EXPERIENCES FROM CLINICAL EVALUATION OF UPPER EXTREMITY PROSTHESES

An introduction to a round-table discussion

A. Forchheimer, B. Klasson, G. Markström, N. Rydell

Karolinska Hospital, Stockholm, Sweden

Introduction

The day after the concluding session of the previous Dubrovnic symposium Professor Tomović collected some members of the scientific committee and a few other participants at the Excelsior Hotel to discuss the role and the future of the conference. It was agreed, that this is the only international event where it is possible to discuss technology in rehabilitation at any level.

It was, however, also agreed that the time has passed, when we could accept to continue our work without knowing more about the true significance of our technological contributions to rehabilitation. It was therefore suggested, that for the next meeting, everybody should go home and stimulate work that would improve the understanding of the clinical relevance of our work and give better guidelines for future work. Papers on this subject would be given priority in the 1978 conference.

This paper is an attempt to give a contribution in this direction, based on a multidisciplinary approach to rehabilitation. We are convinced about, that much of what we say is probably common sense to those of you, who are involved in everyday clinical work, although much of it is very difficult to verify scientifically. We have allowed ourselves to be quite provocative, in order to stimulate for discussions. We hope that we will not kill any enthusiasm, only redirect it if necessary.

"Ever since the legendary prosthesis of Götz von Berlichingen it has been expected that it would be possible, sooner or later, to substitute for the loss of an arm by means of an adequate apparatus. Such an apparatus might even provide more possibilities than those of the lost arm. This expectation has, especially in the engineering world, but not only there, been stimulated in the light of the swift progress of technology in general and by some more spectacular results of it, i.e. the space programme. Human limitations in memorizing and processing data have been overcome, so that not only our physical, but also our intellectual capacity have increased, resulting, of course, in further escallation of technology as the one and only way to a happy future.

Considerable resources have been spent in many countries on the development of new advanced arm- and handprostheses. But as computerized multifunctional manipulative devices, further degrees of freedom and more complex control systems are being introduced, heavier demands are put upon the interface and the interaction between "man and machine". These demands may not only be related to control problems but also to the acceptance of poor reliability, fragility, noise, cosmesis, comfort and to irrational emotional factors etc. There is a discrepancy between the complexity and sophistication of the apparatus and the way the amputee farmer, schoolgirl, clerk, housewife, fisherman, businessman etc views his or her situation, problems and needs.

Frequently biological and human aspects have been set aside or insufficiently searched into, to promote for an apparatus or an engineering solution to appear as an adequate and maybe as the only adequate solution. The gap between unrestricted belief in the potential of the apparatus and the real needs of the amputee is more marked the more complicated the device. It seems that sometimes the fact that the

amputee finally rejects the complicated prosthesis is considered unexplainable or maybe not true. Instead of thinking it all over from the beginning, looking after factors that had not been considered before, we sometimes go on and introduce our improved Mark II. But if we have not found the "carrying wave" for communication with the patient about his needs, expectations, limitations etc., we will never reach him with our efforts.

We can even create a situation, so that we can at least register an intermediate success to be reported. It may be rewarding for the scientist, but not necessarily for the amputee."

The above is a "synthetic quotation", that we, after having followed what has happened during the past 15 years, and after having discussed the situation with numerous of colleagues, have been daring enough to set up to reflect what we know that many involved persons feel at this very moment. The quotation is probably true but also unfair. It is unfair because it does not take into consideration the conditions under which many of us work, and, of course, because everything that has been done so far has been done in good faith and with the best purposes.

After having fitted all available kinds of upper extremity prostheses with results varying from total failure to reasonable success, we at the Karolinska Hospital came to the conclusion, that also we had to redirect our efforts from making advanced systems to searching for better means to analyze and assess the value of the arm/hand-prosthesis for the amputee and to improve the specification of future prostheses. We also came to the conclusion, that it is not possible to approach this problem, unless we can increase our understanding of the role and the use of the normal hand and arm. Furthermore we found that it is necessary to analyze and consider the risk level of our work. Can we, in good faith, spoil the rehabilitation of the amputee with our efforts?

For this purpose the total arm amputee programme at the Karolinska Hospital (KS) has over the past few years been converted into a mixed treatment and research project. All arm- or hand amputees meet the research team and the team is also responsible for the treatment. The team consists of an orthopaedic surgeon (who is responsible for the prescriptions and medical aspects), an occupational therapist, a prosthetist, a research engineer and a technician. If needed, other experts are called upon. So far more than one hundred patients have been subject to systematic follow up.

