children with high level deficiencies and on those with multiple limb deficiencies who didn't have sufficient control or activation forces to operate conventional body powered systems. Considerable time and funds were directed towards the development of externally powered systems for these special children. Unfortunately, almost all of the initial prosthetic fittings were rejected both in Europe and Canada. The thalidomide children used their residual limbs or other parts of their bodies, especially their feet, much more usefully in performing functional activities. These initial powered systems were described as cumbersome, heavy, slow, fragile and expensive.

The concept of externally powered prostheses did not end with these initial prosthetic failures. Newer developments have corrected many of the problems and complaints. It has led to use of these systems for different levels of limb deficiencies/amputations.
One such advancement has been the use of myoelectric fittings for below-elbow type amputations/limb deficiencies. Those individuals who wear the below-elbow myoelectric prostheses describe the following advantages: Stronger prehension, elimination of the "uncomfortable" harness system which includes the cuff and cable system; the ability to easily open the electric hand with the arm in any position; as well as improvement in cosmesis.

Some of the concerns relative to this fitting are weight, durability and cost. Most children adapt to the weight of the myoelectric-operated prosthesis within a short period of time. Unless misused the electric hands and control systems are fairly reliable. Unfortunately cost is still a problem. Currently, patients whose families can afford the much more expensive systems, are being fitted with myoelectric arms. Those families on welfare or who do not have good third party insurance programs are either required to pay a large portion of the cost or must "settle" for the more conventional systems. However in countries where there is national health insurance, it is possible for child amputees to prescribe and fit externally powered prostheses. Therefore much of the current information is derived from clinics in countries such as England, Canada, Germany and Sweden. Unfortunately, in the United States funding is a major problem. Unless the clinic has a special funding source or selects only those patients who can pay, large scale myoelectric prosthesis fittings are not possible. However patients and families are no less interested in these "hi-tech" systems.

This monograph, the most comprehensive to date on fittings of young children and infants with myoelectric prostheses, has gathered information from clinics who have the largest numbers of fittings in the world today. As you will note from reading these very interesting articles, there is still a rather large difference in the acceptance rates from the clinics. Unfortunately it is difficult for this reader to glean from these studies, the specific reasons why we still have a rather significant rejection rate in all clinics except one and possibly two programs. It definitely is not a matter of cost. One can easily assume that it's due to the fact that we still don't have a good functional replacement of a "normal" hand but there must be other factors. We still don't have an understanding why some patients develop excellent use and wear patterns, whereas others still have difficulty in integrating the prosthesis into their normal activities.

Another factor which is alluded to in some of the studies but not studied specifically is the effect on prosthetic fitting of the psychosocial concerns. One must not forget that the most effective treatment of the child with an amputation/limb deficiency is the interdisciplinary team approach which focuses on the total needs of the child and his family. The psychosocial concerns and how the family adjusts to the limb loss have a great deal to do with their ability to participate positively in a prosthetic habilitation program. The parents' reactions to the birth defect will affect their feelings towards the child, their expectations regarding treatment, their compliance with the prosthetics program and ultimately their attitudes towards the prosthetics program.

Until we develop a more qualitative and specific method of evaluating those factors that are important in prosthetic replacement, we will continue to have problems in funding external powered systems for our pediatric amputee population.

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ELECTRONIC LIMBS FOR INFANTS
AND PRE-SCHOOL CHILDREN

Carl D. Brenner

Throughout the past 20 years, advancements within the field of electronics technology have had a steadily increasing impact on the field of upper limb prosthetics. This has led to the use of electronic limbs by a broad segment of the adult amputee population, as well as increasing numbers of children and infants with acquired and congenital limb deficiencies. For the purpose of this paper, the term “infant” will be used as defined in Stedman’s medical dictionary as “a child under the age of two”.  

The advent of fitting infants and pre-school children with electronic limbs had its beginnings in Sweden in 1971. At that time, a three year old girl named Asa with a congenital below elbow limb deficiency, was fitted by Rolf Störbye at the Regional Hospital in Örebro, Sweden. Asa was the first pre-school child at three years of age to be fitted with a myoelectric prosthesis utilizing a 6 3/4” Otto Bock electronic hand.  

Over the next 14 years, the successful experience in Sweden eventually generated similar activity in a small number of centers in North America, leading to the next breakthrough in infant electronic fittings, which occurred in 1985. At that time, a twelve month old infant girl named Erin, with a below elbow congenital limb deficiency, was fitted at the Michigan Institute for Electronic Limb Development, in Detroit, Michigan (Fig. 1). Her prosthesis included a two-site, two-function electronic control system, and the Systemteknik electronic hand, developed by Störbye in Sweden (Fig. 2).  

As a fulltime wearer and active user of her prosthesis since the age of one year, Erin provides an encouraging example of the benefits to be gained by the early use of an electronic limb (Fig. 3).
Practical Considerations and Outcomes

In the past ten years over two hundred electronic limbs have been provided to children seen at the Variety Club Myoelectric Center in Detroit, Michigan. The age of the patients fitted has ranged from twelve months to nineteen years, with approximately half of the prostheses being provided to children between one and four years of age (Table 1).

<table>
<thead>
<tr>
<th>AGE AT FITTING</th>
<th>NUMBER OF PROSTHESSES</th>
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<tbody>
<tr>
<td>1 TO 4 YEARS</td>
<td>100 (40%)</td>
</tr>
<tr>
<td>5 TO 8 YEARS</td>
<td>58 (20%)</td>
</tr>
<tr>
<td>9 TO 12 YEARS</td>
<td>23 (11%)</td>
</tr>
<tr>
<td>13 TO 16 YEARS</td>
<td>16 (8%)</td>
</tr>
<tr>
<td>17 TO 19 YEARS</td>
<td>6 (3%)</td>
</tr>
<tr>
<td>TOTALS</td>
<td>203 (100%)</td>
</tr>
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</table>

When the program began in 1981, one of the overriding concerns centered on the expectation of frequent electro-mechanical failure of the prosthetic components being used by small children. At the time, it seemed reasonable to assume that fitting infants or preschool children with expensive electronic hardware could lead to many costly repairs. Hindsight has shown that those fears were largely unfounded, as it has been demonstrated that the electronics being manufactured for use by children was a great deal more durable than originally anticipated. It has also become apparent that the children and their families generally take very good care of this precious equipment, and that the average frequency of electro-mechanical failure is about three times every two years (Table 2).

<table>
<thead>
<tr>
<th>FREQUENCY OF ELECTRO-MECHANICAL FAILURES OR PROSTHETIC ADJUSTMENTS</th>
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<tr>
<td>ELECTRO-MECHANICAL REPAIRS</td>
</tr>
<tr>
<td>PROSTHETIC ADJUSTMENTS</td>
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<td>TABLE 2</td>
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Another major area of concern involves the longevity of the prosthesis fit. Prior to 1986, a technique for building growth liners in electronic prostheses had not been developed (Fig. 4). However since that time, this has become a routine procedure, and has added 24% to the useful life of these electronic limbs, before the child outgrows the prosthesis (Table 3).

<table>
<thead>
<tr>
<th>PROSTHETIC REFITTING AND ADJUSTMENT</th>
</tr>
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<tr>
<td>PROSTHESSES WITHOUT GROWTH LINERS: 14.5 MONTHS</td>
</tr>
<tr>
<td>PROSTHESSES WITH GROWTH LINERS: 18 MONTHS</td>
</tr>
<tr>
<td>NET INCREASES WITH GROWTH LINERS: 24%</td>
</tr>
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<td>TABLE 3</td>
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A third consideration in fitting infants with electronic components deals with the total weight of the prosthesis. Since we fit most infants with a passive prosthesis between four and six months of age, they have sufficient time to acclimate to the weight and sensation of wearing a prosthesis. Thus far, there has been less than a two percent rejection rate, based solely on the weight of the prosthesis. We have found that even a one year old child can very easily tolerate a prosthesis that weighs 12 to 16 ounces (340-454g), and the new light weight, injection molded hand, available from Variety Ability Systems, Inc in Toronto, Canada, makes it possible to build a prosthesis for an infant that weighs less than nine ounces (225 g) (Table 4).

<table>
<thead>
<tr>
<th>WEIGHT OF PROSTHESSES</th>
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<tbody>
<tr>
<td>RANGE: 8.5 to 34.5 oz (241 to 978 g)</td>
</tr>
<tr>
<td>AVERAGE: 20.25 oz (574 g)</td>
</tr>
<tr>
<td>TABLE 4</td>
</tr>
</tbody>
</table>

Lastly, we have learned that, of all the prosthetic components that undergo the normal wear and tear of an active child, the most vulnerable has proven to be the outer glove that provides both protection and a cosmetic appearance to the electronic limb. Based on a decade of experience with cosmetic gloves, statistics now show that children will require between two and three gloves per year (Table 5)

Limb Banking

No discussion of electronic limbs would be complete without mention of the concept of limb banking. A limb bank is a collection of components consisting of electric hands, electrodes and electrode wires, batteries and battery chargers, that can provide a ready replacement for any component that is being used by an amputee. Limb banks are generally built up over a period of time, as components are outgrown by children, and donated to the limb bank by their families. Also, a limb bank can be developed initially by the purchase of new componentry in order to provide additional backup systems when first starting a program. In Michigan, we have been very fortunate because the Variety Club of Detroit has underwritten the original costs of developing a limb bank for the Variety Club Myoelectric Center.
an otherwise successful outcome may become a failure. A successful limb fitting program must include the capability of doing in house repairs for any of the electronic systems being utilized by the patients. In our early experience, it was necessary to ship components back to the manufacturer for service, resulting in several weeks of delay before the prosthesis was able to be worn by the patient.

As a consequence, it was found that developing a comprehensive in house inventory, and a staff trained to deal with all electro-mechanical failures, was the best solution. Subsequently, this has resulted in 80% of repairs and adjustments being completed within two hours or less (Table 6). When a repair cannot be completed within that time frame, it is then possible to use a component from the limb bank, and still provide the prosthesis to the patient on the same day. In those cases where patients live hundreds of miles outside of Michigan, it is possible to limit turnaround time to 48 hours by the use of various overnight/express delivery services. A second advantage of a limb bank is the opportunity to provide a child with an electronic prosthesis, regardless of the family’s ability to pay. Since the majority of the cost of electronic prostheses is related to the electronic hardware, the use of the limb bank componentry, in those instances where financial resources are limited, can be of tremendous benefit to many families. A third benefit of limb bank componentry involves the use of the preparatory electronic prosthesis.

Preparatory Electronic Prostheses
Although this paper started out with an example of two successful cases, one in Sweden and one in Michigan, it should not be assumed that all children or infants are suitable candidates for electronic prostheses. In those cases where the clinic team entertains doubts as to the successful outcome of an electronic fitting, the use of a preparatory electronic prosthesis can be very helpful in identifying the most likely result. Since limb bank components can be utilized, it is possible to provide a preparatory electronic prosthesis at a fraction of the cost of a totally new prosthesis. The purpose of a preparatory electronic prosthesis is threefold, consisting of preparation, evaluation, and training.

The objectives of a preparatory electronic prosthesis include: (a) the establishment of optimum electrode sites, (b) the improvement of myo signal strength and (c) conditioning of tissues to accept the self-suspended socket and weight of the prosthesis. By way of evaluation, the preparatory electronic prosthesis helps to (a) validate the practicability of the socket design and the selected components, (b) assess the motivation of both the patient and the parents, (c) demonstrate the overall functional value of the prosthesis to the patient and the family and (d) provide clinical evidence to support cost/benefit rationale. In terms of training, this prosthesis helps the patient discover the operating characteristics of the prosthesis, and allows the patient to practice appropriate activities of daily living with a properly fitted electronic prosthesis. Although a preparatory electronic prosthesis should be fitted with the same care as any definitive prosthesis, the fabrication process and the components used provide a very cost effective way of analyzing the patient’s true needs.

