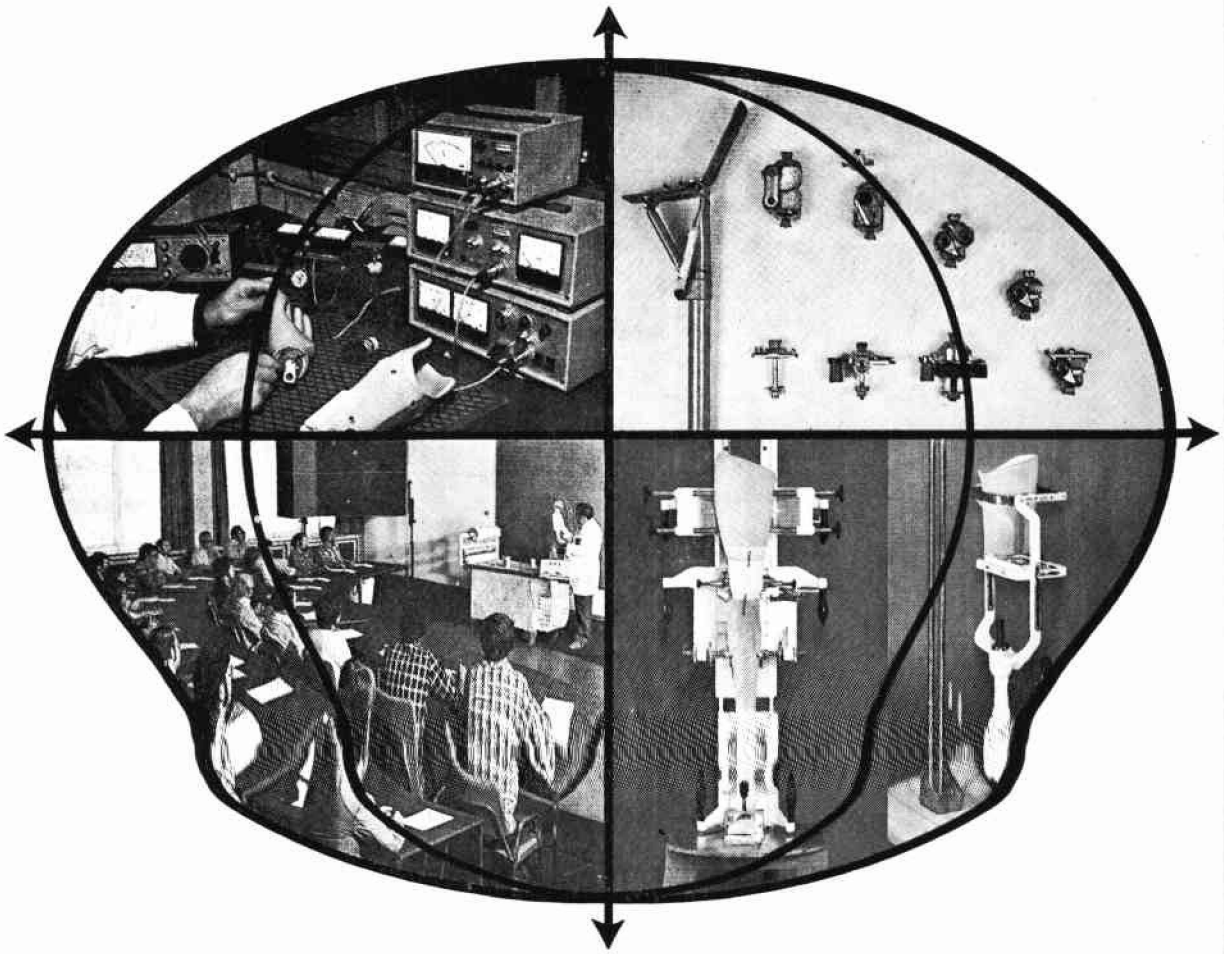
The Journal of the International Society for Prosthetics and Orthotics

Prosthetics and Orthotics International

April 1977, Vol. 1, No. 1



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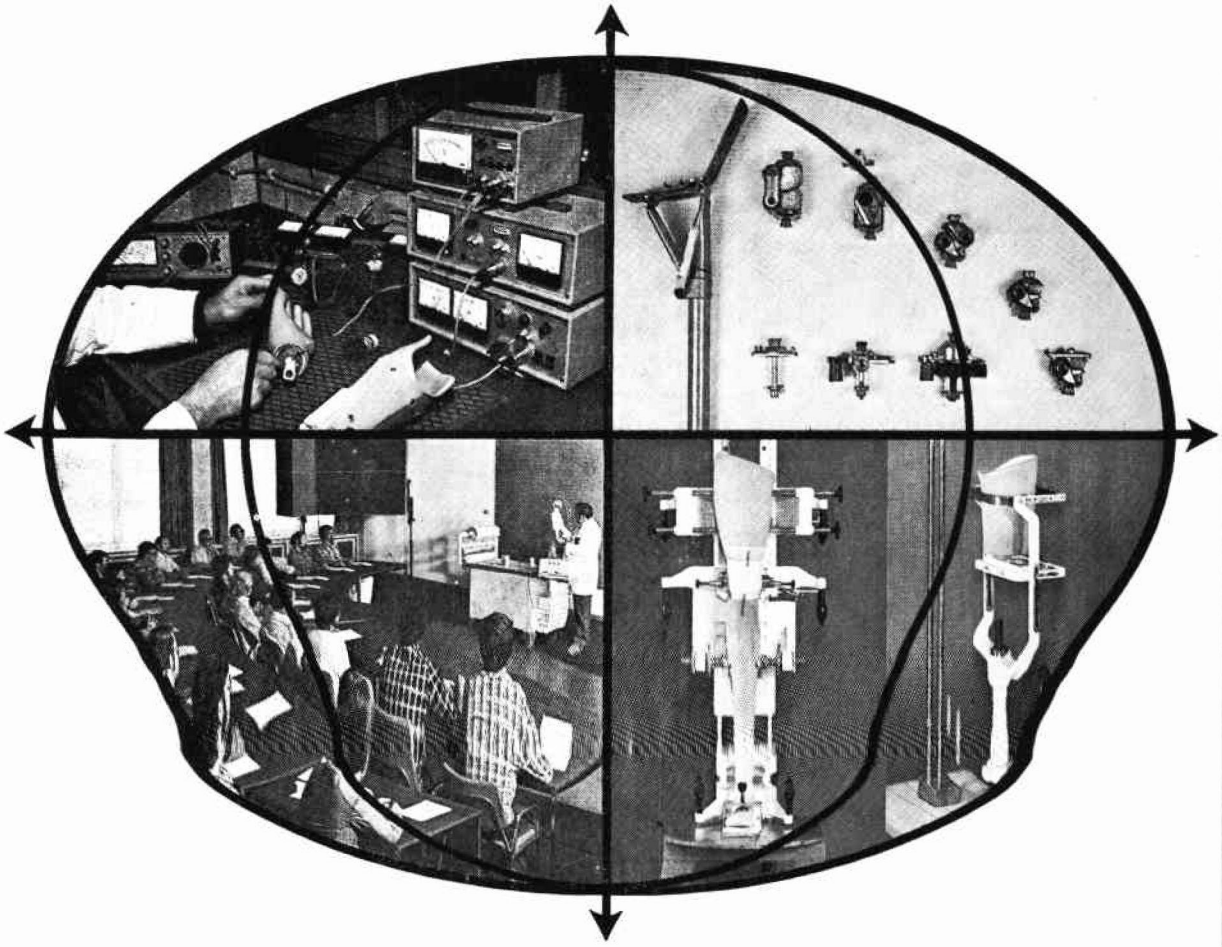

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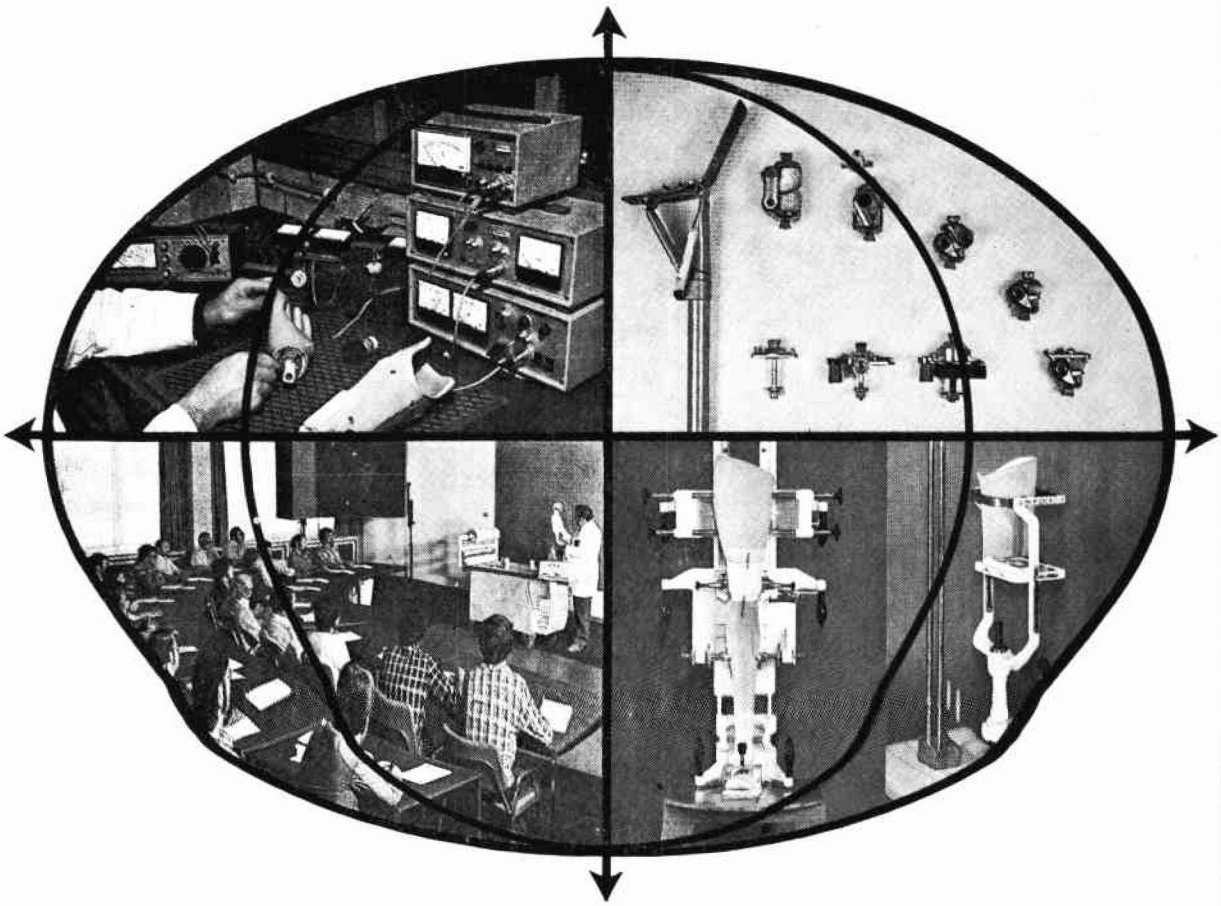

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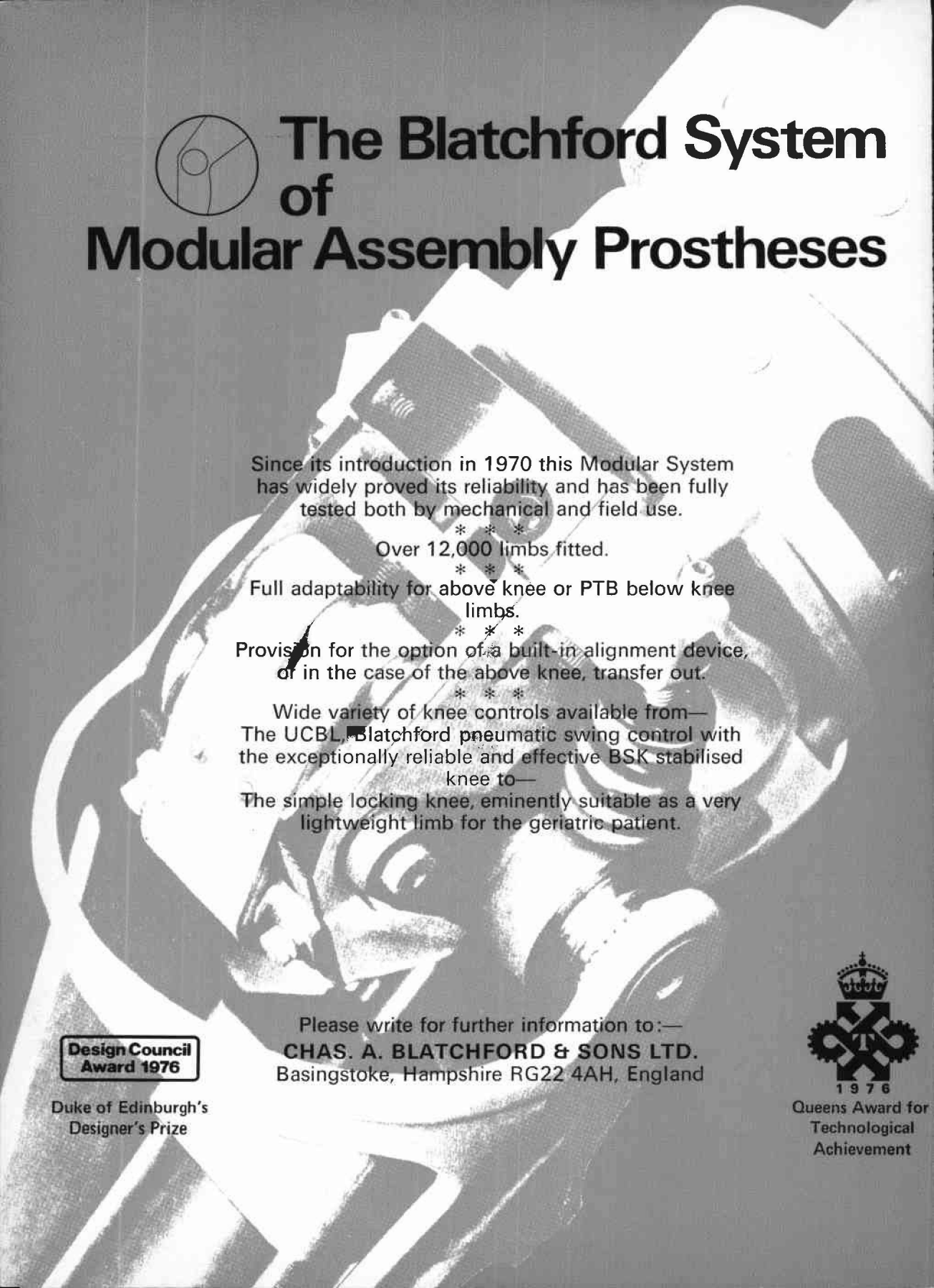

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Prosthetics and Orthotics International, 1977, 1, 1–4

Prolegomena

The President

Dissemination of information and feedback, i.e. communication is of vital importance for an international society, for progress and development. The launching of our new international Journal is considered by the ISPO board to be a great and necessary achievement. It is our hope and belief that the Journal shall become the forum for information and discussion on our multidisciplinary programme, research, education and practice.