To achieve our goals we had to reorganize our routines for the management of the upper extremity amputees. The basic steps of the treatment of each patient consists of:

1 Define optimal criterions of the rehabilitation, considering medical, social, psychological, emotional, environmental, technical, economical and other relevant conditions.

2 Fit (or do not fit) and train the patient according to the above criterions.

3 Clinically evaluate the prosthesis or rather how the prosthesis meets the individual demands.

4 Document the results.

The project is of course backed up by conventional medical and surgical resources, and a big limbfitting shop. Furthermore the project has got access to the design- and construction facilities of the prosthetics research laboratory, for which this project has first priority.

We would like to display some preliminary results from this project and bring forward some questions and thoughts, that we feel deserve attention. Many of these questions and thoughts were brought to attention here by Feeney - Hagaeus 1969 in their report from an early pilot project in our institute.

In this context as well as in most papers dealing with prosthetic devices the terms

"active" and "passive" function are used. Before going closer into functional analysis we want to point out some terminological problems.

Traditionally the functions of arm-hand prostheses fall into two cathegories: active and passive. The first minor problem is, that there is not unanimous agreement as to the definition of "active function". Thus it is sometimes said that a b.e. prosthesis has got an active rotation, if the prosupination of the stump can be used to rotate the prosthesis. But the majority of colleagues agree to the concept that an active function is an internal movement of a part of the prosthesis, actuated by body power via a transmission from a control site, or by an externally powered actuator. This concept implies, that a springloaded thumb does not represent an active function.

In the daily clinical work this concept may be very practical, but we are afraid that it has been misleading R & D or rather limited it to the area where the need of engineering efforts seemed obvious: active functions. The "passive" role of the prosthesis has unfortunately not appeared to deserve any major attention.

MTM-studies

The first general question of the project is: How does the patient actually use those arm-hand prostheses, that we fit today? If we could analyze relevant data about this, we would better understand the role, the importance and the efficiency of the prostheses and the demands upon the prostheses.

For this specific purpose, the interview method is insufficient. It only, with some error rate, tells about the amputees subjective judgement about how he uses his prosthesis, which is not necessarily similar to how he actually uses it.

We limited our approach to the study of unilateral b.e. amputees and analyzed their activities by means of MTM (method-time-measurement) standards. Our reference was a subject with two normal hands. Individual differences in skill were eliminated by normalizing. About 20 different bimanual tasks or activities were selected and filmed. All subjects had achieved considerable skill in the use of their prosthesis.

The first general result of our studies is related to the total efficiency of bimanual activities when the hand prosthesis has an active grasp function or when there is no active grasp function.

In this paper the word "efficiency" is used in the following sense:"The efficiency is high, when a task is performed fast, i.e. with a low consumption of normalized MTM time units".

It was striking (fig 1) that the patient gained so little in efficiency from the possibility of grasping. Obviously the subjects could not fully utilize the availability of the grasp.

Table 1 shows the relative use of the grasp function of the terminal device. The grasp seems to be used less than 30% of the number of times the prosthesis is involved in the activity. (The normal hand is assumed to use the grasp nearly everytime it is involved).

Our interpretation of this is that as there is no sufficient (sensory) feedback to inform about the control of the object in the hand, as it is not possible to change the orientation of the object by means of the grasp and as the delay when using the grasp is so great, the grasp does not contribute efficiently.

In this context it may be of interest to note, that it is well known and documented from MTM research and application, that a blind person is as efficient as a seeing person in picking up objects and placing them in a predetermined way, as soon as the blind person has been able to identify the object and the task.

To us the results were surprising. The tasks were performed in a very skilled and many times elegant manner. It was not until we had analyzed the films frame by frame that we realized, that the subject used the active grasp of the prostheses much less than we had expected.

We were equally surprised to find, that our test subjects, who we felt all had achieved a bimanual behavior after having used there prostheses for a long time, in fact behaved in a marked single-handed manner.

Table 2 shows the step by step analysis of three subjects, all performing one of our selected activities (folding a letter, putting it into an envelope and sealing the envelope). One subject is our normal reference subject, one had a Dorrance split hook (body powered) on his left, never dominant arm, and one used an Otto Bock myoelectric hand on his previously dominant right hand. This latter subject still regards himself being right-handed.