Criteria for Electronic Fittings
The question of when to fit an electronic prosthesis to a limb deficient infant has yet to be decided. Since the application of electronic prostheses at the twelve month age level is a relatively new practice within the last five years, the assessment of its long range implications will not be evident for at least another ten to fifteen years. Although chronological age is the most common quantitative reference used when describing the maturational stage of interaction, it is the developmental readiness of each individual patient that is most crucial to a successful outcome. As Wendt and Shaperman indicated in their 1970 study of early fittings with a cable-controlled hook, there is a definite timetable of neuromuscular maturation that is unique to each infant. Until the child reaches that level of neuromuscular potential, it is unlikely that an activated prosthesis will provide additional function for the patient. Based on the original research done by Halverson 11 and Gesell 12, and more recent investigations by Erhardt 13, it is reasonable to assume that normal prehension in an infant is developed somewhere between twelve to fifteen months of age. However, the findings of Halverson, Gesell and Erhardt are primarily focused on unilateral development, which leaves the question of bimanual function unanswered at the present time.

Aside from the issues connected with normal human development, the area of psycho/social dynamics, particularly at the family level, can have even more influence on the long range results of early prosthetic intervention. As pointed out by Brooks and Shaperman in their study of infant prosthetic fittings, 14 the major reason for rejection on the part of a child is usually related to the lack of support and participation on the part of the parents. The significance of positive parental involvement, has also been identified by Sörbye 15 in his report on children’s myoelectric fittings.

In our experience we have found the question of parental and family support to be an important issue affecting the success or failure of our treatment program. Every effort should be made not only to maintain effective and open lines of communication with the parents, but also to design the treatment delivery system in such a way that even the most common stumbling blocks have been removed. This goal may necessitate the inability to arrange for flexible scheduling of appointments, either with the therapist or with the prosthetist, can pose extreme difficulty in some family situations. In addition, the distance to be traveled either to the clinic for therapy, or to the prosthetist for service can have a detrimental effect on the long range commitment by the parents. Every effort should be made to identify these problems within the family unit as early as possible.

If such difficulties are insurmountable, they can in many instances provide the reason for failure in the future, and should be treated with the same gravity as
Advantages and Disadvantages

Inevitably the question of comparative advantages and disadvantages between the electronic prosthesis and the mechanical cable-driven prosthesis arises. Among the benefits of electronic limbs, the first and foremost would be the more natural, closer-to-normal appearance of the electric hand. Although an infant may have little or no appreciation for the cosmetic appearance of the electric hand, our experience has shown that the parents' acceptance of their child's prosthesis is closely related to its appearance. Many parents have admitted that they have either delayed or indefinitely postponed previous prosthetic treatment, when confronted with the choice of various hook terminal devices as the only option to function. This coincides with the early findings of Atkin and Frantz, and the later study by Sharples of over 300 amputees, which identified cosmetic appearance as the number one priority, most amputees have regarding the prosthesis. Secondly, because the electric hand is externally powered, it provides a grip force that more closely approximates the strength of an infant's natural hand. When compared to the one quarter to one half pound of pinch available on most cable-driven hooks, the four pounds of grip available with the smallest electric hand provides a much more functional prosthesis. A third consideration is the potential ability of the prosthesis to be used in all spatial planes, compared to the limitation of the harness controlled, cable-driven mechanical hook. A fourth element is the ease with which the electronic prosthesis can be controlled by the infant. This is particularly true of the new electronic circuits, which provide single-site, single-function control, whereby a muscle contraction on the part of the infant will initiate hand opening, and total relaxation of the musculature will provide automatic closing. Lastly, the elimination of the shoulder harness provides greater comfort, less resistance to wearing the prosthesis, and as pointed out be Challenger, eliminates the need for unnatural gross body movements.

Among the disadvantages, the financial cost of providing a sophisticated electronic prosthesis is of primary concern. We have found that this problem can be overcome, but does require a concentrated amount of time and effort in order to secure adequate funding. In the USA today, most families have health insurance which covers the majority of expenses, and in cases where both parents work, there are frequently two insurance policies which eliminate the need for any out-of-pocket expense. A second disadvantage is the inability to use the prosthesis within certain environments, most particularly in wet or sandy situations. Since children are inclined to play in sand boxes, and usually develop a fascination with water, it is not surprising that these tendencies will contribute to an occasional malfunction of the electro-mechanical system. Under these circumstances, it is very important that the cosmetic glove be inspected frequently for any cuts or holes, since it provides the basic protection for the underlying components. A third consideration is the use of self-suspended socket designs, which in the absence of a suspension harness, facilitates the ease with which a child may remove the prosthesis at inappropriate times, thereby creating additional frustration for the parents. This problem has been solved recently by the use of an elastic or neoprene suspension sleeve, which helps to secure the prosthesis to the child regardless of how much he or she may want to remove it.

Conclusion

Although modern day technology has provided us with the means to replace a normal human limb with an electronic surrogate, the wisdom of applying this technology to infants has yet to be sorted out. As care givers, we are naturally inclined to provide the best that we can to those infants and children placed in our care. Our mandate at this point in time is to be as objective as possible, in carrying out our duties, while still holding on to the subjective instincts which allow us to provide "high tech" treatment with a "high touch" focus.

References


15 Stedman’s Medical Dictionary, 21st Edition, Williams & Wilkins, Baltimore, 1966


MYOELECTRIC PROSTHESES FOR INFANTS

H J B. Day

The following account is based on, and contains results which were presented by the author at the Hugh MacMillan Rehabilitation Centre, Toronto in August 1990 on the occasion of the Bill Sauter Symposium

The Children’s Clinic

This paper deals only with the experience at Manchester where, for over 20 years, every child with an arm deficiency has been assessed, fitted, trained and followed up by the same team of prosthetists, therapists and doctor. Paediatricians in this region are encouraged to refer children with limb deficiency to our clinic as soon as possible after birth so that we can counsel the parents effectively and sympathetically, plan the child’s treatment, and start to build a trusting, friendly relationship. On the first visit the family is not surrounded by “the Team”, which might be daunting, but I spend an hour or more with them, discussing the nature and effect of the deficiency, its cause or lack of known cause, and the proposed treatment. I obtain agreement to the object of our treatment which is to help their offspring see itself as having the smallest possible handicap both as a child and later as an adult. The whole of this consultation is recorded on an audio cassette which the parents take away as an aide memoire.

The Myoelectric Trial

In 1978 The British Department of Health set up a trial under the National Health Service to investigate the benefit to children of myoelectric prostheses. It was decided to limit this to those who had a level of loss in the middle third of the forearm, had been fitted previously with a conventional prosthesis, and who were aged between 3 1/2 and 4 1/2 years.

All who met these simple criteria were assessed at three centres; Manchester, London and Edinburgh, where altogether 87 children were fitted during the next three years. In 1981 the formal trial, which was judged to be successful, ceased and it was decided to continue fitting suitable children as they reached the age of about 3 1/2 years, and to extend assessment and fitting to include children of other ages, and those with other levels of loss.

In each of the following years an older age group was included in the programme and the Manchester clinic continued to look after those referred from other centres in the North of England as well as those living locally until 1985 when some of the other centres started their own fitting programmes. By this time the major backlog of children had been dealt with and the Manchester clinic was able to expand its fitting programme to include adults. In 1987 changes in the organization of the prosthetics service within the NHS resulted in fewer patients being referred to supraregional centres. All these changes had implications which will be considered further in the section on results.

Present Treatment Programme

The programme, although individual, follows a general pattern dependent on the level of loss. No prosthesis is prescribed for those with longitudinal hand deficiencies or with transverse deficiencies at wrist level or more distally. The child is encouraged to explore the environment and develop as much function as possible; our therapist advises on this and on how to solve
problems as they arise. Opposition devices may be needed to help carry out those tasks which present difficulty; the earliest being to eat two handed. At school, the attention of peers may cause embarrassment, which can be alleviated by providing a cosmetic cover, though this is seldom worn. Later, some benefit comes from a formal prosthesis, perhaps of the wrist actuated type, when it is possible to fit this without too much length discrepancy. It is sometimes possible to fit an electric hand to those with deficiencies at or about wrist level later when the longer natural hand minimizes the length discrepancy.

Those with a transverse forearm deficiency proximal to the lower third are fitted with a passive foam filled prosthesis at about 3 months. We used to provide a functional prosthesis with a split hook at about 18 months, but in the last ten years have preferred to use the CAPP terminal device because:

- the centre pull provides the same efficiency whatever the rotational attitude
- it is better accepted by most parents
- it can be made into a toy
- it is less likely to cause self injury and
- it can hold large objects
- it is supplied earlier, at about 15 months, with benefit although the age of achieving true bimanual activity is unchanged at about 2 years.

The fitting of an electric hand instead of the CAPP TD at 15-18 months might seem logical, but when the trial finished in 1981 first priority was given to those who were too old in 1978. Later, a number of younger children were fitted, but few under three years accepted the weight of the Systemenik hand. Thus forearm deficient children are fitted with the CAPP terminal device at 12 to 15 months, and change to an electric hand is considered at 2½ - 3 years although the time of fitting such a prosthesis is dependant on the size of the child and its attention span rather than age.

In our view there is benefit in teaching the children both methods of control, so that their eventual choice can be based on their own experience. Indeed a number have moved from type to type depending on their requirements at various times.

Virtually all below elbow cases are fitted with self suspending sockets and a simple shoulder loop for the operating cord, instead of the complex Non Corset Appendage or appendage with triceps pad. The preferred socket shape is neither a Münster nor North Western supracondylar, but has a well defined ridge at the brim.

Initial fitting of those with transverse deficiencies at or above elbow level is delayed because the prosthesis is in the way when the baby spends so much time lying down. We usually provide a soft prosthesis with a prefitted elbow at 5-7 months, and change to one with a free elbow with voluntary flexion once the child is walking. A cord operated terminal device is incorporated when the child can use an elbow lock. If the lock is at shoulder level, the infant is encouraged to use its feet for prehension, but provision of a prosthesis, particularly in unilateral cases seems to be helpful in preventing scoliosis.

As patients with a single above elbow loss seldom have difficulty in achieving elbow flexion using the operating cord from the opposite shoulder it is appropriate to fit a hybrid power prosthesis in which body powered elbow flexion and locking is combined with an electric hand. Powered elbow units may, of course, benefit some, particularly those with bilateral loss.

We prefer to control the hand myoelectrically from electrodes over biceps and triceps (or more proximally) but if this is not possible a Systemenik hand with "voluntary opening" switch control or a Steeper positional servo hand is used. There are several alternative ways of incorporating this in the harness. The preferred method is to attach the transducer cord to a belt so the hand is opened by shoulder elevation, and is thus separated from elbow movement produced by protraction. The transducer can be mounted within a belt so that expanding the abdomen causes the hand to open. One mother liked this because it caused her son to drop his fork when he had eaten enough. Inevitably, perhaps, this has been named the Self Limiting Input Method or "SLIM". It is also possible to mount the transducer in the forearm connected to the conventional operating cord, passing through the flexion lever at the elbow. The elbow mechanism includes a switch which enables hand operation only when the elbow joint is locked. This method, whilst effective, has the disadvantage of returning to the robotic sequence of flexion - locking - terminal device operation of the body powered arm.

Assessment for Myoelectric Prosthesis

First, is it technically possible to fit such a prosthesis? This is mainly concerned with the length of the forearm remnant:
- if long, is there space to fit the hand without making the whole arm too long?
- if short, will the prosthesis be too heavy or will suspension of the socket be so inadequate, that the child cannot achieve reliable control?

Second, having decided that it is technically possible, is it the right treatment for the child at this time?

These decisions are made as part of the continuing process of care for those children who already attend our centre, but children referred from other centres attend for formal assessment.

During the first year or two of the trial programme the electric hand was provided on a "try it and see" basis because of our inexperience, but it became obvious that some children, having little interest in the prosthesis, were upset because they were pushed to "succeed". The exaggeration of media reports gives many parents unrealistic expectations of the hand, and they may see its application to their offspring as a means of assuaging the feelings of guilt which so often accompany these deficiencies. It is therefore vital to explain to the parents exactly how the prosthesis works, what it can do, and its limitations, before starting to discuss it in relation to their own child. They must understand that this type of prosthesis is only one alternative to be considered in our objective of helping the child to see himself or herself as having the smallest possible handicap.