The society is most indebted to Mr. A. Bennett Wilson, Jr., who with skill and dedication has produced the ISPO Bulletin through more than five years and thus maintained an important information service and a bridge between the past and the future.

The new Journal may be seen as a resuscitation of Prosthetics International. The International Journal on Prostheses, Braces and Technical Aids, later modified to Prosthetics International was published in four languages in the fifties and sixties, supported by gracious grants from the Danish Society and Home for Disabled, the USA Government and the European Coal and Steel Community. Termination of these grants seriously endangered the programme.

Formation of the International Society virtually widened our horizons, and our continuous development to a fully mature organization has been generously supported by grants from the Government of the United Kingdom and by Danish resources.

This periodical is but one part of the ISPO publication service. Proceedings and reports emerging from courses, seminars and conferences represent the third dimension of our endeavours. These activities which still enjoy support by national and intergovernmental agencies, will continue at a still increasing rate.

The society has now been joined by more than 1100 individual members. The creation of National Member Societies has proven to be a most fruitful constitutional provision. Several of our National Societies have established excellent programmes. Co-ordination of national and international efforts is of course mandatory.

The Standing Committees on Publication, Education, Research and Evaluation are in charge of long-term planning. They are also ready to assist and co-operate with the National Societies. This shall ensure optimum use of our resources.

Through the years the Society has enjoyed excellent co-operation with United Nations and the World Health Organisation.

Obviously the professional potential of our committee also has much to offer individual national governments. Here formal liaison is envisaged, in particular in an advisory capacity.

Today ISPO is self-supporting. The future of the Society and the life of the Journal are in your hands. May it flourish and may we be able to meet the still increasing demands for improved rehabilitation services.

Crescat, Vivat, Floreat!

Knud Jansen

The President Elect

From the start of our Society we have recognized the need to maintain communication with our members and the world around us. Our efforts in this regard have been well sustained but perhaps not wholly successful, primarily because of limited resources. Indeed the income from membership fees was, for the most part, swallowed up by the costs of producing, first, Prosthetics International in the days of ICPO and more recently the ISPO Bulletin which nevertheless appeared without interruption from its inception in January, 1972.

The situation at present is not substantially different and the costs of producing Prosthetics and Orthotics International will again be substantial in relation to our income. The Executive Board is fully sensitive to all the financial implications and is actively pursuing methods of placing our Society on a sounder financial basis. The philosophy of these activities is primarily based on the development of projects in collaboration with individual nations, agencies and other bodies concerned with the welfare of patients in our mutual field of interest. Fundamental to such a policy is the need to ensure that there is as wide a dissemination of information as is proper and possible. The phoenix emergence of Prosthetic and Orthotics International is the key-stone of this policy. The first issue represents a small number of over 200 papers contributed at our First World Assembly held in Montreux, Switzerland in October, 1974 and subsequently revised by the authors. Inevitably many of the excellent presentations from Montreux have not found a place in the limited space available, but may yet appear in an up-dated form in future issues. I am confident that the Editorial group with the help of the Publications Committee and its referees coupled with the experience of our past Editor, Mr. A. Bennett Wilson, Jr., will develop Prosthetics and Orthotics International to the point where it can take its place alongside the best of the medical and scientific journals of the day.

However, our efforts must go beyond the Journal itself and we will continue to produce reports of our work as we have done in the past, e.g. Amputee Performance Measurement, Physical Testing and Needs in Prosthetics and Orthotics World-wide. In the near future we can confidently expect reports on Standards for Lower Limb Prostheses following the meeting to be held in Philadelphia on 4th-6th June, 1977 and from the Working Group on the Deformed Foot held in Stockholm on 3rd-6th March, 1977.

The Cairo Report establishing as it did the "State of the Art" in research, evaluation and education, represented the concept of an ISPO Year Book but once again financial constraints prevented the development of this particular philosophy. We believe our present approach is more flexible, will be more productive in disseminating information and in stimulating workers throughout the world to present their results, philosophies and techniques.

These reports and the continued up-dating by our Journal will constitute a body of knowledge invaluable to all workers in the field. It is the responsibility of members to respond to these publications in the way that the Chairman of the Publications Committee and the Editors outline. We want to do as much as we can for our members but our performance can only be improved if the membership itself responds and contributes. That contribution can take many forms—in submitting material for publication in the Journal, in serving on Committees and Working Groups and in developing ideas based on our priorities and guidelines for the development of projects. My hope and belief is that we will see this response, as the aggressive policy of the Publications Committee now provides an assurance that the members' efforts will find physical expression in Prosthetics and Orthotics International.

George Murdoch

The Chairman of the Publications Committee

In these days when new techniques can be developed by teams working in different countries, the need of a means of inter-communication is more necessary than ever. In the last 50 years, orthopaedic techniques have developed rapidly and widely and show every sign of continuing to do so. When ISPO started nobody could foresee either this vast expansion of knowledge, or the world-wide relationship we have today. Especially in these days, everybody must work hard with maximum efficiency, so that it is essential each of us keeps abreast of every new technique that we develop.

We live in an era of team work. In ISPO, this idea is working particularly well; in fact I think we can say it is working in a marvellous way. We have wonderful co-operation between Doctors, Engineers, Prosthetists, Orthotists and Physiotherapists. We are all very glad of this and the benefits it brings to our patients. I look forward with interest and pleasure to our Journal actively linking together all sides of our work.

But such a Journal can only work if we ourselves make it work: the Editors can do nothing, if they have nothing to edit. We, the Publications Committee, look forward to publishing your articles; articles not only about your successes, but also about your theories that went wrong (a half-finished failure in Buenos Aires may complete a theory in Stockholm). We want your letters about your problems, your questions, your opinions and your ideas about other people's problems, questions and opinions. Discussion is healthy. Naturally any theories or discoveries that are sent to the Journal will be fully protected. Different nationalities, different languages, different levels of development must not hinder our efforts.

So, ladies and gentlemen, fill your plaster casts with champagne "Here's to a long life for our Journal!".

André Bählern

The Editors

We are pleased to present the first issue of the new Journal of the Society—"Prosthetics and Orthotics International". We are, of course, well aware of its ancestry and hope that the Journal will live up to the high reputation of its predecessor "Prosthetics International", which was published by the forerunner of our Society, the International Committee on Prosthetics and Orthotics.

The core of each issue of the Journal will be scientific, clinical and practical papers on all aspects of prosthetics, orthotics, rehabilitation engineering and related orthopaedic surgery. Although no firm decisions have been made as to the balance of the articles which will appear in each issue regarding disciplines or specialty, we hope to ensure that every member will find a large proportion of the material of interest to him. The first two issues will be devoted to the presentation of up-dated versions of papers originally presented at the World Congress in Montreux. The future issues will be a blend of papers based on our congresses, invited papers and, in particular, papers submitted by the membership. Instructions for intending authors are included elsewhere in the Journal. We will also, from time to time, hope to produce issues which present symposia on subjects selected by the Publications Committee, or indeed identified by the membership as deserving of a high degree of priority in our attention.

This publication will be unique in providing on a wide international circulation a scientific forum to meet the specialized needs of our multidisciplinary Society.

In addition, however, we must recognize that it has the equally important function of acting as the organ of the Society and as a vehicle for inter-communication. Your views on any subject expressed through its pages will reach right across the membership and we would wish to encourage lively communication on all aspects of our activities.

We intend to be very flexible in our approach and attitudes within the formative period. The Journal will be shaped to the requirements of the whole of the Society. Consequently we must depend on the membership to identify the form they would like their Journal to take. Although we are sure of in-put on policy matters from the Publications Committee and through it from the Executive Board, we would like to encourage you, the individual members, to communicate your views to us.

John Hughes Norman Jacobs

Prosthetics and Orthotics International, 1977, 1, 5–7

Leg amputations due to defective arterial circulation

R. BAUMGARTNER

Orthopaedic University Clinic, Balgrist, Zurich

Defective arterial circulation in our latitudes is the cause of 80-90 per cent of all leg amputations. This figure has almost tripled during one generation, and continues to rise in spite of all the success of conservative and operative treatment, particularly vascular surgery. A comparison with other countries shows that this percentage varies directly with the standard of living of the population, or with the percentage of illiterates, the consumption of all energy, or, maybe, of soap. In any event peripheral vascular disease plays a subordinate role in the emerging nations, at least, for the time being.

The correlation with the standard of living indicates the main causes: longer life expectancy, lack of exercise, overweight, abuse of nicotine, and perhaps climatic conditions.

The shockingly high percentage alone, however, does not justify separate consideration of these patients. Rather, it is felt that there are other, more differentiated problems that make rehabilitation so difficult, and often impossible.

As in all other cases of leg amputation, the amputation and the fitting of a prosthesis in cases caused by defective arterial circulation are of focal importance. The result to the patient is not primarily affected.

Contrary thereto, amputation of the leg on account of defective arterial circulation is not the primary cause of the affliction, but one of the many possible consequences of a general illness. The basic illness is arteriopathy of highly varied origin, an incurable illness which can at best be retarded in its progress, but cannot be arrested, to say nothing of being reversed. Not only the lower limbs are threatened but also the heart, lungs, brain, sensory organs, kidneys, etc. Where today the stump and the fitting of it with a prosthetic device are at the centre of interest, tomorrow a heart infarction, an apoplectic stroke, or an arterial occlusion on the opposite side may call for completely new priorities. It is no wonder, therefore, that even today not only the patient and his family, but even the physician, yield to discouragement and become sceptical, pessimistic, and sometimes even opposed to all efforts for a comprehensive and rapid rehabilitation.

It is, therefore, also understandable that for many years the surgeon saw his task as amputating the limb of a vascular patient principally through the thigh in order to achieve rapid healing without complications. The patient cannot be faulted for being accessible to these considerations, because he wants to be rid of his gangrenous leg quickly, and for good. If his physician is not aware of it, how can the patient be expected to know that rehabilitation is twice as difficult for one whose leg is amputated through the thigh rather than through the lower leg? How can he know that a person with both legs amputated through the thigh will only in rare cases ever walk again, whereas if both legs are amputated below the knee the patient has a good chance of walking once more? Disconcertingly, we still hear today the watchword "haut et tôt" (high and early). He who believes differently runs the risk of being criticised for "salami tactics." At best, in many circles, only the diabetic is still afforded an option of amputation below the knee.

The increase in the number of patients and the increasing urgency of the most rapid and comprehensive rehabilitation possible impelled us to search for a solution that would serve the patient better for the long term. First, let us emphasise the merits of internal and physical medicine, as well as those of vascular surgery, and at the outset seek a way to avoid amputation. Equally important in "amputation prophylaxis" is proper footwear for feet with poor circulation, or atrophied and often hypo- or even asensitive feet. However, when amputation can no longer be avoided, the first task is to find the level of amputation which should be as

All correspondence to be addesssed to: Dr. R. Baumgartner, Orthopaedic University Clinic, Balgrist, Forchstr. 340, CH-8008 Zurich, Switzerland.

distal as possible and still yield a useful stump, i.e. one which is without pain and can control a prosthesis. The determination of the level of amputation is by far more difficult than the technique of the operation because the quality of the circulation does not decrease proportionally with distance, but, on the contrary, at the same level the tissue may very well have good circulation and at other times none. Amputation "in healthy tissue" however will always be an illusion, because all of the arteries are diseased and constricted.

Now as before, we consider anamnesis and clinical finding the most important criteria for the determination of amputation level. However, evaluation requires considerable experience and even then it is not free of mistakes. We are, therefore, glad for each further diagnostic contribution which would make the determination of the amputation level easier. The method which will generally prevail is the one that does not require a complicated and costly apparatus or a highly specialised technician. The majority of amputations will continue to be performed, not in large centres, but in medium and small hospitals where there is rarely the environment for costly procedures.

The same goes for the operative technique. By far, not each technique is "a priori" suitable for the vascular patient. We prefer the method which takes into consideration, as far as possible, the particular circulatory conditions and which leaves the smallest possible wound surface. The low vitality of the tissue does not tolerate unnecessary traumatisation, foreign material, osseous fusions, bloodlessness, or haematoma. We prefer exarticulation of individual toes, amputation through the bases of the metatarsalia, perhaps in the Lisfranc joint, amputation below the knee, exarticulation at the knee, and only subsequently amputation at the thigh and hip exarticulation. Occasionally, a local gangrene of the heel will heal by hemicalcanectomy. Less suitable are partial amputations of the toe (except for the big toe), transmetatarsal amputations in the distal two thirds, amputation in the posterior foot, and in the distal two-thirds of the lower leg. Healing of the wound must be promoted by timely infection prophylaxis and prevention in which asepsis has priority over antibiotics by stimulating the arterial and venous circulation by physical and, where necessary, medicinal means. However, if the healing of the wound is complicated, conservative wound treatment or local stump correction generally suffice. Only at that time amputation below the knee takes priority in the vascular patient, followed by exarticulation in the knee joint as an alternative to thigh amputation.

Amputation represents the first important step towards rehabilitation. It is however meaningless if the subsequent measures do not follow continuously and are not administered professionally, because care, walking instruction, supply with prosthesis, and rehabilitation of the patient have their own peculiarities. Reduced physical ability considerably restricts the possibilities of physical treatment. Training usually has to start all over as the patients have been bedridden often for weeks and months. Care must be given very conscientiously, particularly when the patient's psychological state is poor. Decubital sores, incontinence of urine and stool, infections of respiratory and urinary tract are complications which should be prevented as much as possible by correct professional care.

A compression bandage on the stump should be applied in a manner to reduce compression from distal to proximal. Early provision of a prosthesis, as a rule after complete healing of the wound, makes it possible to put early and increasing load on the stump and thereby promote good circulation. However, this must not lead to areas of excessive pressure that will aggravate circulatory conditions. The prosthetist must take into account the sensitivity of the stump tissue and the varying stump volume. Only a socket with complete contact is suitable to avoid local stump oedemas and their unpleasant, often very serious consequences. The prosthesis must be light in weight but of sturdy construction and even infirm patients should be able to put on and take off the artificial leg without outside assistance, just to mention a few points. Even after these considerations there remains a limited number of patients who are better off without a prosthesis. In these cases rehabilitation aids, mainly the wheel chair, often solve the problem of independence surprisingly well. We always face the enormous task of instructing comprehensively all persons taking part in the rehabilitation of the vascular patient with an amputation and making sure that our orders are being followed.

The orthopaedic surgeon is in charge of carrying through and co-ordinating a case, which goes far beyond his professional specialty. Whether he likes it or not, he must encourage the co-operation of the family doctor, the internist, the psychiatrist, the dermatologist, the state physician, the social worker, and others. What appears as a matter-of-course to the specialist is by no means a matter-of-course to his colleagues who are faced with these problems only occasionally and are therefore not able to recognise them in their full range. Co-operation is essential. It is one of our most important tasks to venture beyond the four walls of our professional specialty and help our vascular patients obtain optimal medical care where the orthopaedic surgeon is no longer solely responsible.

Prosthetics and Orthotics International, 1977, 1, 8–12

A system of extension prostheses

H. J. B. DAY and J. WRIGHT

Artificial Limb and Appliance Centre, Manchester

Congenital lower-limb deficiencies, which have not been converted by amputation, usually present with shortening as well as deformity and joint defects.