The normal subject demonstrated a true bimanual behaviour. The subject with the split hook on his left non dominant arm performed most of the steps with his intact, dominant right hand. He only uses his hook three times out of twenty and he never used hand and hook simultanously in this activity.

The man with the myoelectric right hand, who still considers himself as right-handed, is obviously wrong in this respect. His left arm is now dominant with regard to the relative frequency of its use.

MTM-studies have statistically shown, that out of the total time we use our hands, the dominant hand is used 50%, the non-dominant hand 25% and both hands together 25%.

Table 3 shows that our OT, when performing all the selected activities in the project, scored the same figures, and that the amputees from the previous table all show only 10% of simultanous use of both hands. The left non-dominant hand amputee, who only uses splithook, has reduced his time for bimanual activities by 15% (which means more than half of normal conditions) and added these 15% to the time he uses his dominant right hand. The right dominant hand amputee has transferred 5 of the 15% to his remaining left hand and 10% to the prosthesis, when using split-hook, but all the 15% to the prosthesis when using myoelectric hand.

Observe that the figures given in table 3 do not tell anything about the efficiency, i.e. how much that was performed when the different alternatives were used.

Referring to our studies it can be stated that the unilateral amputee is one-handed in his behavior with his healthy hand as the dominant hand, whatever first impression a show or a film might ever give to an observer. To an unilateral amputee the non-amputated arm objectively always is dominant, although the amputee himself may believe the opposite. The reason is that the normal hand is so much more efficient than the prosthesis. Whilst the difference in efficiency between a normal dominant and a normal non-dominant hand is only a few percents the prosthetic device today rarely reaches 2/3 of the efficiency of the normal hand, irrespective of which kind of prosthesis.

The environmental influence on the behaviour

There would be no disagreement, that people behave differently in different environments. There is, no doubt, a social pressure on everybody, to behave as normally (related to the environment) as possible. Handicapped people have often reported that to them this is a challenge as well as a pressure, and thus very serious.

Non-handicapped persons make things easier for themselves, if they are not observed, provided that there is an easier way available than the socially acceptable way. (Drink from the bottle when nobody sees it is a good example). For the hand amputee the easy way is not necessarily acceptable, at least not to his own impression. During our experiments we have seen how subjects struggled with tasks and failed,

although we knew, that they would easily solve the task unobserved. A typical example is opening the Swedish paper milkpack. The subjects approached the task by using hand and prosthesis with poor result. If unobserved they do it comfortably with one hand and their teeth. This gives rise to believe, that the above results are more favourable for the use of the prosthesis, than they would have been, if the tasks would have been performed in an unobserved environment. The fact, that the performance was recorded on film put further demands on the subjects.

Compensatory functions

Nevertheless we saw that the subjects used compensatory behaviour. They used their knees, they held objects between their arm and their body, they used their teeth etc. Everybody who regularly deals with amputees knows this, and most of us have come to the conclusion, that current arm prostheses cannot functionally substitute for the lost arm. They can only, hopefully, together with other compensatory capacities, make it easier for the unilateral amputee to live with one arm. The prosthesis is part of the compensatory system, that is available to the amputee.

On the other hand we feel that there are colleagues, who have set up as a goal to develop arm prostheses, that would make compensatory functions unnecessary. We believe that this concept is unrealistic.

Instead of specifying devices that can take over the total role of the lost arm (which not even a functionally intact, but anesthetic human arm can do), we have to specify the prosthesis from the viewpoint of a realistic, compensatory role.

Compensatory functions without prosthesis may, however, be more efficient but still inconvenient. The cosmetic inconvenience, that makes the amputee diverge from "normality" in his appearence is often mentioned. We would like to focus on the asymmetry. For the unilateral arm amputee the limited length of the stump results in asymmetrical hand-stump activities that may be difficult and tiring. The amputee also looks less relaxed, which is an additional cosmetic drawback. If heavy weights are carried or the amputee in other ways excerts high forces (i.e. to push something with both arms), the asymmetry may even be hazardous. The hand-arm prosthesis often improves the symmetry.

Compensatory function, "hyperutilizing" the remaining hand, may also sometimes not be available. The remaining hand is frequently overstrained, and it may sometimes be injured by accidents, inflammations etc so that it is useless. Then the use of the prosthesis and consequently the reliability of the prosthesis becomes more important.

The value of the prosthesis for the amputee

Our clinical work has told us many things that are well known in all fitting centres. We would still like to mention some of them here, because we need them for our conclusions.