While this discussion is proceeding, the child, who is playing with toys, has been watched unobtrusively to see how he or she uses the deficient arm and prosthesis. The child is encouraged to play with a myoelectric prosthesis to judge reaction and attention span, and then examined to make sure that it is technically possible to fit this type of prosthesis. Having confirmed this, we have to make a judgement as to its potential benefit.

- If the child has shown some interest, electrodes are held on the arm or a simple Myotester is used, partly to assess ability to control, but mainly to see whether the interest can be maintained.
- If not, or if the attention span is short it is better to delay and assess again at a later visit.
- If the child has not worn any prosthesis recently, a trial period with a conventional arm is advised. It may be worth loading this gradually in order to accustom the child to the weight.
- If the child always wears a split hook, an interchangeable mechanical hand can be
tried to see whether the different grip geometry is accepted.
- We need to know what is planned with regard to education as we wish to avoid fitting a child with a powered prosthesis at the same time as starting or changing school.
- The attitude of the parents must be gauged; are their expectations reasonable? Are they going to cope with the equipment? Do they understand its capabilities and limitations and realize that parental pressure may affect their child’s happiness as well as prejudicing prosthetic success.

Indeed, even with an excellent parental attitude, the interest of relatives and friends evinced by the wonders of the “Bionic Hand” may apply unwelcome stress to both parents and child, so it is necessary that those children who are not interested are identified and fitting delayed until such time as they develop a more positive motivation. The same basic considerations are used for older children (and adults) who have to be positive in their desire for the prosthesis, and willing to practice diligently to achieve good results. If it is decided that the electric prosthesis is not suitable, a full explanation is given to the parents, and a promise made to reassess the child in the future, if this is indicated. A significant number of children who were considered unsuitable for one or other of the reasons given, were reassessed and fitted at a later date.

We have not found pretraining to be helpful in young children. In general we feel they should learn to control a hand rather than electric toys, and hand operation and positioning should be practiced together. Originally mother and child stayed for a week’s training after fitting, but as we found that most children became bored after two or three days, we now give no more than two days training at a time. The parents are encouraged to telephone us for advice whenever they want between follow up appointments and the therapist maintains liaison with local colleagues and the school.

Results

Patient Section

The following results refer to those fitted between August 1978, when the trial started, and the end of 1988. These patients could be divided into two groups depending on their address.

1. Children living in the area normally serviced by the Manchester centre had been seen there since shortly after birth, so any who for various reasons (eg level of loss) were unsuitable to this type of prosthesis were excluded at an early stage. The decision about the optimum age of fitting the others was made as part of the continuing process of care 89 of these children have been fitted, but there are no figures on those for whom the myoelectric prosthesis was considered unsuitable.

2. Many more children living in the north of England were referred to Manchester, but it should be realized that their assessment was in stages - firstly by the clinic team at their local centre, secondly by their willingness to travel (although expenses were paid) and finally as a formal assessment when they arrived.

In all, 222 of these children were seen and 177 (80%) of these were fitted (Table 1).

### Table 1

<table>
<thead>
<tr>
<th>Selection</th>
<th>Accepted</th>
</tr>
</thead>
<tbody>
<tr>
<td>From other centres</td>
<td>222</td>
</tr>
<tr>
<td>Local Children</td>
<td>89</td>
</tr>
<tr>
<td>Total</td>
<td>311</td>
</tr>
</tbody>
</table>

Male - 54.7%  
Female - 45.3%  

Jonasity - Left - 58% 
Right - 42% 

Cause - Congenital - 96% 
Birth - 4% 

Level - Below knee - 94% 
Others - 6% 

Patient Characteristics

During the period under review:
- 266 children were fitted with electric prostheses
- The sex distribution of those fitted = 55.3% male; 44.7% female (distribution of the 311 considered = 54.7% male; 45.3% female)
- The ratio of left to right arm was 58%; 42%
- Over 96% of the total were cases of congenital limb deficiency
- 245 (91.4%) had a level of loss in the forearm

As 8 children are untraceable the remainder of the results refer to a total of 266 - 8 = 258. Of these, 116 (45%) were under the age of four years when fitted with the electric hand (Table 2).

The remainder were more or less equally spread across three age bands. Whereas the number of young children fitted each year has been fairly constant (Figure 1) the older age groups show the effects of the logistics of the programme mentioned before, i.e. that a relatively large number of each age group was concentrated into a short period. Furthermore the effect of the change of regional policy now shows in the decreasing overall number fitted in the later years.

### Table 2

<table>
<thead>
<tr>
<th>AGE: when first fitted with electric hand</th>
<th>NUMBER OF PATIENTS FITTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL REPORTED: 258 (266 - 8 untraceable)</td>
<td>258 (100%)</td>
</tr>
<tr>
<td>Under 4 years</td>
<td>116 (45%)</td>
</tr>
<tr>
<td>4 - 8 years</td>
<td>43 (16.6%)</td>
</tr>
<tr>
<td>8 - 12 years</td>
<td>49 (19%)</td>
</tr>
<tr>
<td>12 - 16 years</td>
<td>50 (19.5%)</td>
</tr>
</tbody>
</table>

Outcome

If we are to determine whether the myoelectric prosthesis is beneficial, we need to know first how many have abandoned it, when, and for what reason. Problems arise in getting reliable answers, as parents and patients may be unwilling to admit that the hand is no longer worn. The figures relating to the time of giving up are also suspect, particularly if this has occurred more than about 4 years after fitting. However by a combination of follow up appointments, and an analysis of repair patterns and particularly glove replacement, it is possible to have some confidence in one’s figures.

![Figure 1: Number of patients fitted, by age](image)
It is appropriate to consider first the percentage who gave up wearing the electric hand in the first two years, as all members of this group of 258 children were fitted before the end of 1988. Furthermore this figure should be reasonably reliable because they are likely to still be regular attendees at the clinic.

A total of 28.7% of all those fitted (Table 3) had abandoned the electric hand within the first two years, and the percentage of individual age groups range from 20 to 36% (of 89 adults fitted, 31.5% gave up during this period)

The figure for those who discarded the hand later, whilst factual at the time of writing, will increase as the follow up period of those children fitted recently lengthens.

The reasons given for abandoning this type of prosthesis are many and varied, including unwelcome attention from peers, failure to meet (unrealistic) expectations, and lack of reliability of control. But the weight of the hand is by far the most frequent cause, particularly among the younger children.

The positive figure of those who continue to wear the prosthesis is obtained by difference, and it is worth noting that the percentage only varies between 46 and 54%, with an overall figure of 50.4%.

(The percentage of adults who remain wearers (67%) is inflated by the fact that no adult has a longer follow up than 5 years).

The situation is further complicated because a significant number of children, having given up the hand, are fitted again later. Thus it becomes impossible to express the results as a percentage either of the age group as a whole or modified by the numbers fitted in more recent years and a more effective way of showing utilization is needed.

The actual number of patient/years worn can be expressed as a percentage of the total possible e.g. Suppose 5 patients were fitted 10 years ago

1 gave up after 1 year = 1
1 gave up after 4 years = 4
2 still wear the arm = 2 x 10 = 20
1 gave up after 3 years = 3
and started again 4 years ago = 1 x 4 = 4

The total actually worn = 32
The total possible = 5 x 10 = 50

The actual utilization would be 64%

Applying this method (Table 4) shows that the utilization of the four age groups only varies between 66.1% and 70.8% with a figure for all ages of 68.2%. These figures confirm our subjective impression that the age of first fitting has little effect on the long term acceptance of the electric hand.

<table>
<thead>
<tr>
<th>AGE FIRST FITTED</th>
<th>UTILIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 4 years (116)</td>
<td>67.5%</td>
</tr>
<tr>
<td>4 - 8 years (49)</td>
<td>66.1%</td>
</tr>
<tr>
<td>8 - 12 years (49)</td>
<td>69.2%</td>
</tr>
<tr>
<td>12 - 16 years (50)</td>
<td>70.8%</td>
</tr>
<tr>
<td>Total all ages (258)</td>
<td>68.2%</td>
</tr>
</tbody>
</table>

It is now necessary to discover from those who continue to use the hand, for what purposes it is preferred, and why it is liked and disliked. In 1990 therefore, a questionnaire regarding their use of the hand was sent to the 130 children who were confirmed as users of this type of prosthesis. 87 replies were detailed enough for analysis and these children reflected the age distribution adequately (Table 5).

The first set of questions addressed the use of the hand at work or school, and it should be noted that the age of the children in 1990 ranged from 4 to 5 years (a child aged under 3 when fitted in 1988) to 23 years (16 years old when fitted in 1983).

The patient or parent was asked to complete a time table of wear during the week, the result of which was averaged into one of five grades:

- less than 1/4 of the working day
- between 1/4 and 1/2 of the working day
- between 1/2 and 3/4 of the working day
- between 3/4 and full time use
- all day, every day.

The results are shown in Figure 2 of those who do not wear the electric hand "all day, every day", 14% wear a splint hook (or similar terminal device), 4% a passive hand and 46% no prosthesis for the remainder of the time.

Use in the evenings and at weekends was divided into wear in the home, and socially.

Of the whole group 44.7% use the electric hand, 9.4% passive hand and 45.9% wear no prosthesis as their first choice in the home
Table 6 shows the preferences as percentages of each age group. It is too complex to present all the possible second choices, but overall 26% wear the electric hand all the time and a further 34% some of the time.

Of the whole group 67.8% wear the electric hand, 20.7% a passive hand and 11.5% wear no prosthesis when going out socially in the evenings and at weekends.

Table 7 shows these preferences as percentages of each age group. Again the second choices are complex, but overall the electric hand is worn always by 50.6%, usually by 17.2% and sometimes by 3% of the respondents.

Why do they like them? Some perceive a functional advantage, others are attracted by the dynamic cosmesis which this hand provides, despite its somewhat robotic appearance, and of course most find both aspects advantageous.

The hand is found useful for all those activities which require bimanual use and particularly when reaching at full arm length or in confined spaces, both of which make shoulder cord operation difficult if not impossible.

Overall 60% rated its appearance between 8 and 10 on a 10 point scale, and 72% rated

children and the age of first fitting does not have a significant effect on that acceptance.

Indeed one half of those fitted more than five years ago, and one third of those fitted ten years ago are still wearing powered prostheses.

Table 8 combines information from Figure 2 and Tables 6 and 7 to show the percentage of each age group who prefer the electric hand.