It is normal practice to equalize the length by the use of a bootee, prepared from a cast, which is attached to a platform mounted above appropriate prosthetic components. In writing the prescription for the prosthesis (Fig. 1), consideration must be given to the ability of the limb to bear weight, and the range of movement, power, and stability of the joints. Partial relief is provided by a thigh corset whilst full weight relief will require ischial support. The provision of either type of corset will suffice to control lateral instability of the knee. Some restriction of knee movement may require alteration in the normal alignment of the prosthetic joints and/or the provision of locks, whilst gross restriction of movement or ankylosis of the knee in a limb which cannot bear full weight calls for solid side bars joining the shank to the thigh corset. The bootee, especially if made of soft leather, provides comfort but is not particularly efficient at transferring force to the prosthesis, and does not give a good cosmetic result.

This project was intended to investigate whether the bootee, together with any outside container or supports, could be replaced by a laminated plastic socket which might improve both the efficiency and the appearance.

The major problem is that the shape and size of the foot deny access to a rigid total-contact socket. The simplest way of overcoming this difficulty is to use an "access trap" as in the Canadian Syme's prosthesis (Foort, 1956). This can be used only when the foot is narrow as in absence of the fibula. (Longitudinal Deficiency: Fi—complete; Ta—partial; MT complete 4, 5; Ph complete 4, 5 (Kay, 1974)).

All correspondence to be addressed to: Dr. H. J. B. Day, Artificial Limb and Appliance Centre, Withington Hospital, Cavendish Road, Manchester M20 8LB.

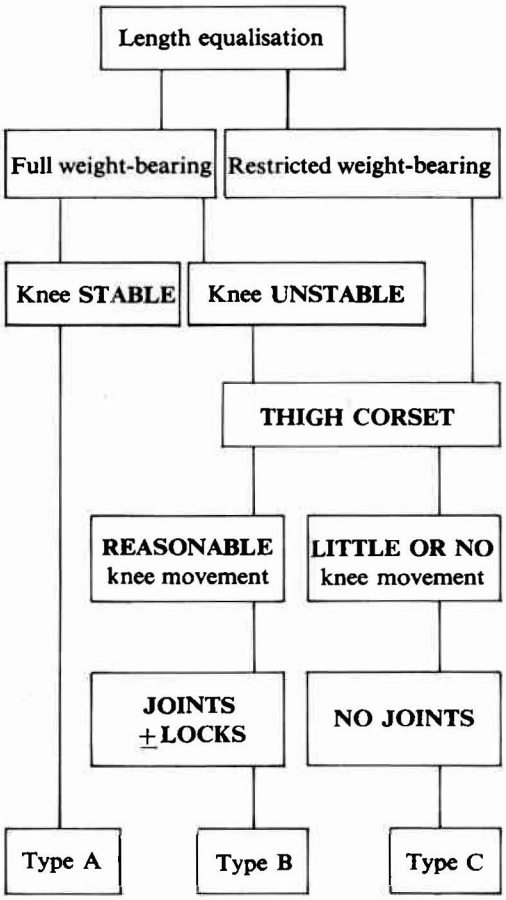

Fig. 1. Prescription scheme.

This is a Type A case and, whilst conversion by amputation is usually desirable, many parents refuse or wish to defer operation until the child is older. A socket is made with a posterior aperture which allows the heel to protrude while the toes and forefoot are gaining access to the front of the socket (Fig. 2). The aperture is closed with a rigid cover held in place by

Fig. 2. Access trap socket.

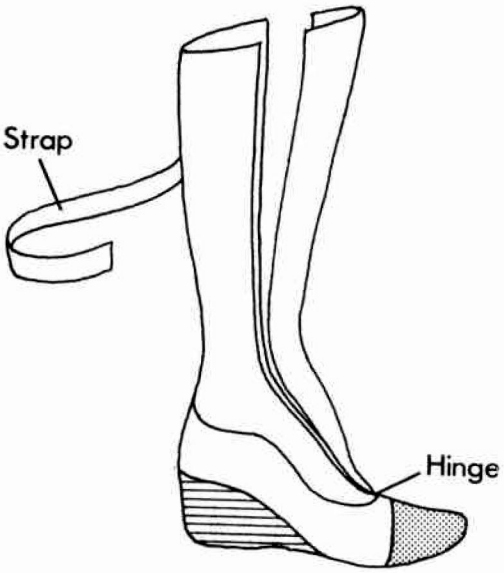

Fig. 3. Hinged split socket.

elastic straps. The socket is mounted at an appropriate height on a wooden foot incorporating a wedge-shaped heel cushion and felt toe piece. This type of prosthesis has been fitted to five children, all of whom have been wearing it for more than three years. A similar approach has been used in three cases of proximal femoral focal deficiency, but in these the sockets are longer, giving ischial support, as required in Type C cases.

The "Access Trap" method is not suitable when the foot is of normal size and will not enter a rigid socket unless the brim can be opened. This can be achieved in two ways. In the first, almost the entire front of the socket is made detachable. The second and, in our view, the more desirable method is to split the socket down the sides and hinge the two halves together at the toe. The posterior half which includes the plantar surface of the socket is mounted on the foot. The socket is opened to allow the foot to gain access and a strap or elastic is used to hold the socket closed round the leg (Fig. 3). This technique was also used for a girl of 12 years who had an amputation of the forefoot and shortening of the leg due to multiple tibial fractures. When wearing a surgical boot, her function was excellent but the appearance ungainly. The circumference of the hind foot was considerably larger than that of the leg below the knee. A socket was made incorporating a hinge distally and cut down the sides.

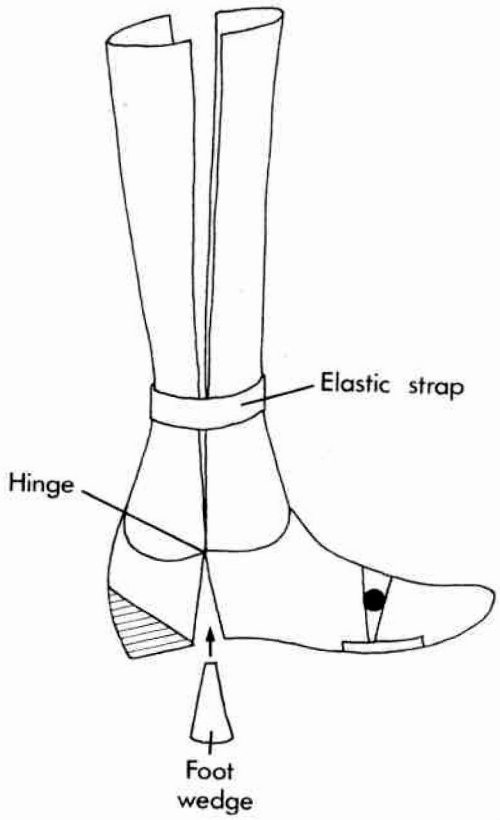

Fig. 4. Hinged split socket with wedged foot.

This was mounted at the correct height on a foot from which an inferior wedge was removed (Fig. 4). The socket opened for insertion of the leg and the wedge was then replaced under the foot and a normal shoe was worn. An elastic strap round the socket completed the prosthesis. Because her leg, even in the socket, was smaller than the sound leg, a more recent version has been built up with Plastazote to improve the appearance. This patient has been wearing this type of prosthesis for six years with complete success.

A similar technique has been used in a Type C case of a boy with a congenital absence of the forefoot, ten inches (250 mm) of shortening, and the knee ankylosed in 40 degrees of flexion. He had worn an extension prosthesis consisting of a platform-mounted leather socket attached to a thigh corset by rigid side steels. Access to a total-contact rigid socket is prevented more by the flexed knee than by the size of the hind foot. A split socket, hinged distally, has provided him with a prosthesis which is lighter, easier to don, and cosmetically more attractive. In this case the anterior half was attached to the limb structure.

The Type B case, using a socket attached to a thigh corset by jointed side steels, presents another problem. If the foot is narrow the posterior "Access Trap" method can be used, but the hinged type of socket, which would appear to be indicated for a normal-sized foot, cannot be used because a complete rigid brim is needed to provide a strong attachment for the jointed side steels. Instead, the proximal part of the socket is enlarged sufficiently to allow passage of the foot in conjunction with a posterior access trap lower down (Fig. 5). A separate inner liner is inserted into the top of the socket after donning the prosthesis in the manner of the KBM or Fillauer wedge (Kuhn, 1966 and Fillauer, 1968). So far experience of this type is limited to one case, but will be extended in the near future.

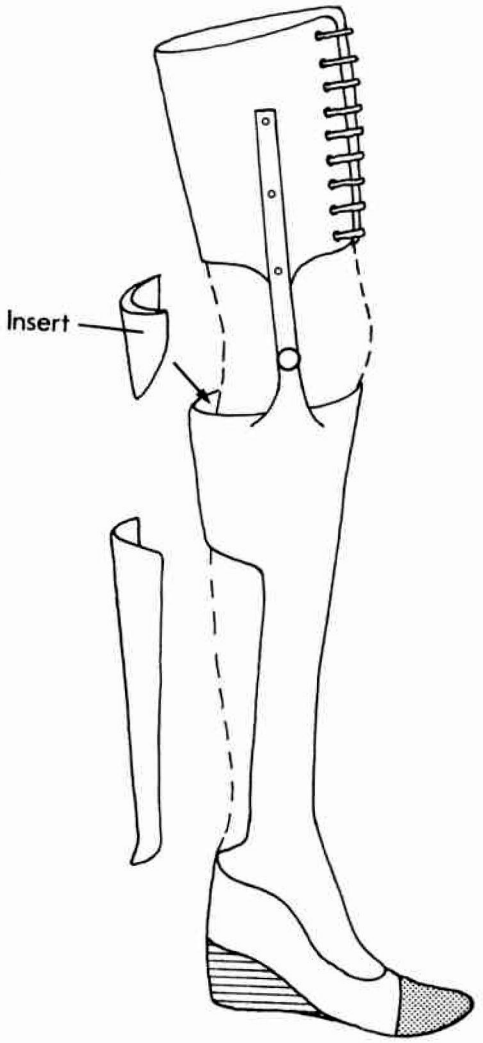

Fig. 5. Access trap socket with thigh corset, joints, and insert.

Selection of Type of Prosthesis

The first step is to decide, by examination of the patient, which of the three basic prescriptions A, B, or C is required. This information, together with an assessment of the foot size, allows the most suitable type of prosthesis to be chosen from the table shown in Figure 6.

Measurement

Measurement and cast-taking follow standard practice. The cast is taken over a tailored stockinette cast sock and a positive model is poured. This is modified as necessary to provide relief for any bony prominence and rectified for patellar-tendon-bearing if considered necessary. A wool sock is applied to the positive cast and a plaster check socket is made from this. The patient is given a trial fitting using the check socket in order that:

(a) it may be established, in cases where doubt exists, whether an access aperture or a hinged socket is appropriate;

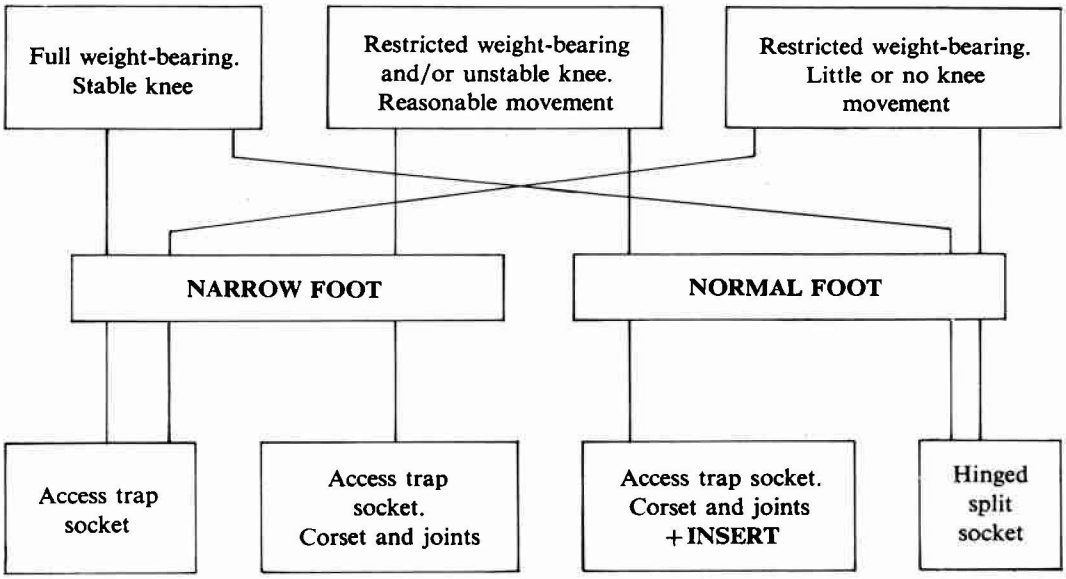

Fig. 6. Table for selection of correct prosthesis.

(b) the size and position of the access aperture may be found and reinforcement of the socket planned;

(c) a static alignment may be obtained;

(d) fitting alterations may be made, if necessary.

A positive model is made from the check socket. At this stage a further negative cast may be taken for record purposes, as the positive model will have to be broken out of the plastic socket.

Fabrication Technique

Access trap sockets. In general, the fabrication is similar to that of the Syme's prosthesis. In certain cases of proximal femoral focal deficiency, an anterior position of the trap may be preferred, and in all cases the trap covers are retained by elastic and Velcro fastening.

Hinged socket. The fabrication of this type of socket is unusual owing to incorporation of a hinge. The method is to lay-up on the positive cast:

Wool sock
PVA sleeve
2 nylon stockinette sleeves
3 layers of tubular glass cloth
1 or 2 polypropylene strips as a hinge
3 layers of tubular glass cloth
2 nylon stockinette sleeves.

A mixture of flexible resin and white pigment is stippled into the hinge area. Spread of the mix beyond this part is prevented by masking. The lay-up must be thoroughly impregnated and the resin allowed to gel. The masking is removed and a full-length PVA sleeve applied. A mixture of 80 per cent rigid and 20 per cent flexible resins with pink pigment is poured and allowed to cure. Surplus resin at the distal end is cut or sanded away until the white flexible resin is visible. The socket is then cut down the medial and lateral aspects as far as the hinged area.

Prosthesis with thigh corset. The heel-instep diameter of the cast is taken, and the posterior aspect at mid-patellar-tendon level is built up to the same measurement.

Extra reinforcement is required in the lay-up medially and laterally at the site of the knee-joint attachments. An insert is shaped to fill the space between the leg and socket posteriorly, and this incorporates the clip which holds in position the posterior access cover.

Results

Sixteen children and two adults have been fitted with these prostheses. Follow-up ranges from six months to seven years and all but two patients prefer the new type. Because of growth the children have required replacements and

altogether 103 prostheses have been made. Of the fourteen patients who had worn conventional appliances previously, six no longer need a thigh corset because of the improved stability provided by the rigid socket.

Summary

It is suggested that three basic types of extension prostheses are required as shown in Figure 1. Four methods of achieving these prescriptions using rigid, total-contact, polyester laminate sockets have been described, and the table (Fig. 6) indicates the correct method to be used for each type. These prostheses have proved very durable and repairs have been limited to replacing the straps and foot coverings.