There are contradictory opinions from different amputees about nearly all kinds of arm-hand prostheses. There are amputees who have used prostheses with built-in active functions and finally turned over to a passive prosthesis, as they did not find the active functions were very useful for them. Other amputees are always prepared to try new prostheses with new or altered functions. Apparently many patients insist, that they will continue using the same type of prosthesis they are accustomed to, no matter if it is obviously heavier and "coarser" than more modern prostheses, made from lighter and maybe better materials. Amputees who do heavy work seem to prefer very strong devices, made from steel and leather. Often such b.e. amputees want an a.e. corsett. These amputees tend to have a very negative attitude to modern myoelectric prostheses. They think these prostheses are functionally week and merely of cosmetic value. Amputees who do not utilize the functional capabilities of more advanced prostheses sometimes suspect that they have got this "redundancy" instead

of something that would be more useful or valuable to them, i.e. reliability and strength. The amputees initial and final attitudes to different prostheses and their aptitude to utilize them is obviously a matter of background, experience, habits and personalities.

It is not very common that adult congenital amputees choose to use prostheses with built-in active functions if they choose to use prostheses at all. They have from earliest childhood developed compensatory habits for most of their needs, and they have never themselves experienced the loss of resources - they never had them. However, most of these amputees were never subject to the kind of child amputee fitting programmes, that have been conducted during the last 15 years. Normally the congenital, unilateral hand amputees seem to regard themselves as non-handicapped and totally independent. Also more severe cases, like bilateral congenital hand amputees, take pride in demonstrating their independence, although they agree that certain activities are diffficult to perform. Even at the most severe level, bilateral amelia of the upper extremities, it seems possible to develope a sufficient (acceptable) independence without the aid of prostheses.

In spite of modern child amputee fitting projects we still see that severely handicapped congenital arm amputees, all levels, initially refuse or later reject their prostheses and still get along very well. Although our research work for the moment is concentrated on the unilateral b.e. amputees, our general clinical experience does not indicate that there is any correlation between the level or laterallity of congenital amputation and the disposition to accept a prosthesis. This, of course, said without statistical verification. Objectively, however, the higher the amputation level, the more difficult to compensate.

In our team we have come to the conclusion, that in most cases the only way to fit a congenital amputee permanent is to imprint needs on him by fitting him at a very early age, i.e. before two years age. Frosthetic improvements, however, may very well change this situation.

We have been surprised to find, that some of our most active users of b.e. prostheses do not accept what we call a "good" fit. They prefer a loose fit, that they can adjust themselves (by stockings). But they are very critical about harnessing and control-transmission.

The foremost important factor as far as acceptance is concerned is the fixation of the prosthesis to the stump, i.e. the fit and the comfort of the socket. The importance of good fit has always been emphasized. Notwithstanding the general concept, that the prosthesis is a functional extension of the stump, limited by instability, discomfort etc, comparatively small research and development efforts are spent on improving the situation. The angular osteotomy (Marquardt) seems to be the only progress lately.

The cosmetic function of the prosthesis is usually referred to as a passive function, and is therefore said to be of less interest for the developing engineer. For many amputees, however, cosmetic restauration is the dominating need, and the active functions of the prosthesis are then of secondary interest, if any. Others use the prosthesis actively utilizing internal functions as well as passively for pushing, pressing, supporting etc, but they do not want to sacrifice cosmesis.

It seems to be very difficult to produce a satisfying cosmetic glove for an active hand prosthesis. The cosmetic result is better for passive hand prostheses. As many amputees for this reason discard the active prosthesis although it might be useful for them in ADL-activities etc, it seems obvious that the cosmetic function of the hand prosthesis must be improved. Unfortunately this is not only a matter of making cosmetically acceptable gloves. Those gloves available today are very sensitive to wear and dirtying. The cosmesis of a glove may be spoiled after reading the morningpaper. The mechanical strength of the glove is often not sufficient when using the hand prosthesis for work. Consequently the amputee all the time has to keep in mind that the glove has to be protected. Instead of giving him an aid we have supplied a burden.

Most cosmetic gloves also restrict the movement of the fingers, the more the more mobile joints. Most developers of advanced hand prostheses have said, that when the hand is ready for use, there will also be a suitable glove. But no significant improvement seems to have been demonstrated since the early APRL-development. The problems of the glove have obviously been severely underestimated.