From this we note that overall some two thirds of the patients prefer this prosthesis for the majority of time at school or work and when going out socially, but under half choose to use it at home. This pattern is
expected but the behaviour of each age group merits attention
1. A fairly constant percentage of the youngest prefer the myoelectric type for all
activities, and this may indicate a degree of
compliance, appropriate at this age, leading
to habit
2. The 4-8 year olds have the smallest
percentage using it in all three milieu, but
particularly at home, which may indicate a
“quid pro quo” for wearing it at school and
socially. A significant number of parents
said in the survey “I let him/her take it off
after school”
3. The 8-12 group (and it should be
remembered that the majority of this group
were aged between 15 and 19 when they
answered the questions) shows a very high
use at school or college and the highest use
of all socially. This latter reflects the
cosmetic benefit of a moving hand
Interestingly nearly 40% wear it at home as
a first choice
4. The last group, of whom the majority
are now aged between 18 and 23, appear to
be less keen on the hand for college or work,
although 70% of them wear it for between
1/4 and 1/2 of the time (Figure 2). But a high
percentage of this group wears it socially
confirming the concept that one of the major
advantages of the myoelectric prosthesis is
its dynamic cosmesis
5. Two thirds or more of adult wearers
prefer the myoelectric prosthesis throughout,
and particularly in their social life. The
benefit provided by this hand was
highlighted in the statement of one young
man, with a congenital deficiency, who had
worn a conventional prosthesis until he was
21 years old “For the first time in my life I
feel part of the human race. Not only do I
have a hand that looks and behaves (at a
glance) in a natural way, but it also operates
in a way that makes me feel human. I could
not envisage life without the electric hand
and I couldn’t leave the house without it”
However despite this statement, the
myoelectric does not “become part of the
body image
Experience shows that a number of
patients retain and use both myoelectric and
body powered control for different purposes,
and a number of children having worn one
type for a few years have then reverted to
the other with no loss of skill. Indeed 2 of our
children, fitted originally more than 8 years
ago are now wearing electric hands for the
third time, having been successful on each
occasion

The Optimum Age of Fitting
We accept from these results that the
myoelectric prosthesis is the most
satisfactory type for the majority of those
with upper limb deficiency, particularly at
the forearm level
At what age should it be fitted to infants?
Because of the logistics of the situation in
the UK the smallest hand available was the
Systemtik 2”. We have fitted this to
children of 2 1/2 but the majority were aged
between 3 1/4 and 3 1/2. At a lighter hand had
been available, such as the VV 103 or the
Bock Electrowand 2000, I would certainly
have tried fitting some younger children, but
it seems unlikely that any real benefits
would accrue from fitting earlier than about
18 months for the following reasons:
1. Strength of grip Many parents rightly
perceive a danger of self-injury from split
hooks in young children, indeed the safety of
the CAPP device is one of its advantages.
We have seen young children grip hold of
their noses (or other protruding parts) with
the electric hand and be unable to release it.
Suggestions that the hand should be
connected to its battery only when the child
is supervised will only serve to confuse the
child whose hand only works some of the
time. Indeed unreliability of hand operation
has proved to be one of the reasons for
discarding the prosthesis
2. Whilst almost all children fitted with a
CAPP device at 12-15 months soon achieve
voluntary opening, few use the device in
a deliberate and effective prothetic manner
under the age of 18-24 months
3. There is no doubt that providing this
type of prosthesis adds some stress to
parents and child, and this is particularly
marked if the child’s skill with the device, or
indeed its level of use, does not improve as
fast as the family hopes
The declared objective with all these
children is to help them to grow up to see
themselves as having the minimum
handicap, and this is most likely to be
achieved if the child is allowed, at this early
age, to develop its own skills in its own way,
without being encouraged, cajolled or frankly
pressed into a different activity
4. As the results obtained in Manchester
over the last 12 years do not indicate that
children fitted before the age of 4 accept or
use this type of prosthesis any better than
those fitted later, it seems unlikely that
fitting at under two years will make any
significant change
5. Fitting the child with a passive
prosthesis at 3 or 4 months, changing to an
active body powered type at 12-15 months
and then to an electric hand at 2 years or so
provides an educative process which later
will help the child to make a decision based
on its own experience
The principal factors in determining the
success of any treatment are those concerned
with culture, need, and self (and family)
perception, which are interwoven in a
complex manner. For example, the greater
use of the split hook by adults in the United
States, which LeBlanc suggests is due to
national characteristics, might also be due to
the greater frequency of arm loss there. In
England and Wales, with a population of 50
million, out of 5500 amputees who were
referred to the prosthetic service in 1987,
only 250 were cases of upper limb loss,
representing an incidence of 1 in 200 000 of
the population. Whereas, in the USA
population 238 million, Atkins and Meier quote an estimate of 40 000 amputations
annually, of which 12 000 are cases of upper
limb loss representing an incidence of 1 in
20 000. The fact that adult arm amputees are
ten times as common in the U.S might be a
reason why the hook is accepted there, while
in UK the comparative rarity of arm
amputees leads many to want to conceal
their loss. Other cultures find any prosthetic
terminal device other than the best possible
cosmetic hand unacceptable.
Another factor which plays a major part
in determining success is the system of
prosthetic supply and its funding. In the
United Kingdom there is no need for private
purchases as the Health Service provides the
clinic advice, counselling, continuing care
and prosthetic supply, without charge. Most
parents, recognizing that the members of the
clinic team have no financial interest in any
particular treatment, trust them and their
advice and neither feel that they are
“entitled” to come particular form of
treatment, nor seek some unattainable
solution elsewhere

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HUGH MACMILLAN REHABILITATION CENTRE
PRE-SCHOOL MYOELECTRIC EXPERIENCE

Sheila Hubbard

At the Hugh MacMillan Rehabilitation Centre (HMRC), a team approach is used in the management of the juvenile upper extremity amputee. The clinical team is comprised of physicians, prosthetists, physical and occupational therapists, a social worker and nursing staff. Psychology and Rehabilitation Engineering personnel complement the group. The Powered Upper Extremity Caseload averages 240 patients and clinics are held on a weekly basis.

The children are usually referred as infants to the clinic and the family is given an orientation to upper-extremity prosthetics. A passive prosthesis is provided at approximately 5-6 months of age. When the child approaches 12-15 months of age, the various options for activation, both conventional and myoelectric, are presented to the family and they are encouraged to participate in the decision making process.

Historical Background

Our Pre-School myoelectric program originated in the years 1978-80 with three experimental fittings. The parents of these children knew that older children were being routinely fitted myoelectrically and were determined to have the same provided for their children. We had also had the opportunity to read and hear Rolf Sörbye speak of his work in Sweden and were excited about the possibilities of fitting younger children.

The first child, fitted at the age of 2 years, 9 months, was given a Swedish electric hand controlled by an Otto Bock two-muscle system in September, 1978. Her control ability was limited until the control system was converted to a U.N.B one-muscle, three-state control system some months later. The other two children both aged 2 years, 11 months at time of fitting, were also given three-state control systems, one in October, 1979 and the other in May of 1980. Both of these children demonstrated good control at the time of fitting. All three of the children continue to wear their myoelectric systems today.

Pre-School Study

In 1980 a two year formal research project was funded by the Hospital for Sick Children Foundation to develop effective strategies for training the preschool child to operate a myoelectric prosthesis. Two protocols were developed: one home-based with the parent as primary trainer, and the other, Centre-based with the therapist as trainer. Eighteen children, who had an established wearing pattern with their conventional prostheses, were selected and alternately assigned to the two training regimens. The age range at time of training was 2 years 7 months to 5 years 1 month with a mean age of 3 years 7 months. The youngest subject, however, was subsequently dropped from the home based protocol as the parents were unable to attain sufficient cooperation to carry out the training procedures. The youngest child to complete the study was 2 years 9 months.

Briefly, the results were as follows: seventeen children were successfully trained and fitted and both training protocols appeared to be equally effective, proving that informed parents could assume responsibility for myoelectric control training. Sixteen were fitted with the Otto Bock two-site system while one child
required a one-muscle system and the UNB three-state control system was used. Adjustments to the myoelectric prostheses by the children varied considerably. Some accepted the prosthesis readily and quickly became full time wearers while others were slower to build up tolerance to the added weight, heat and supracondylar suspension. The parent training proved to be cost effective when compared to the therapist training. Age of the children at the time of training did not appear to be a significant factor.

A rating scale test was also developed to assess the prosthesis skill attained at one, three and six months following fitting. The test was recorded on videotape and scored by an outside evaluator. Results for the therapist-trained group were higher at one month but not significantly different for subsequent tests. At six months the mean score for the group was 30.5 out of a possible 35 points. Their functional ability was therefore considered to be quite promising. A variety of training aids including toys and the imaginative use of the training hand were found to be essential in order to capture and maintain the interest of pre-school aged children. No particular difficulty occurred in the actual fitting or fabrication of the prostheses. This study was subsequently published and a comprehensive report and training manual were made available.

With the success of this project and the financial support of the Ontario Government’s Assistive Devices Program (A.D.P.) and the War Amputees of Canada’s CHAMP program, myoelectric prostheses then became a standard below-elbow option for children aged 2 1/2 and older at the HMRC. A less formal training protocol was used but the same strategies were employed. If the child was able to demonstrate voluntary control readily at the time of assessment we proceeded with fitting. Otherwise, a home training program was implemented. Use of the Swedish hand was discontinued in favor of the newer lighter VASI VV2-6 hand when it became available in 1984.

A three year follow-up of the original research group was carried out in the fall of 1984. The aims of the follow-up were three-fold:
1. to determine the technical problems for young children over a 3 year period;
2. to obtain information about the child’s normal use of the prosthesis and the attitude of both child and parent to it;
3. to reassess the child’s functional skill level.

Twelve of the original 17 children were available at that time for testing and the same videotaped evaluation procedure was repeated. The results showed that after 3 years, 16.7% were considered good performers, 58.3% were classed as average and 25% as poor. Some factors determining eventual performance were suggested to be the child’s own inherent ability to control the system, the number of prosthetic repairs necessary and the amount of parental involvement.

Over three years, the mean number of socket replacements was 2.1 and gloves 8.8. The boys and older children in the group required more repairs than the girls or younger children. The most frequent servicing needs included socket brim modifications for growth, replacement and adjustment of electrodes, tightening of the wrist unit and repair of the charger plug.

Fourteen of the families completed questionnaires as well. All of the parents were pleased with both the cosmetic and function of the myoelectric prosthesis and felt that it increased their child’s self-image. Thirteen reported that their children were wearing it 8-12 hours per day while one only used it 4-6 hours per day. It was also known at that time that one child, the oldest subject in the original research group, had ceased to wear any type of prosthesis.

Early Above-Elbow Fittings

Seeing other children’s success with myoelectric prostheses, parents of the above-elbow patients then began to motivate for similar systems for their pre-schoolers. Three children aged 3 to 5 years were subsequently fitted with above-elbow myoelectrically controlled hands in 1983. Various mechanical elbows were used and we did not experience any significant problem fitting myoelectrically at this level of amputation.

Early Bird Project

The next trial period at HMRC occurred in 1984 to meet the increasing demand for myoelectric systems at the time of normal activation. Families were reluctant to accept either the 12 P hook or CAPP terminal devices and preferred to keep the passive hand until a myoelectric prosthesis could be provided to them. Rather than see the children left with a passive device, it was decided to try fitting at an earlier age. Six children ranging in age from 15 months to 27 months then participated in the ‘Early Bird’ pilot study.

It was quickly realized that the children were too young to cooperate with the usual electromyographic assessment or control training procedures. In fact, not only did younger children not understand the cause and effect relationship but they were often frightened by the electric toys or training hand. It was therefore decided to take an “eye-ball” approach to identify suitable electrode sites for the Otto Bock two-site system. The plan was to fit the prosthesis and then allow the children to learn control at their own developmental pace. Parents were asked to keep a journal, and calibration of the electrodes was based on their observations of hand activity.

To ease application and discourage patient removal it was decided to decrease the condylar clamping and supply a harness to assist suspension. The battery cells were placed externally on the harness to lessen the distal weight. Initially, a resistor in the motor leads was added to decrease the pinch force and thus reduce the chance of the children pinching themselves.

For a variety of reasons this endeavour proved to be disappointing. First of all, the external battery placement resulted in constant wire breakage and the need for frequent servicing. The children were thus unable to develop a consistent wearing pattern. Secondly, although fitted younger, the children did not appear to develop voluntary control of the hands any earlier. The norm was 27-28 months of age. The VASI, VV 2-6 hand was also considered to be too large and heavy for this age group. These factors frustrated some of the families and they became less consistent about wear and follow-up.

However, important insights were gained from this experience. It was found that it is essential to have a strong family commitment to ensure the close follow-up needed when patients are fitted at this young an age. More important, it was discovered much later that three of the children were not suitable candidates for a two muscle system in spite of their deceptively long stump lengths. Obviously one cannot expect a child to develop good myoelectric control if the control system itself is not suitable nor calibrated effectively, a task which is difficult to do with a young child. It was also decided that the external battery arrangement was not an acceptable solution and that a smaller electric hand was definitely needed. Our research group was then challenged to
design and develop an infant hand. Our criteria were relatively simple: it should be small, lightweight, cosmetic, and indestructible.