Advantages claimed are improved comfort, efficiency, and appearance, in addition to speed of fabrication and lightness when compared with conventional prostheses.

Acknowledgements

We are grateful to L. Heyes, B. Ward and R. Amor, who have not only constructed the limbs but also given valuable advice on the technique of fabrication.

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Prosthetics and Orthotics International, 1977, 1, 13–18

Biomechanics of the hip disarticulation prosthesis[1]

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Introduction

More than twenty years ago, McLaurin (1954) published his first report on the Canadian hip disarticulation prosthesis. His work was aimed at improving the conventional design of the saucer-type and tilting table prostheses.

A measure of his success can be seen in that the Canadian-type has made the other two almost obsolete. Since its introduction, the prosthesis has changed very little. Modifications have been made to the socket and hip joint, but the principles have remained the same.

Two papers have been published to date which deal with the biomechanics of the prosthesis, Radcliffe (1957) and McLaurin (1969). Although both authors gave an indication of force directions, it was not possible for either to indicate magnitudes since no experimental results were available at that time.

The test reported here provides quantitative information on the variation with time of hip, and knee moments in both antero/posterior and medio/lateral planes, axial torque and axial force in the shank during the stance phase.

There are two main features in McLaurin's prosthesis compared to the other types:

(a) the design and position of the hip joint,
(b) the socket design.

The hip joint is a broad hinge placed well forward and below the anatomical hip joint. The joint allows free rotation in the antero/posterior plane, i.e. flexion/extension. It is rigidly fixed in the medio/lateral plane thus giving lateral stability.

The socket is a bucket-type seat which fits snugly around the pelvis and thus minimizes stump/socket movement. The suspension is provided by moulding over the iliac crests.

Other important aspects of the prosthesis are:

(a) the knee joint is set posterior to the hip joint in such a manner that if a line is drawn through the hip and knee centres it will strike the ground about 20 mm behind the heel, this is to ensure knee stability especially at heel strike,

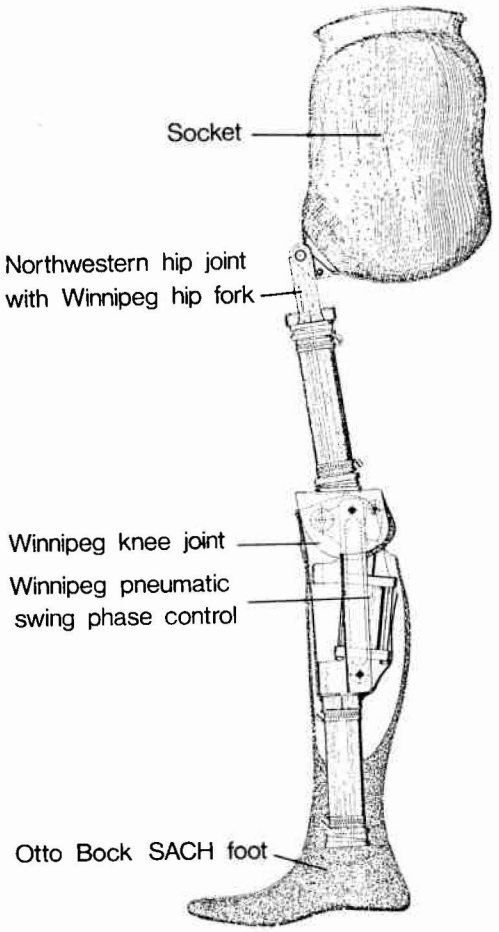

Fig. 1. The Winnipeg Modular Hip Disarticulation Prosthesis.

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[1]Previously published in Orthopadie Technik, 4/76, 58–60.

(b) excessive hip flexion is prevented by a limiting device,

(c) hip joint hyper-extension is prevented by means of a "hip bumper" or extension stop secured to the bottom of the socket.

Subject and Prosthesis

The subject used in the test was a 21 years old active female amputee of mass 51 kg approximately and with a height of 1.65 m. Amputation had been performed on the right side for pathological reasons and she had been wearing a hip disarticulation prosthesis for two years. The prosthesis used was the Winnipeg Modular Hip Disarticulation Prosthesis (Fig. 1) incorporating a Northwestern hip joint and uniaxial knee joint fitted with pneumatic swing phase control. The flexion limiter consisted of a leather strap and buckle attached between the hip fork and the seat of the socket. An Otto Bock SACH foot was used and no cosmesis was fitted. Socket manufacture and alignment were as recommended by McLaurin and Hampton (1962).

Equipment and Procedure

A strain gauged pylon dynamometer and a knee goniometer, as described by Lowe (1969), were incorporated in the shank of the prosthesis. Following dynamic alignment the patient was asked to walk about for about half an hour in order to accustom herself to the limb. The types of activity investigated were level walking at various speeds and walking up and down a ramp (1:7 gradient). Analysis of the results was partly manual and partly with the aid of a PDP 12 computer. The transducer raw data were sampled at a frequency of 10 Hz.

Results and Discussion

Using the information obtained from the dynamometer, force analysis allowed the calculation of:

(a) antero/posterior (A/P) moments at hip, knee and ankle,

(b) medio/lateral (M/L) moments at hip, knee and ankle,

(c) torque about the long axis of the leg,

(d) axial load along the axis of the pylon dynamometer,

(e) A/P and M/L shears at right angles to the pylon axis,

(f) resultant force.

The results for A/P knee moment (level, up-ramp and down-ramp walking), A/P and M/L hip moment, axial force and torque (level walking only) during the stance phase are shown graphically. Six cycles for level walking and three cycles for up-ramp and down-ramp walking were analysed.

The results display considerable scatter which cannot be wholly attributed to the dynamometer or associated instrumentation and must therefore be due to uncontrollable parameters related to the patient, such as effects of change of speed. The first and last 5 per cent of the stance phase cannot be considered as accurate because the sampling frequency used was too low for these areas.

Axial force. This displays a double peak pattern (Fig. 2). There is, however, a much slower increase in value of the axial force when compared with the results obtained with BK and AK amputees (U.C.B. 1947). The peaks occur later in the stance phase, are closer together and less pronounced. The maximum value is approximately 650 N.

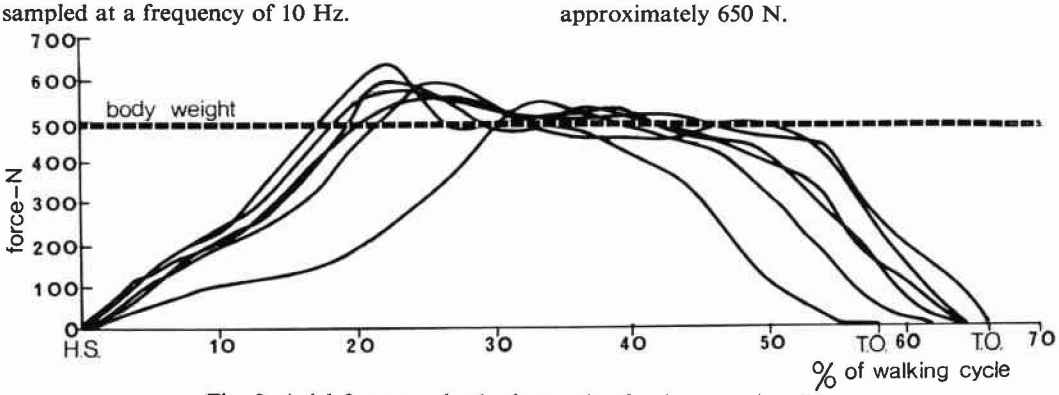

Fig. 2. Axial force on shank along axis of pylon. Level walking.

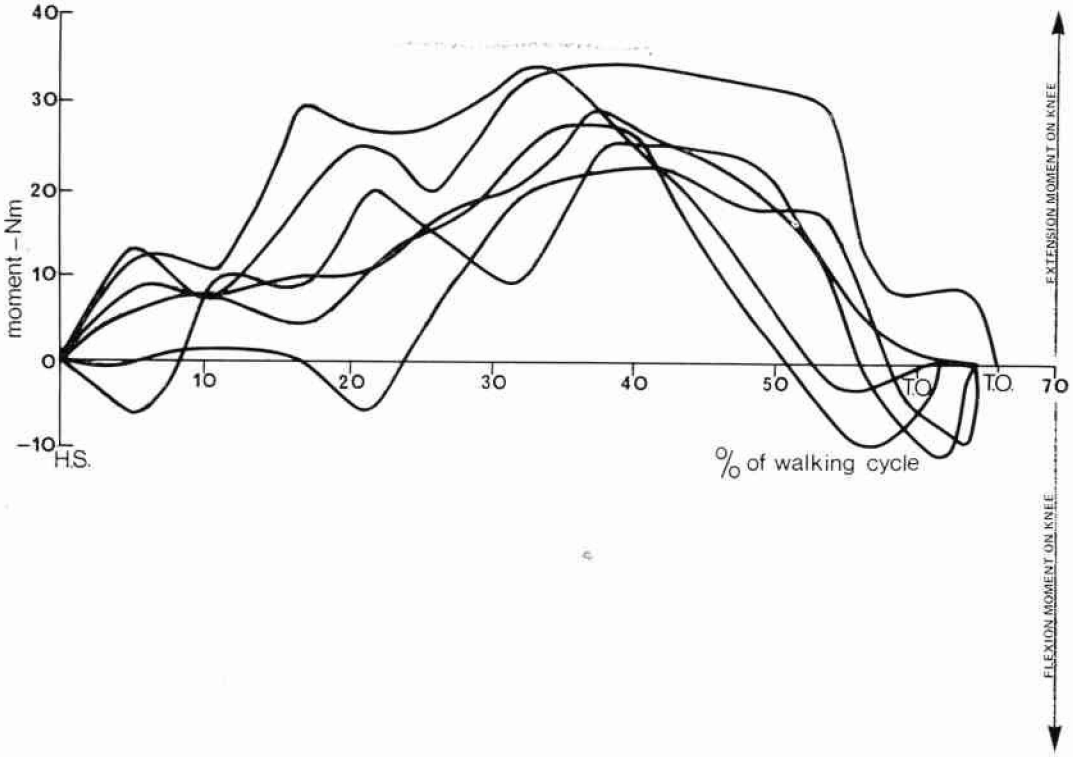

Fig. 3. A/P knee moment. Level walking.

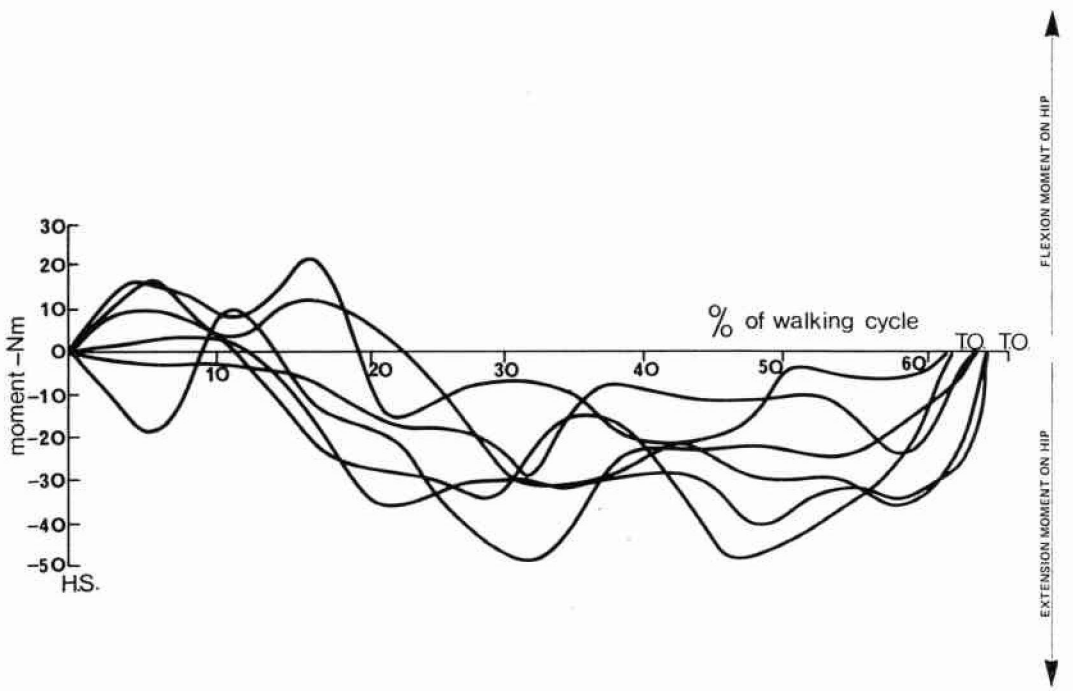

Fig. 4. A/P hip moment. Level walking.

A/P knee moment (*level walking*). Knee extension moment is low up to about 30 per cent of the cycle (Fig. 3). This is due partly to the slow increase in axial load and partly to the backward A/P shear which exists in the first half of the stance phase. The maximum knee extension moment is about 35 Nm. The flexion moments recorded at the beginning and end of the stance phase can be absorbed by the restraining action of the swing phase control unit.

A/P hip moment (*level walking*). The graph (Fig. 4) indicates that following heel strike there is a flexion moment which is due to the resistance of the hip flexion limiter. Between 10 and 20 per cent of the cycle the direction of the moment reverses, indicating that the hip extension rubber stop comes into action in this region of the cycle and remains in contact to the end of the stance phase. The peak extension moment is about 50 Nm. Prior to toe off the patient initiates knee flexion preparatory to the swing phase as the line of action of the resultant force between stump and socket passes progressively posteriorly.

M/L hip moment (*level walking*). The shape of this curve is as expected (Fig. 5) and is similar to that of a normal subject. The moment is predominantly adducting the hip joint with a maximum value of approximately 55 Nm.

A/P knee moment (*walking up-ramp and down-ramp*). As expected when walking up-ramp the knee is stable whereas down-ramp it is unstable (Figs. 6 and 7). This is due to the geometry of the limb configuration in relation to the force actions. The maximum values are 80 Nm for up-ramp and 10 Nm for down-ramp walking. It was also clear during the tests that the amputee had little difficulty in walking up-ramp but great difficulty walking down-ramp.

Torque (*level walking*). The torque curves (Fig. 8) show a pattern remarkably similar to that obtained for normal locomotion with maximum value of the order of 8 Nm.

Conclusions

The wide scatter of the results, however, makes it difficult to form precise judgements concerning assessment of amputee performance. Before this can be studied in greater depth, the reasons for the scatter must be determined, and attempts made to eliminate the scatter as far as possible. Thereafter, by acquiring a sufficient volume of data, a realistic statistical assessment could be made. However, the information presented in this paper is of value to the designer of prosthetic devices as it provides information on the nature and approximate value of the load actions.