Reliability and strength

In 1972 our team presented a paper here in Dubrovnik on Modern Maintenance Technics. In that paper it was suggested, that a poor reliability of the prostheses may not only eliminate the possibilities of assessing the favourable characteristics of a new prosthesis. It may also cause, that the rehabilitation level that an amputee has achieved by means of his prosthesis be forfeited.

Since then we have been further convinced in this direction. During the sixties we developed a pneumatic arm system. The first generation of this system, also presented here in 1966, had no feedback and a poor control. This first generation was only accepted by a few patients, but we all the time felt that to these patients the friendship and the discussions with the staff of the lab was more important than the prosthesis.

The next generation of the prosthetic system had improved control, as we utilized our pressure demand valves. It was now easier to control the grasp and the movements of the joints in the prosthesis, and the improvements were appreciated by the patients but we could not record any increased acceptance. We then stopped developing the functional possibilities of the system and spent all efforts on improving the reliability an organizing swift repair service. The improved reliability resulted in that the service intervals changed from 1-2 weeks to several months, and now they are much more than a year. Our own valves, joints and structural components were redesigned, and commercially available components were modified, and now this pneumatic total arm is accepted and preferred by all of our patients, that need the capacity it offers.

The first generation of myoelectric hand prostheses suffered from a very poor reliability due to the fragile cables and connections. We would here like to give credit to the Otto Bock Ortopädische Industrie KG for presenting self contained below elbow systems with no external cables. This achievement has improved the acceptance of the myoelectric prostheses.

Nevertheless we have too short service intervals for those amputees who really use their myoelectric hands. For some patients we have seen that if the prostheses are really used as the patient would prefer to use them, the service intervals may be as short as a couple of days. Some patients have given up and returned to more passive prosthetic utilization whilst others have asked us to do something about the situation.

After having analyzed the most important sources for the malfunction (deformations causing excessive wear of bearings) and eliminating these sources, we were able to increase the service intervals from a few days or weeks to about half a year. These efforts have contributed to higher acceptance of the prostheses and the patients now believe more in their aid.

There are two basic rules to be obeyed when improving the reliability: Reduce the amount of components and select or design the remaining components and the structure more carefully. It is our view that the best immediate way to meet the patients needs is not to make more complicated prostheses with more functions, but to convert the current, functionally relatively simple prostheses to something reliable and useful.

Evaluation

A mere assessment of the efficiency is not sufficient when evaluating the value of the prosthesis for the amputee. It is necessary that the patient accepts the prosthesis if it is supposed to contribute to the rehabilitation - physically, psychologically and socially. Therefore some kind of evaluation of the acceptance is a primary component

of each evaluation. The functional value of the prosthesis can be judged subjectively and objectively. The amputee's own impression of the functional value of the prosthesis is decisive for the acceptance, also if objective measurements would not correlate with the opinion of the amputee. ADL and ADW (activities of daily working) tests should be structurized in such a way that they allow for comparisons between different types of prostheses, concerning their functional limitations. Some kind of judgement of the appearence should also be part of the evaluation and finally the engineering status of the device, concerning strength, reliability, maintainability etc should be considered. For this latter purpose well defined laboratory tests should be performed, only that those tests should simulate for real load combinations. The poor correlation between results from current lifetime tests and real lifetime is probably due to the fact that most tests are basicly concerned with the active performance of the prosthesis and not sufficiently with the active and passive loads that the prosthesis is subject to when used by the amputee. The grasp is normally the first step in a sequence of events or manipulations. It is thus obvious that it is not sufficient to limit a test only to grasping the handles of a wheel-barrow, without considering the loads occuring when moving and tilting it. In fact we have sometimes heard that the prostheses are not to be used for the things that the patients really want and spontaneously use them for.

We have felt, that before any significant further resources be spent on specific functions of upper extremity prostheses a more general test battery should be used to investigate which parameters are the most important for the amputees acceptance of the prosthesis. We are in the process of developing such a test battery.

A psychological man-machine concept

It does not seem very sensible to develope a prosthesis, that appears to be an engineering miracle as far as function and efficiency is concerned, if the amputee feels that it is more of an engineering monster. Subjective acceptance is more important than objective data about performance. The conclusion of this is that prosthetic research and development is not only an engineering problem but a searching for balance between man and machine.

The general concept that technology is man's friend and slave is true only if it does not come too close. Physiologically, we utilize different immunity reactions when we are offended and there are analogue psychological mechanisms. It has, as an example, been reported that the investigations performed prior to the specification of the Heidelberg manipulator project, showed that the patients did not want the manipulator to do anything with or close to their bodies. Of course the patients' opinions may change when they get used to the manipulator. It is not necessarily true, that the amputee, if he gets the prosthetic finger, really wants the whole prosthetic hand.