The more usual practice of fitting when the child was found to be cooperative enough to allow for better assessment and fitting, generally between 2-6 months of age, was then followed. Addition of weight to the passive prosthesis was initiated around 18 months in preparation for the myoelectric fitting.

In 1984, the new VASI VV 0-3 hand became available. This made it possible to provide a lighter, more cosmetic prosthesis for younger children. Two other children under the age of two were then fitted myoelectrically with the Otto Bock two-site control system, but again, did not appear to benefit much from the earlier approach.

Single-Site Voluntary Opening Control

The most recent experimentation has involved the use of a single site, voluntary opening control system commonly referred to as the “St. Anthony” or “Cookie Crusher.” Encouraged by the news of Tom Haslam’s success in Texas with a simpler means of control for the very young child, a similar system has been introduced to eighteen of our pre-schoolers in the past two years. Our experience thus far indicates that young children can appear to master this simple mode of control more easily. All of the children have been successfully able to use these systems to operate VASI electric hands. In two cases the children had been unable to control an Otto Bock two-muscle system but were immediately successful with the single-site voluntary opening one. Our youngest patient received his completed myoelectric prosthesis at the age of 13 months and to our surprise was observed deliberately pinching and releasing his own finger within a few minutes of having the prosthesis applied.

Formal therapy training does not appear to be appropriate for the younger infants. Although the children learn how to open and close the hands quite readily, the development of bilateral patterns of prehension is a much slower process. Therefore, suggestions are given to the families to encourage awareness and gradual use of the hand and the children are seen frequently to monitor progress. We have recently started to add a surface “mommy switch” to enable the parent to operate the control system in order to place objects in the hand and encourage voluntary release plan activity. It is hoped that fitting myoelectrically at such an early age will result in a more successful integration of the prosthesis into the child’s body image and ultimately produce a natural, two-handed prothetic user.

In preparation for the possible later introduction of a two-muscle system, our practice has been to use the exterior site for voluntary opening of the hand. Once the child is mature enough for proper evaluation, the most appropriate control system is then determined for that individual. While this approach for managing the young child appears extremely promising, it will be necessary to closely follow a series of these fittings in order to evaluate their cost-effectiveness and determine the most appropriate age to begin myoelectric fitting.

Results/Discussion

As of December 1990, 90 children under the age of 6 had been fitted with powered prostheses.

- **Cause:**
  - Congenital - 104
  - Traumatic - 2

- **Gender:**
  - females - 53
  - males - 53

Side of Amputation:
- left sided - 64
- right sided - 36
- bilateral - 6

Amputation Level:
- 16 above-elbow/S D
- 12 unilateral
- 3 bilateral
- 89 below-elbow
- 87 unilateral
- 2 bilateral
- 1 bilateral with 1 above and 1 below elbow amputation

Age Groups:
- 0-23 months - 14
- age 2 - 33
- age 3 - 29
- age 4 - 15
- age 5 - 15

Below-Elbow Fittings

As of December 1990, 90 children received below-elbow fittings. Age range was 13 months to 5 years. Fifteen patients received wrist disarticulation designed sockets and an obturator or supracondylar cuff was used for suspension. The rest were fitted with hard laminate, modified Hepp-Kühn type sockets and a tube was provided for a pull-in application. Growth adjustments commonly included stretching of the condylar flares, a wedge shaped socket split and posterior rim build ups. Batteries were placed internally if room permitted or mounted externally in the forearm shell.

The Otto Bock two electrode system has been used for the majority of patients. The new Otto Bock analogue electrodes are now being used for the pre-schoolers because of their smaller size and increased E.M.G. sensitivity. However, this system is not always suitable for everyone. For those with only one strong muscle site, a three-state system (Otto Bock double channel or UNIB/VALSI) has been chosen on the basis of residual limb length and muscle control ability. In addition, 15 children have been fitted with the single-site voluntary opening system.

To accommodate for growth it is possible to progress through a series of child hand sizes. The VV 5-9 hand became available in 1989.

Above-Elbow Fittings

As of December 1990, the above-elbow group consisted of 14 children fitted with unilateral A.E. fittings and 3 children with bilateral A.E. fittings. The age range was 22 months to 5 years. Six of the children used switch electric systems, 10 had myoelectric and 1 bilateral had one each. The through shoulder type patients were fitted with hemi thoracic frames with micro switches mounted in the shoulder region. An endoskeletal system was then covered with a cosmetic foam fanning.

The above-elbow design consisted of a hard laminate socket with a silicone extension over the shoulder region. Four patients were able to use an Otto Bock two-muscle system while the rest required a one-muscle control system. Some of the children started off with the VASI three-state control system and were later converted to the Otto Bock double channel system when it became available, in order to save space. Three children are using the single-site voluntary opening control system.

The children were initially fitted with passive elbows. An attempt was made to modify electric hands for use as elbows. Dissatisfaction with that approach finally led to the design and production of the new VASI VV 3-8 mini electric elbow for young children in October 1987. The concept of providing a lightweight, self-contained myoelectric prosthesis for the
young child still presents a difficult technical problem. Since previous experience revealed that external battery systems were prone to increased breakdown, various battery configurations have been used in order to incorporate the batteries into the prosthesis whenever possible.

Wearing Patterns
A survey in January, 1990, revealed that reported wearing patterns varied considerably. 10 subjects were from out of province and had been lost to follow-up. Results for the remaining 96 children were as follows:
- 69.8% were wearing their prostheses on a regular basis
- 24.0% were them most of the time with the exception of some recreational activity
- 19.8% wore them for school hours plus social use
- 13.5% wore them for school
- 6.2% wore them partial days
- 3.1% were occasional wearers
- 27.1% were no longer wearing their prosthetics

The relationship between wearing patterns and age at time of myoelectric fitting is shown in Figure 1. Although the numbers were small, the children fitted at 2 years and younger showed a stronger trend toward full time wear. The critical time for fitting seemed to be under the age of 5. The younger children showed reasonable patterns of wear with rejection rates of 7% to 30.8% whereas the 5 year olds had an extremely high rejection rate of 60%.

The relationship between wearing patterns and level of amputation was also studied (see Figure 2). As one might expect, the use was higher for the below-elbow amputees. Rejection rates were 23.3% for below-elbow, 26.7% for above-elbow and 38.1% for the wrist level patients.

![Wearing Pattern Related to Age](image)

Figure 1

WEARING PATTERN RELATED TO LEVEL OF AMPUTATION

Rejection factors were perceived to be:
- Long residual below-elbow limb length, older age at initial fitting, poor family support, frequency of breakdown, and distance from fitting facility
- We have not recently tried to evaluate the functional skill level of the children in any formal way but are presently working on an appropriate protocol for the future. Plans include using both our micro-computer based control test as well as the UNB Test of Prosthetic Function

Ideally, prosthetic use at school and in the community needs to be assessed in order to more adequately judge functional benefit and to address research and developmental needs for the future. Unfortunately, functional use is often not a primary concern of families and carry-over of training to daily use is less than anticipated. Further training is thus provided during clinic visits and re-fitting periods. The children also appear to benefit from additional training and encouragement by therapists in their local communities.

Psychosocial Issues
At the time of a 1989 caseload review, our social worker interviewed a number of the parents to determine how the families felt about their experiences with myoelectric fittings for their pre-schoolers. While the number of interviews was small and the methodology informal, the issues and concerns that emerged were so repetitive that they bear notice.

Overwhelmingly, parents identified the need to prepare their children for the second crisis stage, the entry into school. Parents were united in their wish to provide "the best" in terms of options and expressed a tremendous feeling of fear over how their children would be accepted by both students and teachers. Consistently, myoelectric prostheses were perceived to be the best because they were hi-tech, the hands moved and they had no straps. The latter two factors make the prosthesis appear more normal in the eyes of parents who perceive that myoelectric prostheses elicit positive responses from other children and adults.
As well, parents clearly feel the reaction of others in public is minimized by the cosmesis of the arm, making the situation easier for both parent and child.

Another theme that emerged strongly was the need to feel competent as parents. To not provide or advocate for what is perceived to be the best would reduce parental self-esteem and cause great anxiety.

Parents did not identify function as their main reason for fitting. Most indicated that the child used the pinch motion on command or to gain the interest of peers but were hard pressed to identify areas of spontaneous use in everyday life. Yet the hope remained that with continued wear the arm would be used more functionally.

Young children will usually aspire to meet adult expectations. When these are unclear, the child is easily led into a trap of failure. Therefore, a comprehensive definition of how well and how practical function in daily life is vitally important to the parents as well as to teachers and other professionals working with these children.

Communication between parents and professionals needs to be addressed as well. A considerable number of parents articulated their feelings of guilt over the fact that much staff time had gone into the fittings and this, combined with the expense of the arm, seemed to make it difficult for the parents to express any negative concerns they might have had about the fittings. Staff need to be very clear about the role they expect the parents to play and to be realistic in their expectations.

Parents also need to know what to expect from their child at different stages in order to react appropriately. The normalisation of patterns of behaviour seen by the professional is a helpful way to reduce guilt, concern of rigid expectations of wear and function. As with any other child, effective parenting skills are required to produce a healthy well-adjusted child.

In addition, there is a need to encourage open communication between parent and child to ensure that the child’s needs and feelings are considered as well. Parents should be aware that the children may see the prosthesis as a nuisance to their level of activity and be sensitive to resultant frustration or passive resistance. Considerable support and encouragement may be required.

Finally, from a psycho-social perspective one cautionary note should be addressed. The question is often asked by team members: “Are we fitting the child or the parent?” The answer may well be that with the 0-5 year group we are indeed fitting both. As professionals we must also examine our own motives and interests, and look clearly at any implicit or subliminal messages being given to families. If the criterion for success is not simply the number of hours a myoelectric device is worn, but instead, a well adjusted amputee with a healthy self image, we must determine whether sufficient energy is going towards focusing on what the child has and not what the child has not.

Summary

In summary, it has been our experience that it is both exciting and worthwhile to provide myoelectric prostheses for pre-school children. The field is new and evolving so quickly, however, that it is impossible to speak in absolutes. Many of the questions being raised about early myoelectric fittings will remain unanswered until considerably more experience has been gained. Ideally, a multi-centre, longitudinal study should be undertaken to determine the cost effectiveness of early myoelectric fitting.

Recommendations to others for a successful effort would include having: a skilled and dedicated team, a family committed and involved in the decision making and training process, an efficient repair and back-up service and a lot of patience.

Improved means of assessment and training are required for the young child. We have recently completed a research project which involved the development of several new microcomputer strategies to enhance myoelectric management. The program includes tools to improve EMG assessment, site selection, calibration and control ability evaluation. The age criteria for subjects in this study was 6 years and older and we are now in the process of evaluating its potential for the pre-school age group.

Other technological needs for the future include the development of more durable gloves, lighter, high capacity batteries and hands which provide greater function.
FITTING YOUNG CHILDREN WITH MYOELECTRIC PROSTHESES

Rosa Jacobs

History: “Cable vs. Myo” to “Myo or Not”

Myoelectric Prosthetics in Children

When we first started our program of fitting children with myoelectric prostheses, we devised a criterion that we felt would guide us in deciding whether a child should be fit with a cable system or whether he or she should go into a myoelectric system. In time, that criterion was dropped. At the present time, unless rare circumstances prevail, children who come through our program are fit only with myoelectric or other electrically powered arms. The question is not cable versus myo when a child comes to us, so much as myoelectric or not. In a case where a child’s wear and follow through are questionable, we go the route of the passive arm, and make our decision from there.

Myoelectric Prosthetics Program
Basic Program Outline and What Makes it Work

In order to understand our statistical summary it is important to give a basic summary of our treatment methods. In an ideal situation, we see a traumatic amputee within 30 days of his or her surgical amputation. That patient is fit immediately with a myoelectric prosthesis and undergoes an intensive therapy program. With a congenital limb deficient patient, ideally, we fit children with a passive prosthesis at 2 months old, depending on how they are progressing developmentally, we fit them with a myoelectric prosthesis around 5 to 8 months old.