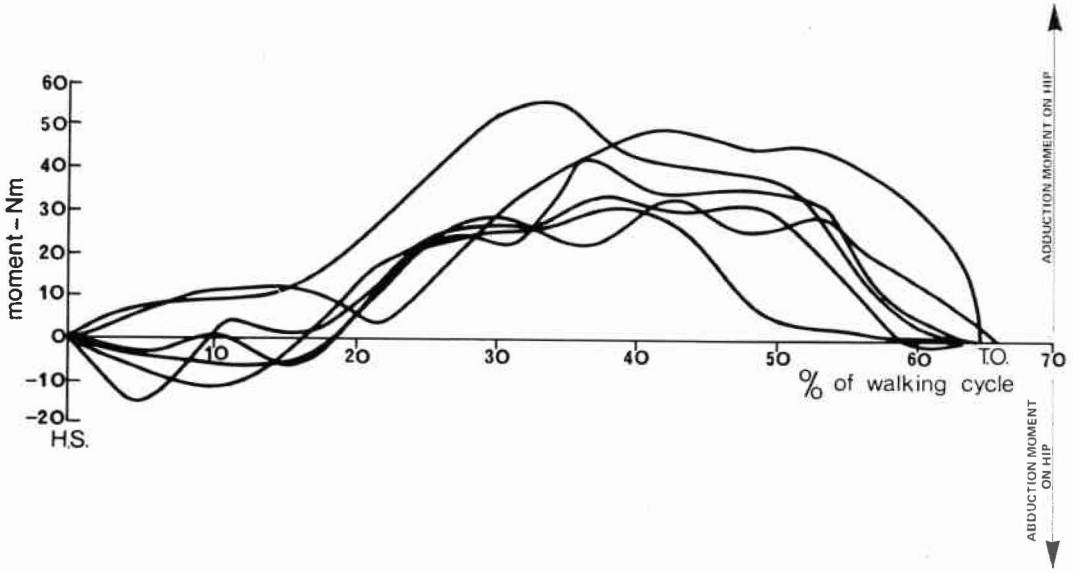

Fig. 5. M/L hip moment. Level walking.

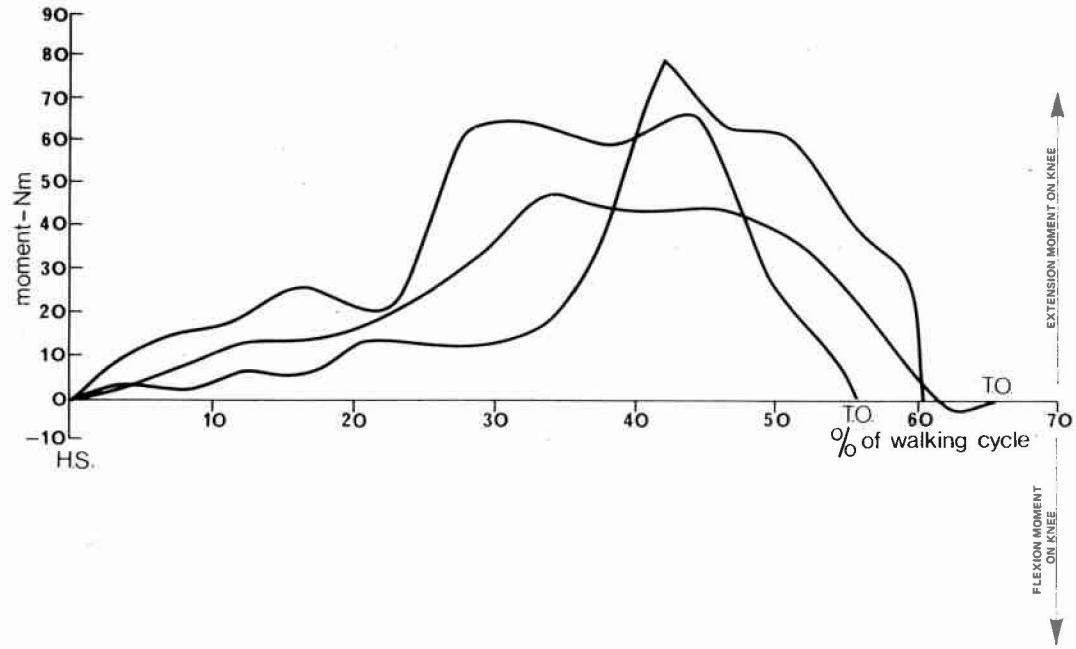

Fig. 6. A/P knee moment. Walking up ramp.

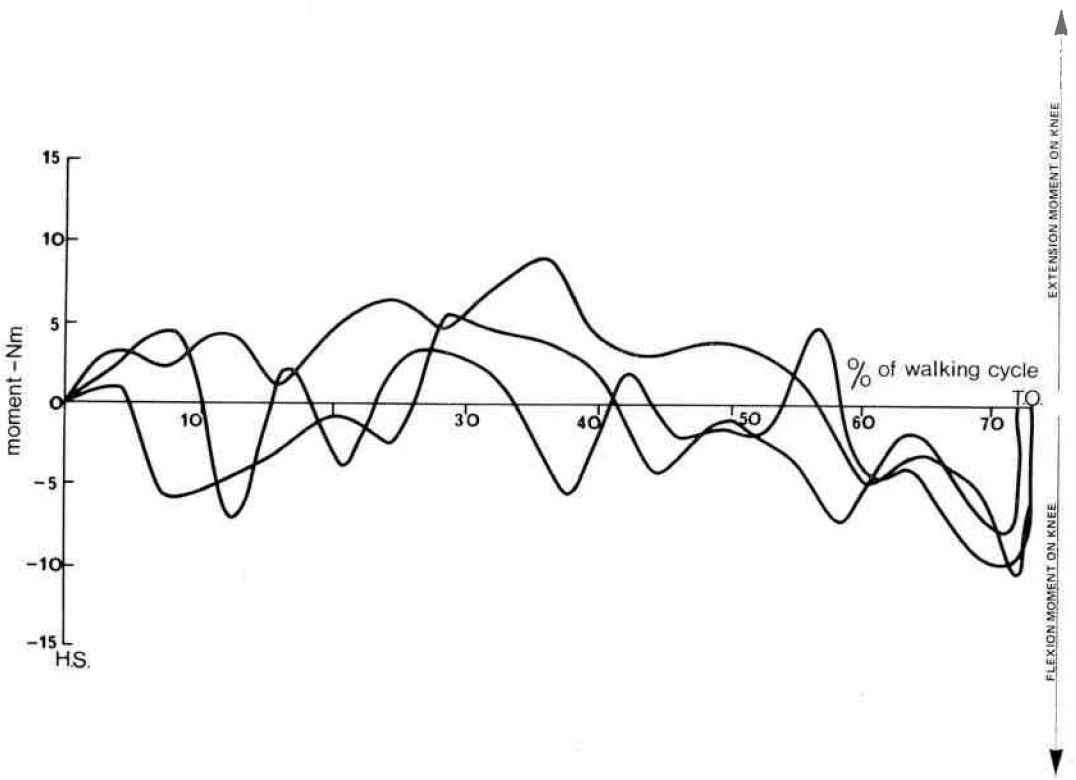

Fig. 7. A/P knee moment. Walking down ramp.

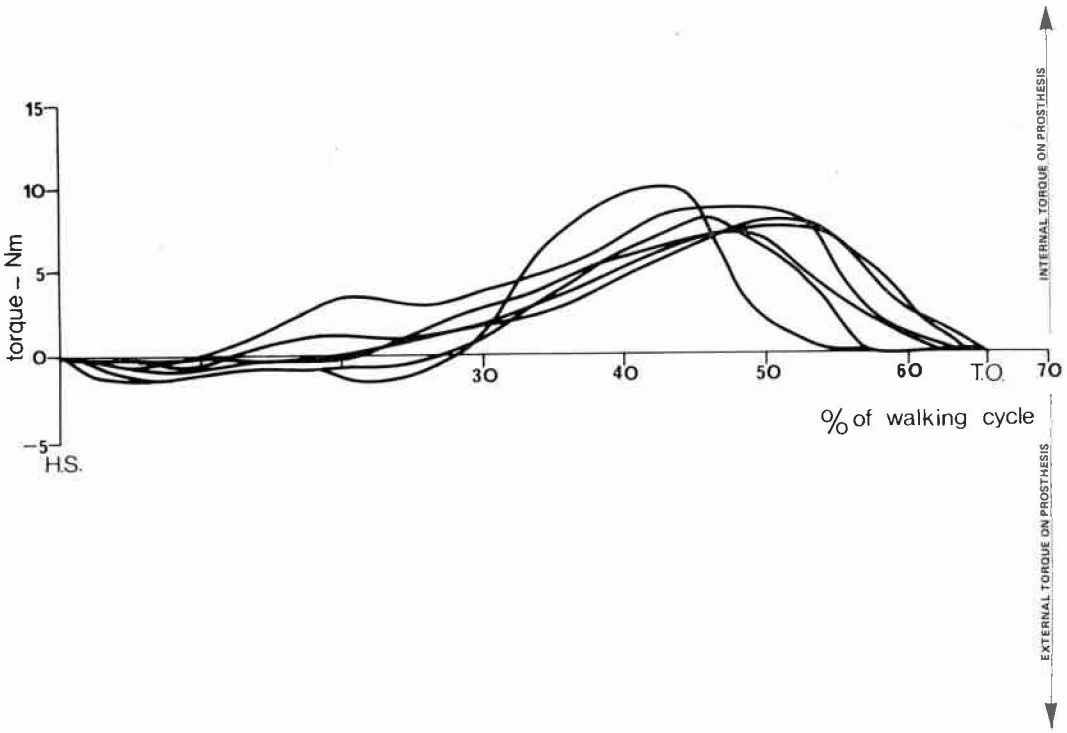

Fig. 8. Torque. Level walking.

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Prosthetics and Orthotics International, 1977, 1, 19–20

One-cable control of the mechanical elbow with flexion-extension and locking

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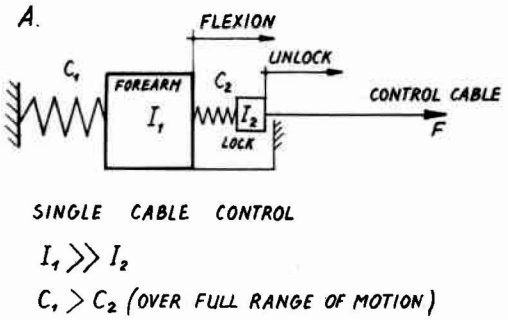
During the last few years, development in upper limb prosthetics has been focused on the use of external power. Now the introduction of the endoskeletal structure of body-powered arm prostheses requires completely new developments of such traditionally established designs as the mechanical elbow joint. The standard exoskeletal elbow requires for operation two control movements, one for flexion-extension and one for locking. Operation of this traditional elbow is not easy for patients and it is far from being an optimal design.



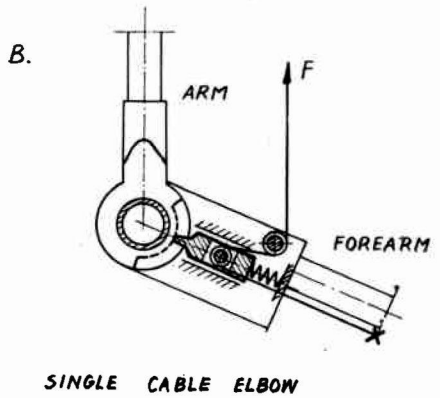


Fig. 1

A new mechanical endoskeletal elbow has been developed that can be controlled with only one cable. The flexion-extension and locking actions are carried out with only one movement of the single control harness. The model of elbow operation is presented in Fig. 1a. The separation of elbow extension and locking is possible due to the inherent difference in inertia of the forearm and the lock. The forearm as a whole presents a large inertial force I_1 to rotation in the elbow joint. The inertia of the mechanical lock I_2 is much smaller. Both mechanical systems are connected in series to one control cable. The cable runs through the elbow mechanism passing through two pulleys (Fig. 1b). The first pulley, placed on the forearm, creates the point of application of the forearm flexion force. The second pulley mounted on the lock creates the point of application of the force pulling out the lock from the cut-out of the arm portion. The lock return spring C_2 is weaker than the forearm extension spring C_1 which, in the given case, is due to gravity on the forearm.

The sequence of elbow operation is as follows: when the cable is pulled, the lock goes to the unlocked position and then the elbow flexes. The extension or locking functions depend on the velocity of the cable release. Slow release of the cable keeps the lock in the unlocked position and the elbow extends. When the cable is released rapidly, the lock, owing to its smaller inertia, moves faster and locks the elbow in the desired flexion position. This mode of elbow control is more physiological and easier for patients to use than a standard two-cable elbow. The lock-control harness is not required.

The control cable runs through the elbow mechanism and afterwards goes outside the elbow and may be connected with some other

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prosthetic mechanisms. This makes it possible to operate additional devices using the same cable which controls the elbow. For example, the pull-switch controlling the electric hand, coupled with the elbow, forms the single cable controlled hybrid arm prosthesis, which in our experience is actually the optimal fitting for high level bilateral above-elbow amputees.

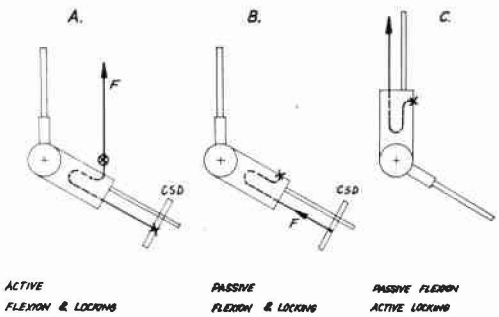

Fig. 2

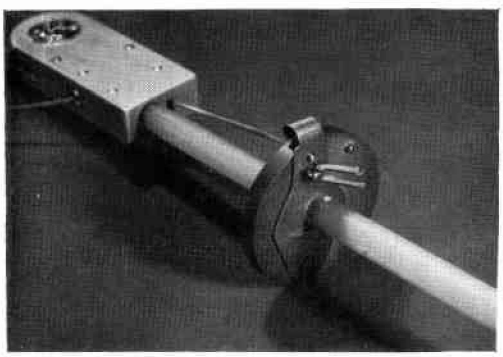

Fig. 3

The operation of the elbow locking device is possible from the upper arm, as well as from the forearm side (Fig. 2). The end of the control cable may be fixed within the forearm, directly on the elbow housing or coupled with the cable shortening device (CSD) as can be seen in Fig. 2a. The cable shortening device presented in Fig. 3 is provided for easy elbow control in the upper range of elbow flexion, especially when the patient is sitting and working at a table surface.

For patients requiring free forearm swinging during walking, the CSD serves for stable unlocking of the elbow. The only modification needed is to make a knot on the control cable (the x in the circle, Fig. 2a). The same configuration of the elbow and CSD may be used for a cosmetic arm, with passive elbow flexion and locking (Fig. 2b).

If the locking mechanism is placed in the forearm position, even extra long stumps can be fitted with the described elbow. In the case of the elbow exarticulation stump, the distance between the stump end and the axis of the elbow joint may be reduced to 15 mm.

The elbow mechanism can be used also in reversed position (Fig. 2c) and it then offers the patient active "rapid" locking and semi-active flexion. By swinging the upper arm, the forearm swings up and can be locked in the desired position ("inertia" forearm flexion).

Due to the small dimensions and light weight there is only one elbow size, the same for children and adults.

This universal elbow control offers a wide variety of elbow configurations, stimulating the development of the new kinds of arm prostheses.