Consequently, in rehabilitation engineering the most advanced application of technology is not necessarily equal to application of the most advanced technology.

The concept of non-destructive testing

Engineers often deal with destructive testing (materials testing, lifetime testing) as well as non-destructive testing (functional tests, documentation of performance). In no case it is accepted, that a medical test be conducted, if it affects the prognosis of recovery or survival in a negative sense.

When developing and supplying prostheses and other technical aids we conduct tests during and after the development on test subjects and we try new devices in the rehabilitation programme of individual cases. It may be reasonable to try and penetrate if this introduces any risks as to the final outcome of the rehabilitation. Many arm amputees appear to have reached a very stable state of rehabilitation. Irrespective of what kind of prosthesis they use, they have accepted their prosthesis and use them in a very skillful way and they cannot imagine that anything else could be better. When we suggest that a new prosthesis might offer further possibilities and should be tried,

there is no positive response. These amputees do not seem to be interested in trying anything new. They sometimes do not even mobilize any interest in learning about the possibilities of the new prosthesis.

We believe that the state of rehabilitation is not always as stable as it may seem to be. Before it was reached, there were broken expectations, failures etc. In fact the amputee defends his state of rehabilitation against fatal disturbances. If such an amputee is not strong enough to resist our eagerness to get the new developed prosthesis fitted and if the new device has obvious advantages, but fails in performin well enough in critical situations or fails performing at all due to poor reliability, we have opened the patients eyes to something potentially better and than taken it away from him. We may very well have destructed his state of rehabilitation.

Over the past decade newspapers and TV have released sensational reports about new developments in our field. We have probably participated very actively in order to promote for our funding, but we have not sufficiently taken into account that we have given rise to unrealistic expectations for many amputees. Especially for many new amputees the confrontation with realities has had tragical effects. Many an amputee who has achieved a reasonable level of rehabilitation has questioned whether in fact he should accept his current state or try these new things. He is in his full right to do so. We also are in our full right to develope new devices, but we are not in our full right to missuse the amputees' confidence and expectations by introducing devices, which are unreliable and may cause unnecessary stress when given to amputees, who are badly motivated or otherwise unsuitable as test subjects.

Test subjects should be carefully selected. There are very flexible and realistic amputees who are interested in trying new devices and would not take any harm if the experiment fails or if the way to success is very long. It is usually no problem for the clinical team to determine, if a patient is suitable, but the clinical team must always be allowed to refuse to make less stable patients available for test. A random selection of amputees for testing a new hand prosthesis, based only on physiological conditions, i.e. amputation level, is cynical as it may hazard the rehabilitation level for some of them, and it is not necessary.

The above and the fact that the patient is always more important than the test object, is an endless source for missunderstandings and conflicts between those who work in the rehabilitation team and those who work outside it. The best solution to this problem is beautifully expressed by "Mike's law": "Everybody who is involved in prosthetic research and development should see at least one patient per day".

Priorities in upper extremity prosthetic development

Our goal is to produce devices that are accepted and used by the amputees. We may apply different design concepts, but the design concept is only a way, not a goal. Our conclusion, as to the relative priorities in upper extremity prosthetics development is the following:

1 Reliability

The amputee must be able to trust his technical aid. It must have a reasonable lifetim so that service and repair does not become a dominating routine in life. It must be reliable, so that it does not fail in critical situations, and thus forfeit the level of rehabilitation reached.

Most current prostheses are far from a reasonable state in this respect, the further, the more complicated. It may be questioned, whether in fact many prototypes fail in demonstrating their potentials, because early, trivial malfunction convert the test subject from a positively interested to a negative patient.

2 Cosmesis

When cosmesis is called for it must be acceptable for the amputee statically as well as dynamically. Most hand prostheses do not fulfil this condition.

It may be questioned, whether in fact the situation is, that many interesting hand prosthetic designs have come to a point, where they have to wait for a solution of the cosmetic problems, before the acceptability of the prostheses can be investigated on its new merits. The materials of cosmetic gloves must be improved, so that they become much less sensitive to wear and tear and dirtying. As it is now, they convert the prosthesis to something to be protected instead of something to be used.

3 Comfort

If the relative importance is taken into account, far to little interest is being spent on systematic analyses and solution of the problems of the fixation of upper extremity prostheses to the body. There are many subquestions to the basic questions: stability, cosmesis and comfort.