We consider an infant as progressing well when the infant is wearing the passive arm comfortably all day, waving it around without hindrance from the weight, and using it for gross motor skills. The child should also have good neck and trunk control, and should be taking an active interest in manipulating toys.

In the case of an older child or a traumatic amputee who has gone a considerable time without a prosthesis, we generally start the amputee with a passive prosthesis prior to myoelectric fit. This is to allow him or her to develop a wearing tolerance, to get used to the heat and weight and to begin to think in two-handed terms. If a child has been consistently wearing a body driven system, we would most likely skip the passive prosthesis and go directly into the myoelectric system.

In all cases, patients go through an intense therapy program in order to assure graduated weight and wear schedules, to teach them electrode usage and give initial feedback, and to guide the patient into incorporating the prosthesis into his or her lifestyle, not just opening and closing the hand on command. Therapy is age related and concentrates on two-handed skills. Even an infant has a repertoire of age appropriate skills on which to draw, such as developmental skills, hand to mouth skills and eye-hand coordination. For all ages, repetition leads to naturalness of use, and family, friends and siblings are an essential part of the rehabilitation effort.
New Question - At What Age Should a Child Be Fit
Immediate Results and Training Ability vs Growing Up With It

The dilemma that this study pursues pertains to when a child should be initially fit with a myoelectric prosthesis. In the case of a traumatic amputee we are thoroughly in agreement with the Malone VA studies. A traumatic amputee should be fit within 30 days of amputation, and each day beyond that decreases prosthetic rehabilitation success. This has proved consistent in our traumatic clientele.

This study, therefore, reflects just the congenital limb deficient patients. If we look strictly at the immediate trainability and response to the prosthesis, our answer would be simple: ages 4 to 10 years old are ideal prosthetic patients. Let us explore the different age groups and what you may expect if you observe rehabilitation immediately upon receiving the prosthesis.

Infants - 5 months old to 1 year old
This group cannot follow directions well. They have very short attention spans, and they do not comprehend the significance of therapy. They have no conception of how other people see them, other than direct Pavlovian response: “If I open my prosthetic hand mother claps with delight and smiles at me.” It takes significant repetition in order to get the infants to retain therapy lessons from one session to the next. They are difficult to schedule and often arrive at their appointed therapy session sound asleep or intensely hungry. On the other hand, they are an open slate to learning and developing habits and patterns. They are not set in their ways, or used to wearing or not wearing anything. They are discovering their bodics for the first time, even though this usually means hand to mouth tendencies and thus a soggy prosthesis.

Toddlers - 1 year to 4 years old
This group still has a short attention span. Therapy sessions generally involve jumping from one activity to the next just to keep them motivated. They have often just discovered their legs, and therapy may consist of chasing them around the room with a task. They are discovering their independence (better known as the terrible twos) and may refuse to perform on demand. On the other hand, they are bundles of curiosity and delight with each new endeavor or newly developed skill. They are perfecting their motor skills and zeroing in on fine motor skills. They are moving towards school age and just becoming acquainted with dressing, feeding and grooming skills.

School-Agers - 5 to 10 years old
This is often the age of first contact with a significant sized peer group and these children often come in motivated for a task. Their parents as well as themselves are excited about the possibility, yet also have come to terms with the limp loss. They are at an age where their attention span is longer and they are able to persistently pursue a task with more patience. They follow directions better and understand the concept of learning. They perform each task on command and their sphere of abilities is greater (scissor usage, drawing skills, tying bows, shooting bow and arrows, dressing skills, etc.) On the other hand these children have developed years of habits and wearing or not wearing patterns.

Adolescents - 11 to 16 years old
These young adults are at an age of peer everything. Acceptance and social skills mark their prosthetics motivations.

Generally, the decision to get a prosthesis is completely theirs. They have good attention spans and learn and perform tasks swiftly. On the other hand, they have even more years of habits, routines and wearing or not wearing patterns.

Adults - 17 years and up
Often the decision to obtain a myoelectric prosthesis at this age is based on specific educational pursuits, professional, job, leisure/sports or daily routine requirements. The decision is based on lifestyle needs and direct motivations. Adult patient are interested in all aspects of the prosthesis (mechanism, care, physiological response, rehabilitation, and research and development). They learn fast and perform a multitude of tasks including carpentry, housekeeping, job related tasks, computer skills, cooking, etc. On the other hand, they have still more years of habits, routines and wearing or not wearing patterns. There is no mom or dad to insist on consistent follow through at home. Adults can be the greatest procrastinators of all groups (“after this meeting” or “once the kids are settled down” or “I’ll really get going on the weekend”, etc.)

Statistical Overview: Age Fit vs Wearing Pattern Two Years Later
The quandry, however, is not which group is the easiest to train upon initial fitting of their first myoelectric prosthesis. It is the long run benefit that we are concerned with. The significant issue is: at what age is it most advantageous to the child to fit the initial myoelectric prosthesis? Our study, therefore, reflects each of the age groups 18 months or more after their initial myoelectric fitting. We have looked at children who were fit as infants, and marked their wearing patterns (prosthetic adjustment), actual use of the hand and personal attachment to their prosthesis 18 months or more after their initial powered fit, and similarly for each of the others age groups. Though the ultimate consideration is to check their response 10 or 20 years later, our program is still too new to have such records.

Statistical Results and Conclusions
Figures 1-3 summarize our results. Data were collected for the study through a questionnaire sent to the families through the mail, and then updated by phone check on the child’s progress as well as re-evaluation during socket refits (See appendix for a copy of the questionnaire.)

Wearing Patterns
Non-wearer = Patient has rejected the myo-prosthesis
Event wearer = Patient puts on the myoelectric prosthesis to attend certain events but does not have a daily wearing routine
Scheduled wearer = Patient wears the prosthesis 3 to 4 hours every day (Vacation Wearer)
Hand Usage

**Puts Up With** = Patient wears the prosthesis because he or she has to but can't wait to get it off after the scheduled period.

**Gross Motor** = Patient wears the prosthesis comfortably without thinking about it, but does not use it unless reminded.

**Gross Motor Hand User** = Very natural with the prosthesis and gross motor movements. Automatically uses the hand for certain activities, but must be reminded or concentrate on using the hand for new skills.

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![Graph showing hand usage percentages.](image)

**Figure 3: Personal Attachment**

- **Intrinsic Hand User** = Very natural with the prosthetic arm and hand. Uses the arm for balance and gross motor skills. Uses the hand without a second thought for holding, grasping and fine motor skills.

- **Personal Attachment**
  - **Prosthesis** = Regarded the arm simply as a prosthesis.
  - **Helper** = Thinks of the arm as an assistive device; a functional, essential tool.
  - **Part of Themselves** = Regards the prosthetic as his or her arm and has a personal attachment to it as "mine!"

We have found that a congenital limb deficient child who is fit with a first myoelectric prosthesis between the ages of 5 months to a year, gains the most prosthetics independence in the long run. Although it may take longer to see the results, after a period of around eighteen months to two years that child generally is more natural with his or her myoelectric prosthesis, both the arm itself and the hand, than the child who is initially fit later. This child may reach for things with either hand and passes things back and forth between hands without thought. These individuals usually view the arm as a part of themselves, and consider it "their arm." They wear the arm all waking hours and many times for naps also.

The child who is fit between 1 and 4 years old tends to rely inherently on the arm for gross motor skills such as balance and crawling, however, is not as intrinsic with the hand itself. This child also tends to wear the arm all waking hours. Results are mixed in the personal attachment area in that some view the arm as part of themselves, while others see it merely as an assistive device.

Children who are initially fit between the ages of 5 to 10 years old tend to be scheduled or vacation wearers and are generally not intrinsically comfortable with the arm or the hand. This group usually sees the arm merely as an assistive device.

Surprisingly, to us, the adolescent group did amazingly well. This group generally became full time wearers, donning the arm first thing in the morning and keeping it on until early evening. Though not intrinsically natural with their hands, they tended to utilize the arm and hand regularly, and came to view it as a part of themselves.

The group that was fit with their first myoelectric prostheses as adults was also mixed. As a whole this group became scheduled wearers, wearing and utilizing their prostheses for certain tasks, chores and activities. Though they became efficient with their prostheses for these particular skills, they generally were not comfortable utilizing them for just any task. This group tend to think of the arm as a helper or assistive device.

In the adults, for the first time, however, we saw a group that switched from a cable device to the myoelectric with excellent results. In the previous age groups, wearing a cable or other body driven device prior to the myoelectric did not appear to increase hand usage. Children who had body driven prostheses prior to receiving their myoelectric arms did better as far as wearing time, than children who had no previous prosthesis, however, use of the hand itself was not advanced. Our adults, however, who were previous cable-wearers tended to become full time wearers, and became very efficient with both the arm and the myoelectric hand itself. They came to view the arm as a part of themselves, also.

Based upon our experience and our findings, we feel that the ideal age to fit a child with a myoelectric arm would be between 5 months to one year old. It is at this age that children discover their physical abilities and gear themselves towards fine tuning their control. A child's prosthetics development will be much like walking and speech development. With speech, for example, the child may experiment with it at 8 months old, say a few words at a year and then appear to ignore it for another 6 months, after which he takes off on his vocabulary. It is important, however, to keep that stimulation there and consistent, and allow him to develop and understand it at his own learning rate. In the same way, a baby should be taught how to open and close his hand and be stimulated to do so on command, but allowed to incorporate it at his own rate. When the early fit child generally starts to utilize his myoelectric hand on his own regularly, it is with an ingrained ability that has been nurtured and enhanced and becomes perfected with time.

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**Other Factors That Add to Good or Poor Wearing Patterns**

Obviously, there are exceptions within each group. There are children fit initially at 3 or 4 who are full time wearers and utilize the hand without a moment's thought. There are also those children who were fit at 6 months old who ignore the hand completely. There are adolescents whose hand has become a part of them and there are adults fit right after a traumatic amputation who...
only wear the arm for special occasions. These are the ones that add questions to the results of the statistical data. The reply to that, however, is crucial to understanding a rehabilitation program. The subjects of the study are more than numbers that fall into a statistical outline by age group; they are more than patients with certain medial, physical conditions and remnant limb levels. They are individuals with their own experiences, needs and motivations. Some are stubborn, some are finicky, some are high-strung, some are low key, but they are each their own person.

Let us address, however, some of influences that appear to have a great deal of effect on prosthetic wear.

Vacation Day Wearing Patterns

This is a type of wearing pattern which I have coined “vacation day wearing.” It is extremely common in the group initially fit at five years and older. The typical pattern of wearing is one where the child wears the arm to school, but takes it off immediately when he gets home. Weekends and vacations also are spent without the prosthesis. In other cases, prosthesis wearing is scheduled. Wear the arm for 3 hours in the morning, and leave it off in the afternoon. We put it on for church and prior to any shopping expedition. The problem with this type of wearing is that the arm becomes an activity. It never becomes a part of the person. Although this is not wrong, the arm is never accommodated into a person’s activities, and is generally viewed as somewhat awkward and in the way. Those who utilize “vacation day wearing” usually have to remind themselves or be reminded to put things in their hand. Despite outward appearances, leisure time and play times are when people develop more fine motor coordination and body awareness. Watching T.V. and passing a

coin back and forth from hand to hand is a person’s unconscious way of perfecting hand coordination. Tinkering with gadgets or new toys develops a person’s confidence in “his hands.” If the prosthesis is not there it cannot be integrated into a person’s physical manual system.

Parental Follow Through and Excitement

As in any learning experience or development of habits, the consistency, motivation and feedback rewards that the parents, relatives and secondary caretakers give play a major role in the child’s level of prosthetic wear. A child can obtain a well-fitting prosthesis at an ideal age, receive excellent follow-up therapy and be a motivated learner, but, if his parents are not enthusiastic about his prosthetic milestones, his teachers are afraid of him breaking his arm with any new activity or the baby sitter feels it is too hard to put on, then all our ideal steps may be overridden.