Prosthetics and Orthotics International, 1977, 1, 21–24

The importance of information feedback in prostheses for the upper limbs[1]

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In view of the progress achieved in the last few years in prostheses for the upper limbs, it has been found difficult to make further improvement without a system for information feedback. Research is being carried out to increase the speed of gripping of artificial hands in order to integrate better their movements within the functional capability of the amputee. The artificial hands in use at present have a gripping speed of between 8 and 12 cm/sec. These values constitute the limit that can be managed by digital controls. Higher gripping speeds require proportional control of speed. This, however, will not be sufficient by itself if one intends to use gripping speeds around 40 cm/sec. In this case it will be necessary to control the development of the gripping movement by means of information feedback. Because artificial hands will soon be made with high speeds of gripping, we have made studies in our Centre that have demonstrated that further progress in the work so far carried out is possible only with a thoroughly effective system of information feedback. We have therefore devoted a large part of our research effort to this aspect of the problem.

Before beginning the new development work, we carried out a survey among upper limb amputees. The enquiries were based on the following points:

(1) what type of information will be necessary in the future,

(2) what information methods are most suitable to the human organism as regards its capacity to receive information and as regards the tolerance of the body,

(3) what type of device can be manufactured with the least cost, bearing in mind especially its useful life, its reliability and energy?

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We have proceeded in our work following these points and have achieved experimentally the following possibilities of use:

(a) information feedback concerning the strength of gripping,

(b) information feedback concerning the position of the fingers,

(c) a tactile disconnecting device for switching off, on contact, for hands with fast movements.

In addition, a microdevice is being prepared for the location of close objects intended above all for sightless persons without hands.

We began our development work with control information on the gripping strength. In this case we fitted, in the elastic tips of the fingers, highly sensitive extensiometers which served as variable resistors, to receive and pass on the various gripping strengths. However, in practice this device was found to need repeated repairs and was, therefore, not suitable for a functional hand.

During the following phase of development a system was devised making use of a micropotentiometer (Fig. 1) connected to a specially

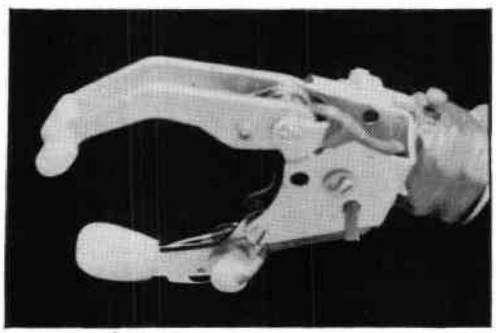

Fig. 1. Experimental hand using a micropotentiometer to detect amount of grip being induced at the fingers. The micropotentiometer is installed at the thumb joint.

[1]Previously published in Medizinsch-Orthopadische Technik. 2/75, 31–33.

prepared electronic amplifier. This is a linear amplifier with analogue to digital convertor. The signal is then rectified so that in the rest position the amplifier output voltage is zero. When the case thumb encounters resistance, it varies the angular opening of the joint (Fig. 2)

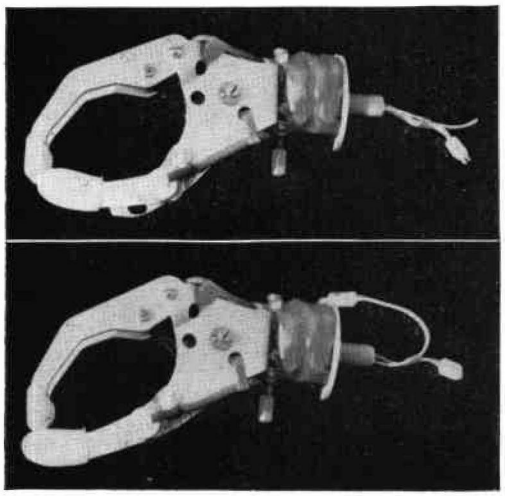

Fig. 2. Two views of the experimental hand shown in Figure 1. The force at the finger tips moves the thumb about the joint at which the micropotentiometer is installed.

in which the micropotentiometer is incorporated. This therefore changes the output voltage of the amplifier in proportion to the angular opening. In other words, as soon as the hand seizes an object, the output voltage increases in proportion to the pressure that the thumb exerts on the object. This voltage is then fed to the linear amplifier (Fig. 3) with analogue digital convertor. The input voltage is transduced in logical impulses of an approximate duration of 0.1 m/sec and at a frequency that varies, according to the pressure exerted, between 0 and 60 cycles/sec. Later these impulses are amplified and raised to 20–80 volts, which is varied according to the sensitivity of the individual. These are information impulses that stimulate the skin directly.

During these tests we were able to establish that the main component of information feedback on the strength of grip can be utilized also for information feedback of the finger position. The only difference lies in the fact that for finger position information feedback we insert the micropotentiometer in the main phalange

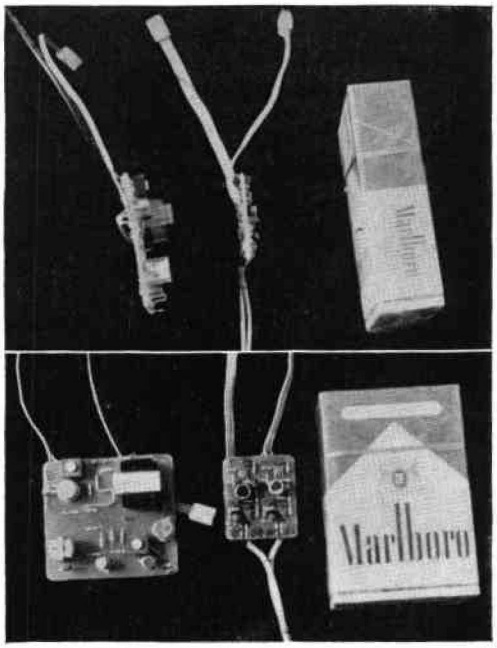

Fig. 3. Two views of the linear amplifier used in the experimental hand shown in Figures 1 and 2.

of the forefinger and middle finger (Fig. 1) in such a way that with the hand closed (that is, with the thumb, index and middle fingers closed), the potentiometer is in the "zero" position. According to the experiments we have made so far the finger position control information will be of practical use only to blind bilateral upper limb amputees.

For gripping strength control, a final thumb phalange was made which was passively mobile, in the joint of which a potentiometer was placed (Fig. 4). A return spring for the end phalange of the thumb was adjusted in such a

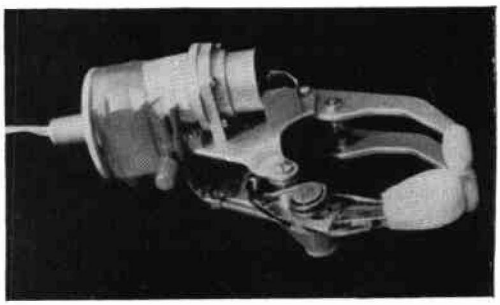

Fig. 4. View of experimental device showing the passively mobile thumb phalange and micropotentiometer for control of gripping strength.

way as to create a proportional relationship with the effective gripping strength of the hand. The receipt of control information was originally obtained by means of vibrators applied to the skin. It turned out, however, that after some time the amputees noted a diminution of the reception intensity. It is for this reason that we use two skin electrodes for the direct stimulation of the skin (Fig. 5) which, however, must be mounted outside the socket of myoelectrically-controlled prostheses. In applying the information electrodes, one must look for zones of the body that are especially sensitive. Particularly suitable are the medial parts of the arm and some central parts of the back. Practical research has demonstrated that in a relatively short time amputees on whom this system has been tried out experimentally, have perceived good lasting information feedback over a long period. At a gripping speed of about 40 cm/sec it is extremely difficult to exercise control of the grip even with proportional regulation. Nevertheless, in our enquiries we found some patients who were able to control an experimental hand at the above-mentioned speed. However, given the enormous concentration required, the effort, in the long run, was found to be too great for the patient.

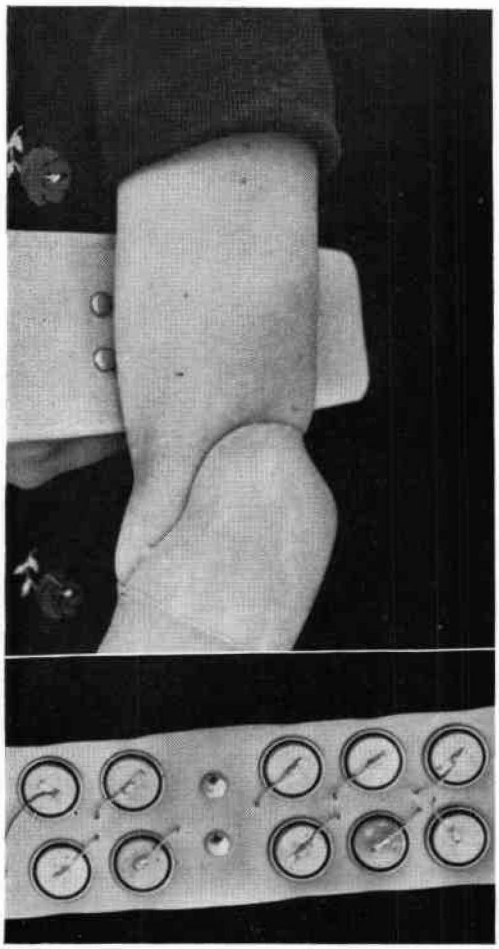

Fig. 5. Two surface electrodes are used over the arm to provide directly to the skin signals proportional to action of the prosthesis.

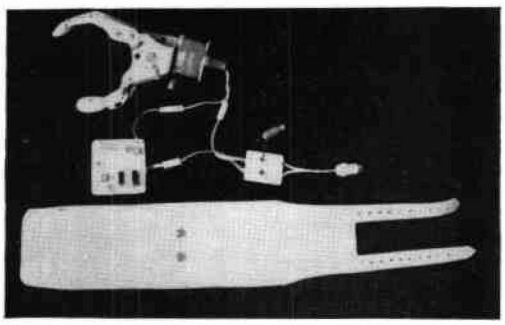

Fig. 6. The complete experimental system.

After various trials we arrived at the following system. At the tips of the fingers and on the inside of the index and middle fingers a disconnection system is inserted, which causes the breaking of contact when the finger touches an object. To prevent an amputee with a fast-moving artificial hand from being subjected, in spite of proportional control, to too great an effort due to the control itself, a tactile switching-off device has been made which, as its name indicates, automatically comes into operation when there is contact and therefore interrupts the movement of the hand. This mechanism ensures that the amputee shall not get into difficult situations especially when he has misjudged the movement. At the same time that the gripping movement is interrupted, information is relayed to the amputee giving him precise information on the pressure of the fingers. The interruption of the contact is for about 300 ms, a value that is in the range of reaction time. The combination of tactile switch-off, with simultaneous gripping strength information feedback, has given excellent results because there is no question of a pre-established programme. In fact, the amputee is allowed complete freedom in the entire control of the movement.

In releasing the object, that is, when contact with the fingers no longer exists, the tactile switching device is switched out without interrupting the finger movements. The information feedback system is connected to the regulating system and operates only as long as the hand moves. This results in a considerable saving in energy. The feedback system devised constitutes a logical process. The experiments clearly demonstrated that the amputee who took part in the tests immediately accommodated to the system. He showed greater assurance in gripping and above all clearly improved function.

To conclude, I should like to add that though this is an experimental project, the practical research has clearly shown that the functional possibilities in an artificial hand can be enormously increased with this system.

We are perfectly aware that this is only the beginning of the practical introduction of a system of information feedback, but it is certain that progress in the field of prostheses for the upper limb will depend upon the development of such a system.

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Developments in modern orthopaedics for children

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During the past three decades my generation has seen a fundamental structural change in the field of orthopaedics. At the time of our youth, one-third of orthopaedic patients suffered from tuberculosis of the joints, i.e. from tuberculosis of the bones, another third suffered from the sequels of poliomyelitis, while the remaining third included all other orthopaedic diseases. In the interim, the first two groups have disappeared almost completely and their places have been taken by other orthopaedic defects.

Patients with Meningomyelocele

Due to the technical advances of modern paediatric surgery almost all new-born suffering from rachischisis or meningomyelocele, who almost always have a complete cross-sectional paralysis as well as total incontinence of bladder and rectum, are now kept alive by immediate plastic resection whereas before they died within a few days from the decubital ulcers associated with ascending spinal meningitis. Today, these new-born children are transferred, after just a few weeks, from paediatric surgery to orthopaedics where they are given further medical and orthopaedic-mechanical therapy which continues throughout their lives. The therapy consists firstly of the fitting of mechanical devices with individualised complementary corset structures, and secondly, of later orthopaedic-surgical treatment, either by means of stabilisation of the hip through corrective postural osteotomy and iliopsoas translocation, or stabilising plastic surgery of the spine in the region of the defective vertebrae.

Of particular interest in this field is the treatment of children suffering from rachischisis with mechanical devices enabling them to achieve an upright position and subsequently to walk. It is the first task of orthopaedic technique to help rehabilitate these "problem children", enabling them to assume the basic *orthostatic* posture with the help of a mechanism for standing erect. By providing a mechanically achieved upright position through a posture and motion device that supports the affected lower part of the skeletal segment of the spine and the lower limbs, the functions of the internal organs, such as the heart and the circulatory, digestive and renal systems, are adapted gradually to the orthostatic posture of *homo erectus*. In this way, phylogenetic programming achieves by mechanical means an upright position of the human skeletal system which otherwise would be impossible from the ontogenetic standpoint.

The mechanical devices which the orthopaedic workshop of Herbert D. Stolle at Barmbek General Hospital in Hamburg, working together with the Orthopaedics Department of the Head Physician of Provincial Self-Government, Dr. Bernbeck, have developed for total cross-sectional paralysis, are very simple in their basic concept and design (Bernbeck 1954 and 1974), They are light in weight, quickly adjustable, easy to maintain, and inexpensive to manufacture. Plastic materials such as low-density polyethylene (Resur) and low density polyethylene foam (Plastazote) are mainly used.

After a plaster cast has been made, which should be done with a slight allowance for correction of limbs and trunk, the plaster matrix for the construction of the device is moulded and traced. Two-thirds of the total surface of all parts of the body that require to be supported and immobilised are covered by the plastic material. The flexibility of the material makes it easy to don the device. Areas that are especially pressure-sensitive are covered with a double layer of Plastazote. The open one-third of the body parts is protected by kneecaps and Velcro fasteners, or by a partial denim corset, or by wide leather straps at the level of the trunk. These are inter-connected by alu-

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minium or steel strips, with or without articulation. Because such cases are generally associated with deformations of the foot, these devices must be equipped with compensatory foot pieces to ensure stability. Before they are attached, they are machined roughly and then fastened to the parts of the foot by means of polyester cement.

If the devices are too flexible in themselves they are reinforced with strips of Resur, welded lengthwise, or with riveted aluminium strips. For children who are 1.20 to 1.40 m tall Resur of 4 to 6 mm and Plastazote of 5 mm thickness is used (Fig. 1).

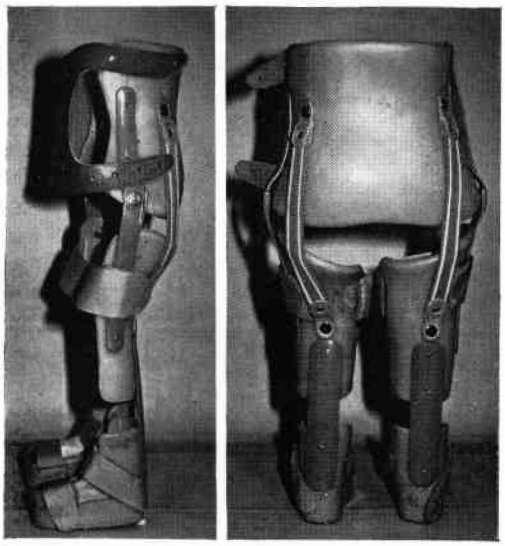

Fig. 1. Lateral and posterior view of plastic orthosis for meningomyelocele patients.