4 Reorientation of objects

Operative analysis of manual activities indicate that turning the object after grasping is a very frequent step in the sequence of events. As this cannot be done by the prosthesis it does not make very much sense to use the grasp at all, when it can be avoided.

We are fully aware, that it is not realistic to conceive a hand prosthesis, that is able to rotate an object in the hand by means of well controlled individual finger movements. The more realistic approach by Herberts and his collaborators, however, gives hope to a reasonable solution of this problem, as it opens a possibility for the b.e. amputee to rotate the hand in three degrees of freedom under adequate control.

5 Sensory information

Over the years it has been frequently stated, that as a hand prosthesis provides no sensory information in the usual sense, the operational efficiency will always be too limited, whatever kind of grasp. We cannot prove this statement, but there is an unambigous limitation in efficiency. We strongly believe, that no significant improvement of the efficiency of hand prostheses is possible, unless the prostheses are able to transfer information about the object and the control of the object. Feedback of forces and movements in the prosthesis are important but secondary, as it only reflects the control of the prosthesis, not of the object.

The above priorities represent huge challenges for research and development. We will only partially be able to defeat them, and as they decrease in importance, new ones will introduce themselves as necessary conditions to be considered.

BEHAVIOUR AND EFFICIENCY OF UNILATERAL BELOW ELBOW AMPUTEES WHEN PERFORMING BIMANUAL ACTIVITIES

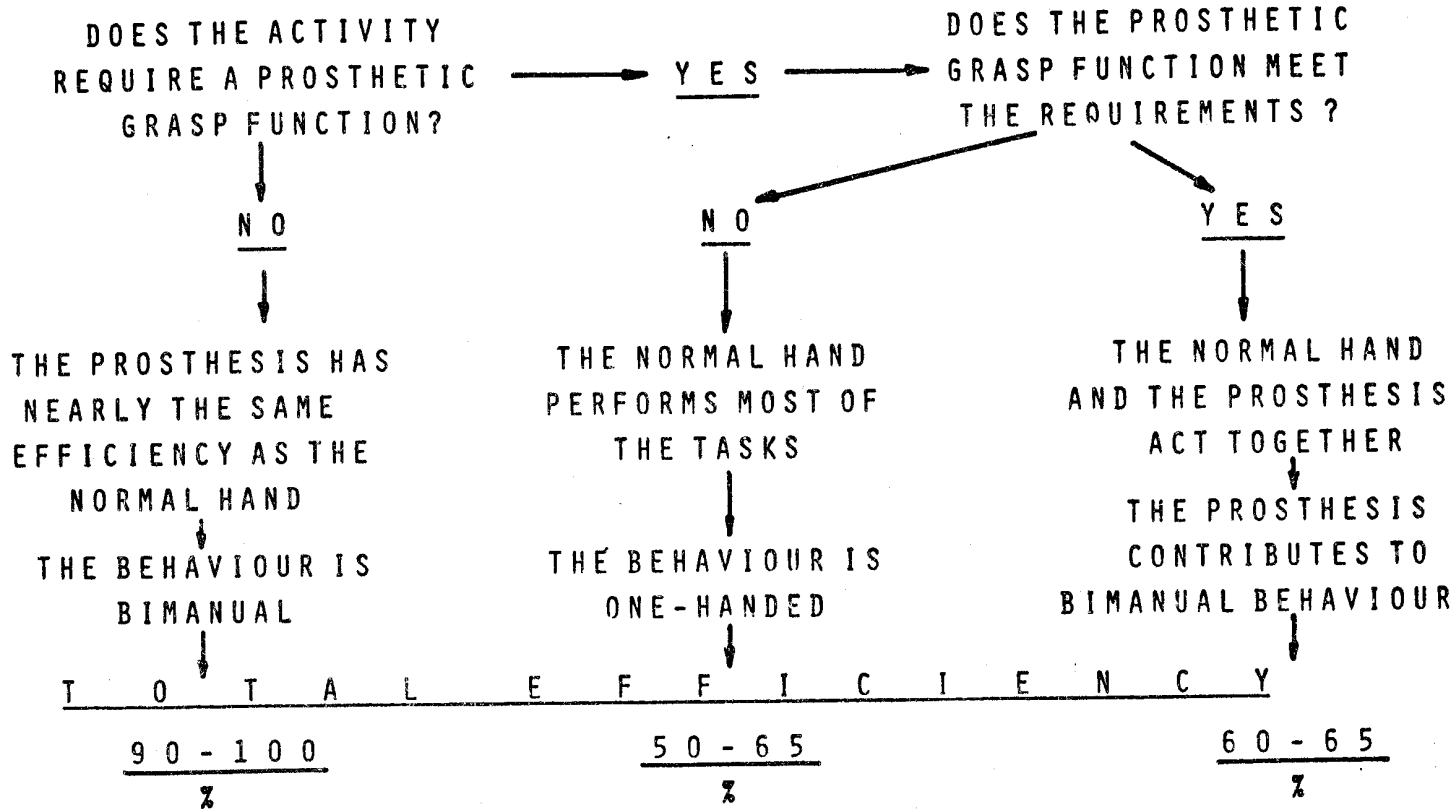

FIG. 1

AVERAGE USE OF THE PROSTHETIC GRASP FUNCTION IN A NUMBER OF ACTIVITIES