Training and Follow-Up Therapy

We live in a world today where families are distanced and/or both parents work. Experience is a wonderful teacher. In days past families lived, as a rule, in the same community. Parents raising their first child received lots of help and training from grandparents, parents and aunts and uncles who passed down helpful tips. Today, however, close relatives often live in another state. Parents learn child-rearing completely from scratch. Both parents may work and cannot always give the one on one care that they would like to give. In such cases outside therapy, and close follow-up to check developmental milestones and acquisition of age appropriate skills such as tying shoes and making a sandwich have been very beneficial to the utilization of a prosthesis.

Right or Left Dominance

All people are born with a certain brain hemisphere dominance. With a traumatic amputation or a congenital arm anomaly a person may be required to learn to switch hand dominance. Though still in the initial stages of study, we have seen a correlation and are currently screening the relationship of natural dominance to increased prosthetic function. For instance, we are finding that a child who is missing his left hand and who tests out as right cerebellar, left body function dominant tends to utilize his left prosthesis more efficiently and more often than a child who is missing his left hand and tests out as left cerebellar, right body function dominant.

Conclusion

The controversy of the prostheses remains an issue at large; however, we feel that enough patients have responded positively to early myoelectric fittings that we are definitely headed in the right direction. To know success is to feel the hug of a two-handed child.

Reference


Acknowledgements

I would like to thank Linda Putback, Elizabeth Obencion, P.T., and Maria Clarin, P.T., for helping me to collect the data. Thanks must also go to R.N. Scott and T. Walley Williams, III, for their patience and encouragement and to The Lanier Co. Inc., for loving our families. Most of all, however, I would like to thank each and every one of our families for the joy, excitement and experiences we have shared together.
APPENDIX

Prosthetic Questionnaire

Prosthetic Wearer’s Current Age:

Date of Birth:

Date First Myoelectric Arm Received:

Prosthetic Wearing Pattern

Please check the answer that best fits you or your child’s prosthetic patterns

1. Current wearing pattern for prosthesis:
   - Puts on when gets up in the morning, and takes off before going to bed at night
   - Wears all day except takes off at nap times or for certain activities
   - Wears at school/work but takes off as soon as gets home
   - Wears only for social or special occasions
   - Wears just for certain activities
   - Wears all day, but has some days that does not want to wear

2. Hour Usage:
   - Wears arm less than 3 hours per day
   - Wears arm 3 to 4 hours per day
   - Wears arm 5 to 8 hours per day
   - Wears arm over 8 hours per day

3. Day Usage:
   - Number of days out of seven that prosthesis is not worn, or minimally worn:

Prosthetic Usage

Wearers of PASSIVE prosthetics only!

Check the one best answer

- Ignores prosthetic limb
- Waves and bats with prosthesis.
- Uses for bilateral skills, balancing and developmental skills such as crawling.
- Uses for bilateral skills and balance but does not crawl with it

Prosthetic Usage: Functional

(Myoelectric) Prosthetic Wearers

4. Prosthetic hand usage:
   - Uses prosthesis passively but ignores the hand
   - Uses the prosthetic hand as an assist when absolutely necessary
   - Uses the prosthetic hand if prompted
   - Uses prosthetic hand as an assist in most all activities
   - Uses prosthetic hand as often or more than the sound hand
   - Uses the prosthetic hand only during certain activities

5. Use of Prosthesis when eating:
   - Does not usually use during eating activities
   - Places on table as a stabilizer
   - Uses only when holding snack bags and eating with the sound hand
   - Uses a good deal for two handed eating needs (cutting meat, spreading butter, holding finger foods, opening containers, etc.)

APPENDIX (Continued)

6. Use of prosthesis for special activities:
   Please list special activities that prosthesis is used for. Example: Musical instruments, dance or ballet, fishing or hunting, etc.

7. Use of Prosthetic Arm versus Prosthetic Hand:
   - Wears the prosthesis when told, but can’t wait to get it off after scheduled time
   - Wears the arm comfortably without thinking about it, but does not use it unless reminded
   - Is very natural with the prosthetic arm
   - Uses it for climbing, balance, crawling and other gross motor skills, however, does not put objects in the hand unless told to
   - Very natural with the prosthetic arm and gross motor movements
   - Automatically uses the hand for certain activities, but must be reminded or concentrate on using the hand for new skills
   - Very natural with the prosthetic arm and hand
   - Uses the arm for balance and gross motor skills. Uses the hand without a second thought for holding, grasping and fine motor skills

Personal Attachment

Check the one best answer

8. Response from other people to prosthesis:
   (For the most part)
   - Very good. If noticed at all most people are fascinated.
   - Good. People are nice, but noticeably polite.
   - Fair. People try not to stare, but are uncomfortable with it.
   - Poor. We get comments like “poor baby” and “how terrible”.

9. Response to own prosthesis:
   - It is my other arm
   - It is a necessary assist
   - It comes in handy at times
   - I could take it or leave it.

10. Personal reaction to prosthesis:
    - Looks for arm in morning, is disappointed if can’t have it. Treats arm possessively.
    - Fights wearing it, uses excuses not to wear it.
    - Wears the arm, but has no personal attachment to it.
THE PROPER AGE FOR FITTING A MYOELECTRIC PROSTHESIS

David Lyttle
Laurie Ringaert

Introduction
The introduction of myoelectric control for upper limb prostheses was welcomed in Canada, and in 1974 we imported the Swedish electrode system to try out with some of our teenage upper limb amputees attending our prosthetics clinic. Young people in Manitoba are fortunate in that all standard prosthetic and orthotic devices are provided without cost to the patient. The Variety Club of Manitoba offered in 1980 to fund a Limb Bank to supplement government funding and make available myoelectric and recreational prostheses when prescribed. It became apparent that the program effectiveness should be evaluated, so a project was undertaken to search out and follow up all individuals who had been fitted with an upper limb prosthesis during the past twenty years; there were 83 cases of upper limb deficiency attending the clinic during that time, and of these 45 had received a myoelectric prosthesis. It was found that the majority of young people had rejected wearing or using a prosthesis and these findings were reported to the 1991 Annual Meeting of the Association of Children’s Prosthetic-Orthotic Clinics (ACPOC).

Purpose of Study
The purpose of this study was to analyze the data obtained about 45 young people who had myoelectric fittings in order to attempt to identify the factors which might predict the continued use of the myoelectric prosthesis. In particular, it seemed important to know if earlier fitting of any prosthetic device, and myoelectric fittings in particular, were associated with more frequent and prolonged wearing and use of the devices.

Case Material
It was possible to follow up 45 individuals who had been fitted with myoelectric prostheses at our facility. The following information was recorded and is shown in Table I:

<table>
<thead>
<tr>
<th>Case No.</th>
<th>arranged in order of age of myoelectric fitting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnosis</td>
<td></td>
</tr>
<tr>
<td>Age First Visit</td>
<td>to the Juvenile Amputee Clinic</td>
</tr>
<tr>
<td>Age First Device</td>
<td>most often an infant passive hand</td>
</tr>
<tr>
<td>Age Myo Fitted</td>
<td></td>
</tr>
<tr>
<td>Age Myo Rejected</td>
<td>(0 indicating non-rejection)</td>
</tr>
<tr>
<td>Age Last Visit</td>
<td>to the Clinic</td>
</tr>
<tr>
<td>Years F-U</td>
<td>the duration of follow-up after strenuous efforts to locate and interview those who had ceased to attend the clinic</td>
</tr>
</tbody>
</table>
The wearing and use patterns over the years were carefully studied and this information is summarized in Table II:

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age Myo Fitted</th>
<th>Years Myo</th>
<th>% Myo</th>
<th>Years Conv</th>
<th>% Conv</th>
<th>Effective Myo Years</th>
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<td>0.0</td>
<td>1</td>
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<tr>
<td>2</td>
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**TABLE I**

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<th>Age Myo Fitted</th>
<th>Years Myo</th>
<th>% Myo</th>
<th>Years Conv</th>
<th>% Conv</th>
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**TABLE II**

**ABREVIATIONS:**
- CLBE: Congenital Left Below Elbow
- CRBE: Congenital Right Below Elbow
- CRWD: Congenital Right Wrist Disarticulation
- ALBE: Acquired Left Below Elbow
- ALSD: Acquired Left Shoulder Disarticulation
- ARAB: Acquired Right Above Elbow
Effective Myo Years
the product of the percentage wearing and the number of years spent wearing the myoelectric prosthesis.
As the review was retrospective, the wearing pattern was determined by the O.T. based on the therapy and clinic notes.

Results
The pattern of wear of myoelectric prostheses is summarized in Table III

There is correlation between the age of fitting and the effective myo years of wearing. (See Figures 1 and 2)

<table>
<thead>
<tr>
<th>Age Myo Fitted</th>
<th>No. of Cases</th>
<th>Mean Years Worn</th>
<th>Mean % Myo Worn</th>
<th>Effective Myo Years Worn</th>
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TABLE III

Discussion
The most obvious reason for an amputee to reject using any type of prosthesis is because it is badly fitted, as explained by Melendez and Leblanc. In addition, the wishes of the patient and the family may not have been taken into account when choosing to prescribe this particular device. In our clinic, much time is spent in explaining prosthetics options and in allowing children to interact with others who have found good solutions to their prosthetics needs. All of the myoelectric fittings were “successful” in that they met the needs of the individual at the time, the fit was comfortable and the training by occupational therapist and by parents effective. Regular follow-up and checking of fit and function was insisted upon by the clinic team. As a child matures, the needs change and when informed decisions are taken later, the decisions are often to reject regular daily use of a prosthesis. Some will continue to use prostheses for specific tasks at work or recreation, and the prosthetics services continue to provide for those needs.

We did not think that time and resources were wasted in fitting children who have congenital limb deficiencies with myoelectric prostheses. The devices helped in the interaction of the amputee with family, friends and school acquaintances in our current social environment. Should that environment change and parents cease to demand that each child appear “whole”, friends accept limb deficiency without pity and acquaintances cease to over-react to the appearance of a missing limb, then the needs of the young amputee might be different.

The stated reasons for rejection of various types of prostheses have been recorded in our data collection. In most cases, the pattern becomes clear at a series of clinic visits that the individual is not finding much use for the device.

When it is eventually handed back to recycle the components in the Limb Bank, the reasons usually relate to the prosthesis
Risk of Rejection of Myoelectric Prostheses

![Graph showing risk of rejection over age]

---

**Figure 2**

Osx's Proportional Hazard Regression

---

**Conclusions**

Myoelectric fittings help child amputees for certain periods of their lives but the majority are eventually rejected. Earlier fitting in childhood appears to be associated with increased wearing pattern of myoelectric prostheses.

**References**


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**WHICH IS THE BEST AGE FOR THE FIRST APPLICATION OF MYOELECTRICALLY CONTROLLED HAND PROSTHESES IN CONGENITALLY AMPUTATED CHILDREN?**

R. Sörbye
L. Hermansson

Applications of myoelectrically controlled hand prostheses in congenitally amputated adults in the 1960’s and some years thereafter were not very successful. After some time these prostheses most often were found to be put away somewhere, and the patients had gone back to what they used previously: passive prostheses, conventional prostheses, or no prostheses at all.

On that background one of us (RS) presumed that the acceptance would be better and this type of prosthesis more used by the congenitally amputated if they were supplied in early childhood. This point of view was not accepted by the experts, and no myoelectric hand of suitable size existed. However, with the smallest available hand, Otto Bock 6/4", 20 children were supplied in Örebro, Sweden, during the years 1971-1977.

Meanwhile a smaller myoelectric hand, for children 2-6 years of age, was initiated from Örebro and developed in cooperation with the firms Systemeknik AB and Centri Gummifabrik AB in Stockholm. From 1976 the small children have been supplied with this new hand.

From 1977 Örebro was no longer the only place where children were fitted with myoelectrically controlled hands. In other centres in Sweden, and also abroad, such applications were now started. In 1978 the first English child was fitted with a myoelectric hand in Örebro, and this led to a trial in Great Britain which later was followed by numerous applications there.