Only after a child who has been cross-sectionally paralysed from birth has become used to orthostatic conditions of life will locomotion from one place to another become possible, initially by the release of one hip joint only. Following an appropriate period of training, it will be possible in most cases to release the second hip joint for hinge-like movement. A gluteal traction device is applied as an additional safeguard against the forward-bending of the trunk. Its advantage consists in the individual release of the movement in the hip joint.

Since in most cases trunk and upper limbs have normal function and strength, it is possible almost always to teach walking on the stabiliser or in a mobile wheeled walker—at first, however, always in the presence of an attendant (Fig. 2).

Further mechanical care will perhaps consist of the traditional fitting of a device like the one used for the after-effects of poliomyelitis. I say "perhaps" deliberately because I am of the opinion that new materials and the experience gathered with prostheses using outside forces, and which operate and are controlled by means of pneumatic, myo-electric or hydraulic energy, show us better possibilities and offer means of more effective help.

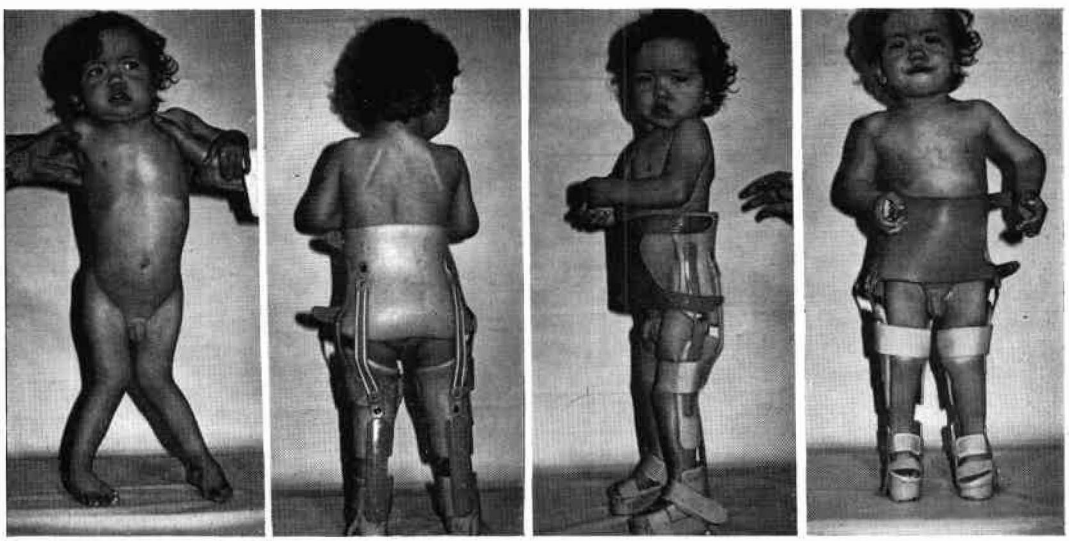

Fig. 2. Views of meningomyelocele patient with and without the orthosis.

It should be considered seriously whether prefabricated parts, that is, ready-made parts, and semi-prefabricated parts, that is mass-produced parts, be used more than they have been heretofore in the design and construction of devices. They could fill a role in our programme of custom-made devices and save time and expense. Our whole endeavour should be to carry these considerations out into practice, since we are seeing more and more new materials and mechanical-orthopaedic devices with anatomically prescribed shapes as they are being developed by our orthopaedic physicians, by the specialised industry in our field, and by ourselves. The building-block system as developed by Helmut John of Hanover, and the system of complementation and interchangeability of standardised structural members as practised by the firm of Otto Bock at Duderstadt are only the beginning of this development.

Scoliosis in Infants

Recently the problem of scoliosis in infants was moved into the foreground of orthopaedic interest, in particular by the pertinent publication of Mau and Gabe (1962), and by the interesting modern concept of Lübbe (1971), paediatrician at Hamburg. In contrast to the Schede (1958) principle that uses direct mechanical redress by a load applied against the vertex of the curvature, Lübbe places the scoliotic infants into a unilateral oblique supine position by means of a padded wedge which is placed under the flattened concave side of the back. The convex side of the costal arch presses against the support, so that the redress effect is achieved by the infant's own body weight. At the same time the region of the cervical vertebrae with the head and also the pelvic region move downward, and this too, has a redress effect, correcting the axis.

In order to be able to apply this method in ambulant orthopaedic treatment to older and larger infants, Wilhelm (1966) of Hamburg, orthopaedic physician, places the infants on a modified scoliosis board. The infant is held by vertically placed slats at the sides of trunk and head. Openings are produced for arms and shoulders. The upper arm of the convex side and the pelvis are fixed by means of one strap each. A wedge of foam rubber is placed, in accordance with Lübbe's basic idea, under the flattened side of the back (Fig. 3 and Fig. 4).

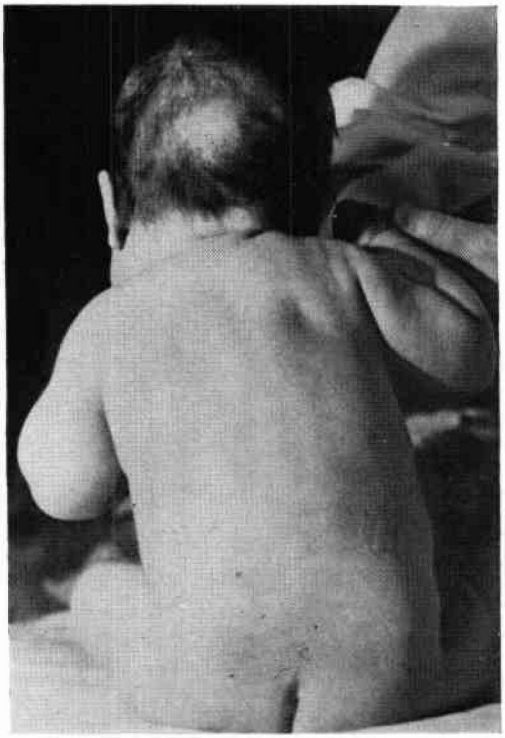

Fig. 3. Posterior view of infant with scoliosis.

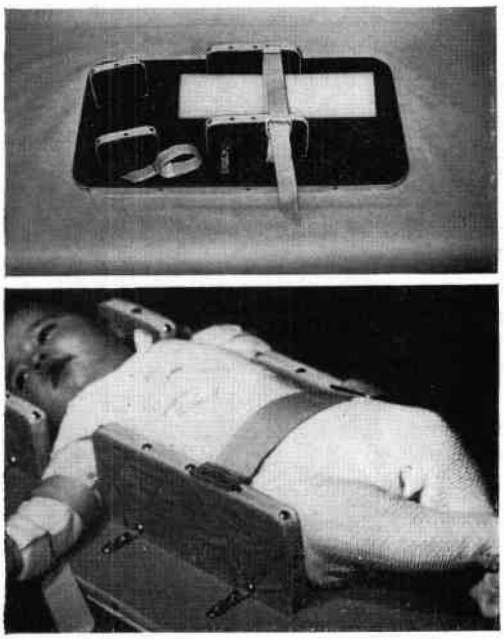

Fig. 4. The scoliosis board.

The scoliosis board has proved its value particularly with active children. At the same time it ensures the correct position, can easily be adjusted to allow for the growth of the infant, and may be transported readily. We have manufactured these scoliosis boards for more than ten years. Figure 5 shows the successful results that may be obtained by using these simple devices.

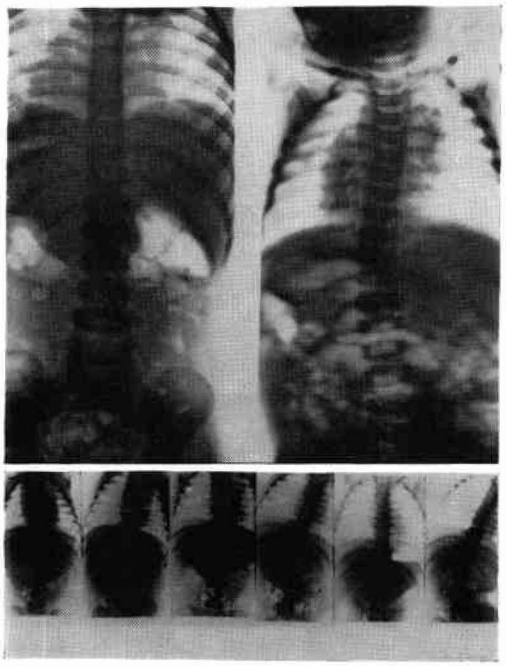

Fig. 5. Some results from use of the scoliosis board.

Some Foot Problems in Infants

Another current topic in orthopaedics is the undesirable results of the prone position of infants which is advocated generally today. Twisting of the neck, lordosis, and an unfavourable development of the hip joint are discussed as secondary symptoms of the prone position. The last-named symptom occurs particularly in the case of congenital dysplasia of the hip due to forced traction. Various deformations of the foot are believed also to be due to the prone position, as a result of the straining effect of the anterior part of the foot. Changes amounting to a flat-foot with abduction of the anterior part of the foot, *pes abductus*, and also rotation defects of the axis of the leg in the nature of an inward rotation (inward rotation walk) have been observed (Fig. 6). The treatment of growth

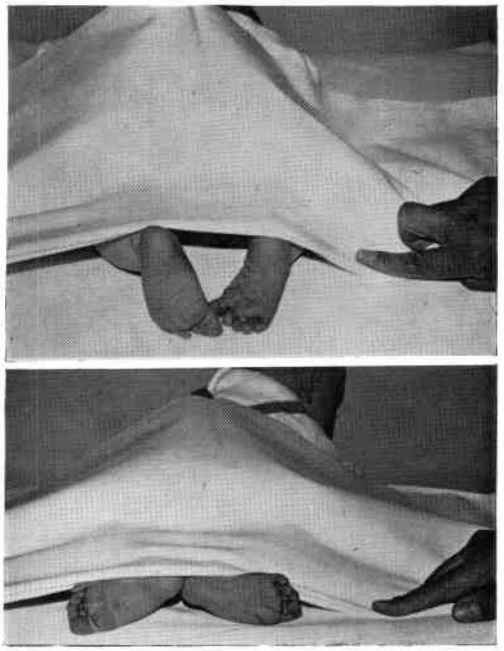

Fig. 6. Some defects of the feet of an infant resulting from the prone position.

defects of this type, consists either in the application of "annular ankle cuffs" or, to obtain a simultaneous favourable spreading of the hip joint, padded wedges for the lower leg are applied, fastening the lower legs or, perhaps, merely the ankle region, by means of straps at appropriate intervals. These padded wedges are manufactured at the suggestion of Professor Bernbeck.

The padded wedge for the lower leg consists of firm foam rubber, in the following sizes:

Small: knee-to-foot length 10 cm, width 20 cm, height 7 cm

Large: knee-to-foot length 15 cm, width 30 cm, height 7 cm (Fig. 7).

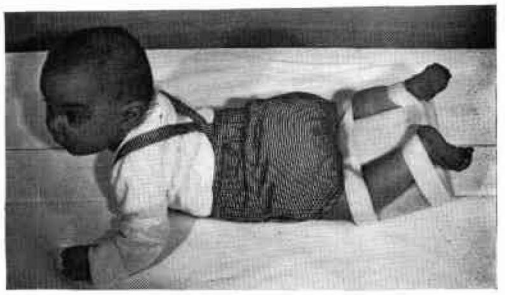

Fig. 7. The padded wedge for correcting certain defects in the infant's feet.

The legs are held by Velcro straps. The intermediate wedge is held by a Velcro fastening. Thus the wedge may also be used for the supine position. In such a case, the high part of the wedge is placed under the backs of the knees. This is a simple but effective device.

By way of concluding these subjects which have been touched upon briefly, I want to call attention to a special development in our profession. In orthopaedics for children, orthopaedic technicians have taken a larger role in the rehabilitation team. We are confronted with orthopaedic problems earlier than used to be the case, and more with the problems of precautionary or preventive measures than with those of ultimate appliances. Whereas orthopaedic-mechanics used to form the end of medical rehabilitation, it is used today right at the outset.

This calls for a readjustment of our thinking and our actions inasmuch as we must develop and design simple inexpensive orthopaedic devices for short-term use, which must be highly effective and afford rapid and maximum help and relief to the handicapped person during every phase of his life.

It is our duty to help the handicapped throughout their life by means of orthopaedic-mechanics. Consequently, we must do what we can as early as possible so that we may not face insoluble technical problems that arise later solely from neglect during childhood.

Contacts within a rehabilitation team will have to be strengthened, since the scope of our function keeps increasing all the time. Our mechanical-orthopaedic tasks of caring for the handicapped commence, more and more, in early infancy and extend to old age. We should remember at all times that precautionary and preventive measures are better than the best orthopaedic-mechanical device.

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Spinal problems in myelomeningocele-orthotic principles

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Spinal curvatures associated with myelomeningocele represent complex problems which, if not recognized early, determine the future ambulatory status of the patient.

In recognizing the importance of functional spinal alignment, it is mandatory to supervise closely a child from infancy and to institute early protective care (Bunch *et al.*, 1972).

Spinal problems are not necessarily evident at birth. Sharrard (1972) reported that 75 per cent of the myelomeningocele patients examined at birth showed no spinal abnormality. An earlier study conducted at Newington Children's Hospital (Raycroft and Curtis, 1972) reported comparable findings. It is of interest that in this study 79 per cent of the 130 patients involved had bony defects limited to the posterior elements. More than 50 per cent of this group developed spinal curvature due to muscle imbalance and deformation inviting positioning by the age of five years, and almost 100 per cent by the age of ten years.

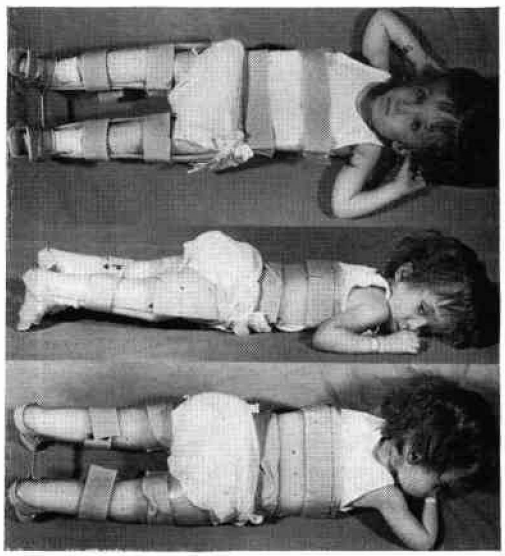

Fig. 1. Patient wearing body-control orthosis. *Upper*, anterior view; *centre*, lateral view; *bottom*, posterior view.