	NUMBER OF TIMES THE PROSTHESIS WAS USED	NUMBER OF TIMES THE GRASP FUNCTION WAS USED	%
AMPUTEE WITH MYOELECTRIC PROSTHESIS ON HIS RIGHT ARM (SCHEME OF ACTIVITIES PERFORMED TWICE WITH DIFFERENT SOCKETS)	174	42	24
THE SAME AMPUTEE WITH DORRANCE HOOK	94	26	28
AMPUTEE WITH DORRANCE HOOK ON HIS LEFT ARM	67	18	27

TABLE 1

HAND L	HAND R	ACTIVITY	2
/		PICK UP THE SHEET	
/		LIFT UP	
	/	GRASP THE SHEET	
/	/	FOLD	
/	/	ADJUST	
/	/	FLATTEN	
	/	ROTATE	
/		PICK UP THE SHEET	
/	/	FOLD	
/	/	ADJUST	
	/	FLATTEN	
/		PICK UP THE ENVELOPE	
	/	OPEN THE FLAP	
/		WIDEN THE OPENING	
	/	PLACE THE SHEET	
	/	SLIDE IN	
/	/	LIFT UP	
		LICK	
/	/	SEAL, PUT ON THE TABLE	

HAND L	HAND R	ACTIVITY	2
	/	PICK UP THE SHEET	
	/	MOVE THE SHEET	
/		GRASP THE SHEET	
	/	FOLD	
/		HOLD THE SHEET	
	/	FOLD	
	/	FLATTEN	
	/	PICK UP THE ENVELOPE	
	/	OPEN THE FLAP	
/		HOLD THE ENVELOPE	
	/	PICK UP THE SHEET	
	/	PLACE THE SHEET	
	/	SLIDE IN	
	/	PICK UP THE ENVELOPE	
	/	MOVE TO THE MOUTH	
		LICK	
	/	PUT ON THE TABLE	
	/	FOLD THE FLAP	
	/	FLATTEN	
	/	PUT ASIDE	

HAND L	HAND R	ACTIVITY	2
/	(/)	PICK UP THE SHEET	
/		FOLD	
	/	MOVE	
	/	HOLD AGAINST THE SHEET	
/		GRASP THE SHEET	
/		TRY TO FOLD	
	/	TRY AGAIN	
/		FLATTEN	
	/	PICK UP THE ENVELOPE	
/		OPEN THE FLAP	
/		TURN UP THE FLAP	
/		WIDEN THE OPENING	
/		PUT ON THE TABLE	
/		PICK UP THE SHEET	
/		PICK UP THE ENVELOPE	
/		PLACE THE SHEET	
/		SLIDE IN	
/		PICK UP THE ENVELOPE	
/		LICK AND SEAL	
/		PUT ON THE TABLE	

AVERAGE USE OF HANDS AND HAND PROSTHESES IN A NUMBER OF ACTIVITIES

	NON-DOMINANT HAND (PROSTHESIS) %	DOMINANT (NORMAL) HAND %	BOTH HANDS %
PERSON WITH TWO NORMAL HANDS	25	50	25
AMPUTEE WITH MYOELECTRIC PROSTHESIS ON HIS RIGHT ARM (DOMINANT BEFORE AMPUTATION)	40	50	10
THE SAME AMPUTEE WITH DORRANCE HOOK	35	55	10
AMPUTEE WITH DORRANCE HOOK ON HIS LEFT ARM (NON - DOMINANT BEFORE AMPUTATION)	25	65	10

TABLE 3