The small Swedish hand was successively sold by Systemeknik AB to a great number of countries, as the initial resistance concerning the early fitting slowly turned into acceptance and in some cases even enthusiasm. This was not always an advantage, as the necessary information, training, follow-up and taking care of the whole family could be more or less missing. On the whole, however, the result of the early childhood application of the myoelectric prosthesis proved to be favourable. Technical improvements and better understanding of the psychological aspects have also extended the use and the usefulness of this type of technical aid.

Which is the best age to be fitted with this type of prosthesis? And what is important to think of?

In Örebro we have started at different childhood ages, and our clinical experience has shown that certain factors increase the possibility of good usefulness: passive prosthesis from the age of 3-6 months, successive increase of the distal socket weight up to the application of a myoelectric prosthesis at the age of 2 1/2 - 4 years, good initial information, effective training, thorough follow-up, rapid repairs, and a good relationship between the family and a prosthetics team of great capability.

The question of myoelectric starting age has now gained a refreshed and increased interest. We have considered again this factor and also other points of presumed importance for the long time results of our myoelectric applications. In this connection a questionnaire has also been distributed to the members of the Swedish Association for
Dysmelic children. From the 269 families we have got 207 answers back.

During the last years an increasing amount of our dysmelic patients from all over Sweden have been definitively taken over by local teams. The reason is the actual general economic difficulties for the different county councils and their instructions to the hospitals not to buy external services. However, many of the local workshops do not have the necessary capability and routine in this relatively narrow field, nor sufficient time for it. Because of these factors, and again for economic reasons, they often do not have the necessary spare parts in stock. For many patients this has resulted in less satisfying prosthetic solutions and long repair times, which in its turn have made many of them get weary of the whole thing.

Compared to our figures found only three years ago, the acceptance of the myoelectric prostheses has clearly decreased in most age categories. An exception is found among the youngest children who mostly are still served and treated as before, by time-consuming information and follow-up visits, as well as skilled socket making and rapid repairs.

Among the 207 completed questionnaire answers it appears that 131 patients have been supplied with myoelectric hand prostheses during their childhood. Among the rest some are still too young to be fitted with such prostheses; others have malformations making them unsuitable for application. Some are exclusively leg amputees. Others again have got other forms of prostheses or other aids with which they are satisfied. And some insist on managing with what Nature has provided them; some do everything with their feet.

Looking at these 131 patients, we find that 13 of them got their first myoelectric hand prosthesis before the age of two years, 77 between two and four, and 41 after four years of age. The first application took place nearly 20 years ago, in a girl who will soon be 23 years old. She is using her myoelectric hand prosthesis all day long in a completely natural way, with smooth and well coordinated movements. Five of the others are now aged 22 years or more. One of them, a girl with a very short forearm stump, rejected her myoelectric prosthesis shortly after the application at the age of 6 years. At that time the smallest available prosthetic hand still was the Otto Bock 6 1/4" size, and this was much too heavy for her. Three of the other four still use their prostheses all day, and one is using it part time.

Initially the application age varied quite a lot, from beneath two years of age up to seven and eight, but successively the children were referred to us at an even younger age. The age interval 2 to 4 years seemed to be optimal for the first application of myoelectric prostheses. Already from the beginning we have aimed at starting with a passive prosthesis at the age of 3-6 months if possible, increasing successively its distal weight before the application of the heavier myoelectric prostheses. We have laid stress upon regular training and long term follow up, and also upon taking care of the families in a calm, friendly, and relaxed atmosphere, as well as rapid repairs. If the patients have shown to be eagerly using the prosthesis, they have been supplied with two Regular training and control visits to a local occupational therapist have been arranged immediately from the application of the myoelectric prostheses.

Involved occupational therapists from all over Sweden, and also whole teams, have come to Ourebro for study visits and conferences, and close cooperation has followed.

To see if our opinion concerning the most suitable fitting age can be "proved" statistically, we have separated the 131 patients into three groups: Those who have got their first myoelectric prosthesis before the age of two years (13 children), those fitted between two and four years of age (77 children), and those fitted after four (41 children). By analyzing the different groups, we find results as follows (Table 1).

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<tr>
<th>Group</th>
<th>All day</th>
<th>Part Time</th>
<th>Rejected</th>
<th>Sum of Users</th>
<th>%</th>
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<td>Two-Four</td>
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<td>67/77</td>
<td>99.6</td>
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<td>15</td>
<td>10</td>
<td>16</td>
<td>25/41</td>
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<td>Total</td>
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<td>26</td>
<td>105/131</td>
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</table>

TABLE 1

Patients cumulatively sampled after their actual age today: (Table 2) (all day use and part time/number of patients in the sample, per cent actual users) best achieved by the follow-up visits to the workshop and the prosthetic team to which the patient is accustomed. Therefore it is unfortunate that county councils for economic reasons "take home" their patients from the expert centres, leaving the patients without the necessary extent of support, often resulting in irritation and long pauses.

<table>
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<th>Age</th>
<th>Before 4</th>
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<th>After 4</th>
<th>%</th>
<th>Sum</th>
<th>%</th>
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<td>80.2</td>
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</table>

TABLE 2

All the 131 patients all ages: 65 + 40/131 —— 105/131 Users

From these numbers it can be seen that the percentage of actual users is relatively high in the youngest patients, especially in the "Before 4" group.
The main difference found in the tables, however, is the high percentage of users in the group "Before 4" compared to the group "After 4", and that is true for all ages. This finding is in accordance with our clinical experience. We have achieved the best long time acceptance of the myoelectric prosthesis if they are fitted before the age of 4 years. This includes also the applications before two years of age. We have no experience of myoelectric applications before the age of 1 year. We think it should be possible to get a good acceptance by such a very early start, and it would be interesting to observe the long time result of such an investigation. But, on the basis of our experience from applications between 1 and 2 years of age, we do not see too great advantages, and no doubt it will give some additional problems to solve and clearly increase the costs. Thus, knowing that one may achieve very good acceptance by a somewhat later but still early start, we think one should concentrate on and offer economic possibilities for a thorough and prolonged follow-up, giving real support to the patient and the family at suitable intervals for many years.

Carl D. Brenner

Carl D. Brenner is a prosthodontist who has practiced in Detroit, Michigan for the past 25 years. As one of the few prosthodontists in North America who specializes exclusively in upper limb prosthetics, he is a frequent lecturer on the clinical and technical aspects of fitting upper limb prostheses. In addition to being a long time proponent of early prosthetics intervention for both adults and children, he also advocates the effective use of limb banking for both groups.

Mr. Brenner is the Director of Prosthetic Research at the Michigan Institute for Electronic Limb Development, and also serves as the Research Prosthetist for the Variety Club Myoelectric Center in Detroit.

H.J.B. Day

Herbert (Binks) Day qualified at King College Hospital London in 1950, and after 10 years training in Orthopaedic Surgery joined the English Artificial Limb and Appliance service. He then worked at the Manchester centre where, in addition to looking after adult amputees, he developed a particular interest in the care of children with congenital limb deficiency. He was for some years a project leader for BRADU, and a member of the British delegation to the International group on Modular prostheses. In 1978 he set the protocol for the official British trial of fitting children with Myoelectric prostheses, and supervised the programme for the North of England.

L. Hermansson

Liselotte Hermansson, O.T., graduated in 1979. In 1987 she received a BSc in Occupational Therapy from the University of Caring Sciences in Örebro, Sweden. She works as a senior occupational therapist at the Department of Clinical Neurophysiology at the Regional Hospital in Örebro (Örebro Medical Centre Hospital) She is also a part-time PhD student in Paediatrics at the University of Uppsala, Sweden. Apart from development of training procedures she is also committed to the psycho-social aspects concerning children with limb reductions.
Sheila Hubbard

Sheila Hubbard graduated from the Physical and Occupational Therapy program at the University of Toronto in 1964. In 1982 she obtained her BSc in Physical Therapy from the University of Toronto.

Ms. Hubbard worked as staff therapist at the London District Crippled Children’s Centre from 1964 to 1967. Since 1967 she has been at the Hugh MacMillan Rehabilitation Centre (formerly called the Ontario Crippled Children’s Centre and the Hugh MacMillan Medical Centre) in Toronto.

Her work involves Physical and Occupational Therapy as well as research in Rehabilitation Engineering.

Ms. Hubbard is currently the Secretary-Treasurer of the Association of Children’s Prosthetic and Orthotic Clinics (C.P.O.C.), and is active in a number of professional associations.

Rosa Jacobs

Rosa Jacobs received her B.S. in Physical Therapy from the University of Colorado Health Sciences Center, Denver, Colorado, in 1981. She holds a Physical Therapy licence for the State of Texas.

From 1981 to 1983 she was Staff Physical Therapist at the Paul Bonariggo Sports and Back Clinic in Bryan, Texas. From 1983 to 1987 she worked as Assistant Director of Physical Therapy at the St. Anthony Center in Houston, Texas; in 1987 she became Director of Rehabilitation Services for the St. Anthony Center. Since 1988 Ms. Jacobs has been Director of Rehabilitation at the Myoelectric Institute of America in Houston.

She is the Director-owner of Dynamic Rehabilitation Services in Houston, a Member of the American Physical Therapy Association and the Committee Chair of the Parent Board of First Experiences.

David Lytle

David Lytle was born in Belfast Northern Ireland. He studied at Queen’s University in Belfast and at the Royal College of Surgeons in Edinburgh, Scotland.

From 1968 to 1971 he was a resident in Orthopaedic Surgery at the University of Manitoba; in 1971 he became certified in Orthopaedic Surgery with the Royal College of Physicians and Surgeons of Canada.

Dr. Lytle is Director of Surgery at the Rehabilitation Hospital in Winnipeg, Manitoba. He also serves as Medical Director for both the Department of Rehabilitation Engineering Health Sciences Centre and the Juvenile Amputee Program at the Rehabilitation Centre for Children.

Dr. Lytle is on the consulting staff of Winnipeg’s Victoria General and St. Boniface General Hospitals and active in prosthetics and orthopaedic research.

Laurie Ringaert

Laurie Ringaert is an Occupational Therapist from Winnipeg, Manitoba. Since graduating with her BMR-OT in 1981, she has practiced Occupational Therapy at Winnipeg’s St. Boniface General Hospital and the Rehab Centre for Children.

Since 1989 she has lectured at the OT Division School of Medical Rehabilitation at the University of Manitoba.

In 1991 Ms. Ringaert began private practice, in partnership with a Rehabilitation Engineer, in Assistive Technology consultation and intervention. She is also working toward a Masters Degree in Community Health Sciences.

Yoshio Setoguchi

Yoshio Setoguchi studied at the University of California and was granted his MD in 1961. In 1967 he was certified with the American Board of Pediatrics.

Since 1967 Dr. Setoguchi has been the Medical Director of the Child Amputee Prosthetics Project at the University of California at Los Angeles (U.C.L.A.).

Dr. Setoguchi is Professor of Clinical Pediatrics at U.C.L.A.; he has published widely on the subject of pediatric limb deficiencies and also serves as Pediatric Coordinator for the Craniofacial Clinic at U.C.L.A.’s School of Medicine and School of Dentistry.

Rolf Sörbye

Rolf Sörbye, M.D., graduated in 1949 from the University of Oslo, Norway. He is a specialist in psychiatry and in clinical neuro-physiology. From 1968 he built up the Department of Clinical Neurophysiology at the Regional Hospital (Ørebro Medical Centre Hospital), Örebro, Sweden. In 1971 he introduced the application of myoelectric hand prostheses in preschool children and made his department a centre for children’s myoelectrics. He was the project leader for the construction and development of the small myoelectrically controlled prosthetic hand produced and sold by Systemeteknik, Stockholm. With his staff he has worked for improved technical devices and control systems and has also been very much committed to the psychological aspects concerning the limb deficient children and their families. Since his retirement in 1985 he has been attached as a senior consultant to the Department of Clinical Neurophysiology in Örebro.