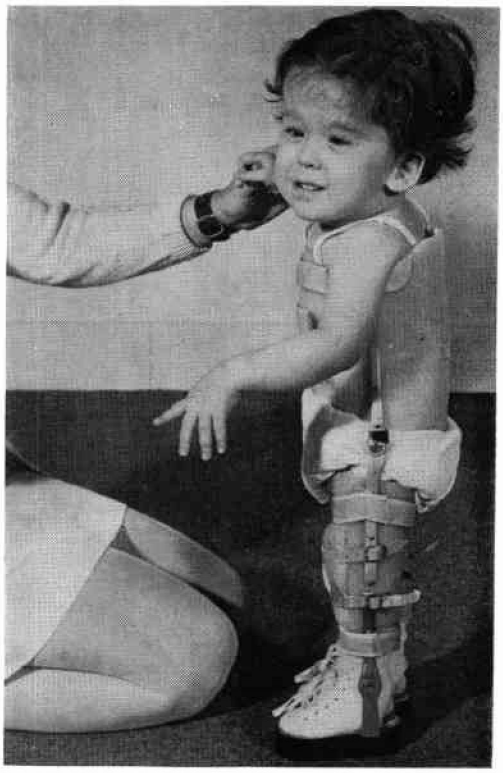

Fig. 2. Preparatory orthosis: lateral view.

A concept of early treatment of these patients, developed at Newington Children's Hospital, has diminished not only spinal curvatures but also problems of hips, knees, and feet (Curtis, 1973).

Principles of Early Orthotic Management

Birth to head control—head control. Myelomeningocele patients should be referred to centres providing the benefits of a specialty

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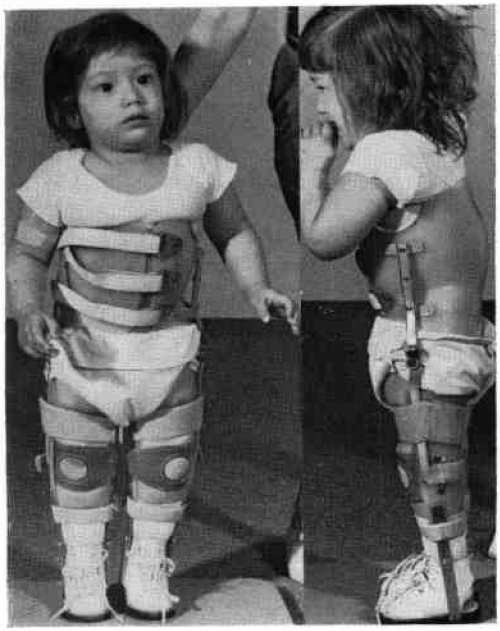

Fig. 3. Thoracic distraction orthosis—kyphotic patient: *left*, anterior view; *right*, lateral view.

team once the lesion is closed, renal and urological tract abnormalities are identified, and early care is initiated.

A body-control orthosis (Fig. 1), was developed (Paul, 1972) which functions as a preventive, supportive, and corrective device. This orthosis provides 15 to 20 degrees of hip abduction for diaper care. Low posterior scar areas are not included in the shell; higher locations of lesion should be relieved within the splint. The shell is made of Vitrathene (Paul, 1970), a polythene plastic, and extends proximally as far as possible without restriction of arm motion. It has a snug over-all fit and includes the lower limbs with knees extended and ankles placed at 90 degrees of dorsiflexion. Special attention must be given to possible pressure areas. The parents need to be cognizant of the splinting purpose and difficulties which can develop in periods of rapid growth.

Sitting—upright stability. The body control or positional type of plinting is maintained until the child has reached the intermittent periods of wanting to sit and stand.

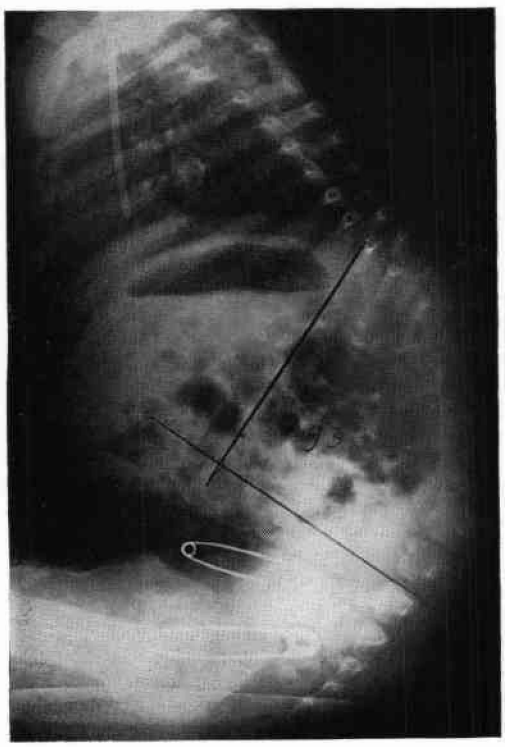

Fig. 4. X-ray of patient sitting unsupported: curve 93 degrees.

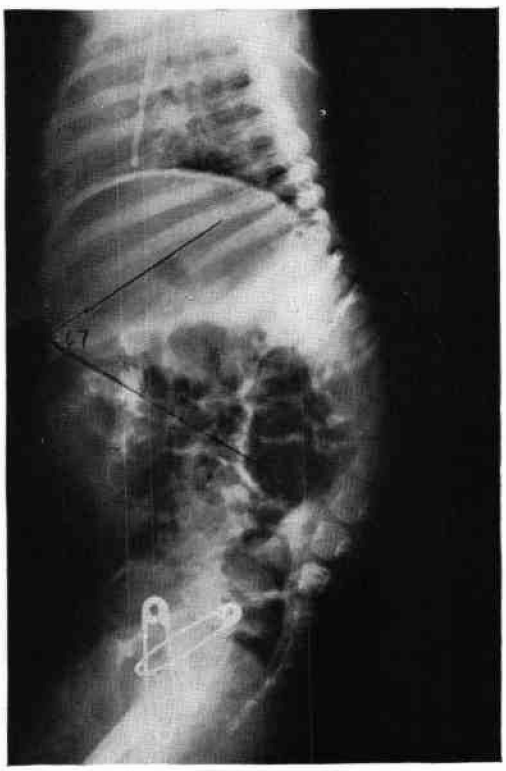

Fig. 5. X-ray: traction reduced curve to 67 degrees.

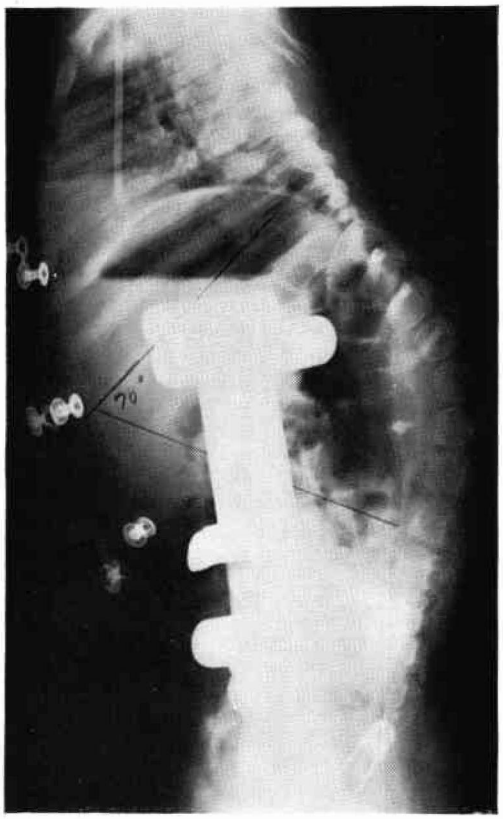

Fig. 6. X-ray of patient standing: thoracic distraction orthosis maintains 70-degree curve.

The original design of the orthosis is now modified to incorporate detachable surgical pre-walker shoes and simple hinges (Fig. 2) at the hip. This splint is now identified as a preparatory device. It is at this age also that bony malformations require surgical correction. Early removal of atypical bodies and segmental fusion have proven successful (Curtis, 1972). These patients were identified at the time of the Newington study as "congenital" cases. They constituted 21 per cent of the Newington study and 25 per cent of Sharrard's.

An additional innovation was introduced when thoracic distraction was recognized as a correcting force in the early treatment of kyphotic, scoliotic, and lordotic curves (Paul, 1973).

The spinal segment of the Newington preparatory orthosis was contoured so that the lower rib cage was exposed to forces through undercuts (Figs. 3a and 3b). Distraction was achieved by raising the splint and so avoiding

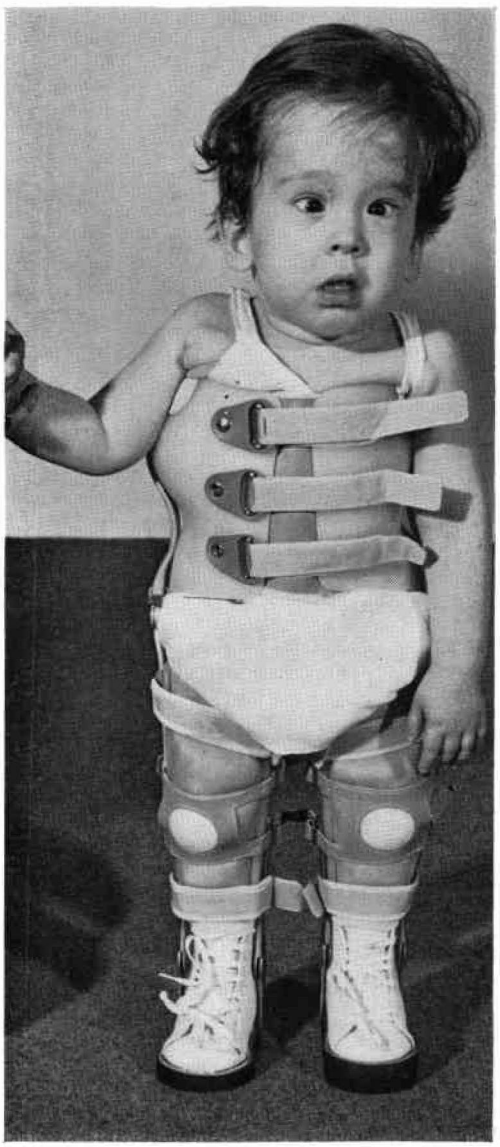

Fig. 7. Patient with severe spinal anomalies wearing thoracic distraction orthosis: anterior view.

total heel contact by approximately 4.5 to 6 mm. The correction obtained (Figs. 4, 5, and 6) was dramatic. Another case is illustrated in Figures 7 to 10.

The patient should return to the clinic every four to six weeks. At that time, fit and function of the device should be evaluated.

In the presence of pronounced bony processes, it was found advantageous to mould plastic foam with the thermoplastic to provide

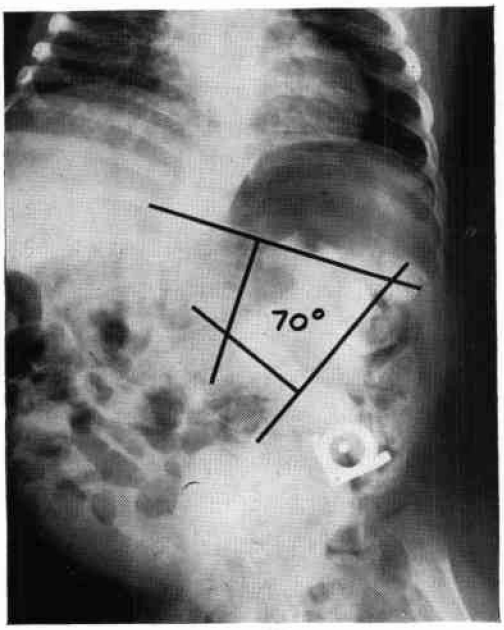

Fig. 8. X-ray of patient sitting unsupported: curve 70 degrees.

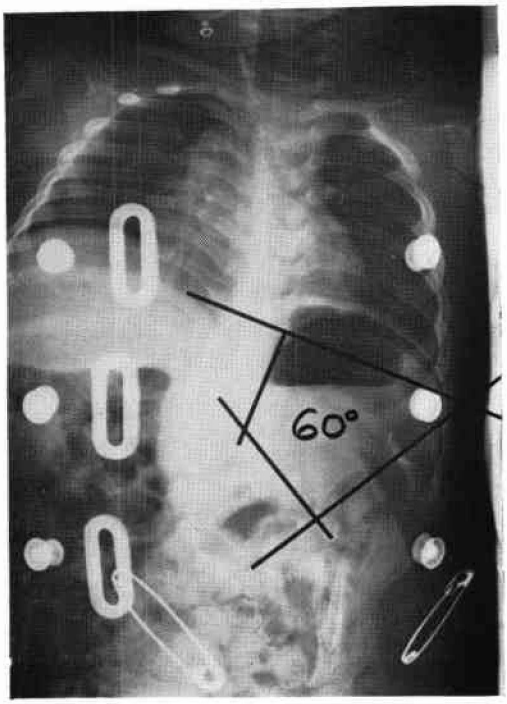

Fig. 10. X-ray of patient standing, wearing thoracic distraction orthosis.

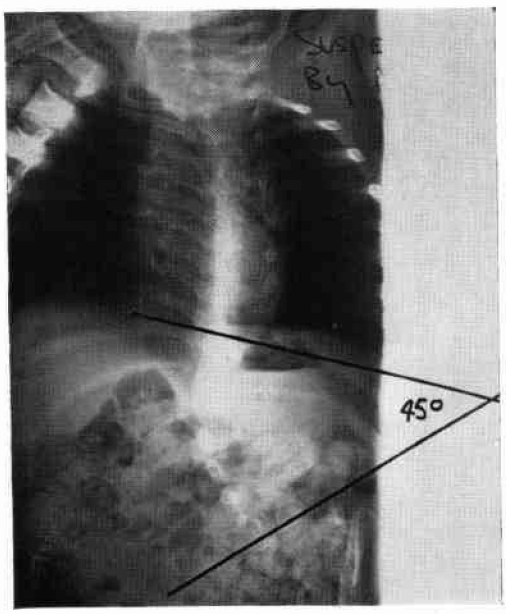

Fig. 9. X-ray of patient: curve reduced to 45 degrees by axillary suspension.

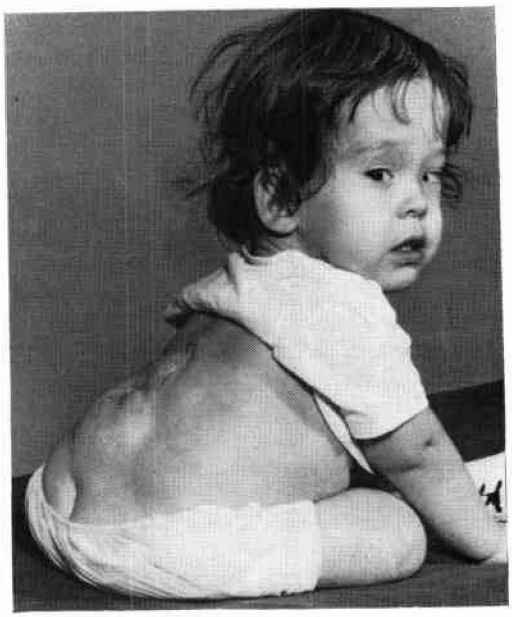

Fig. 11. Patient sitting unsupported.

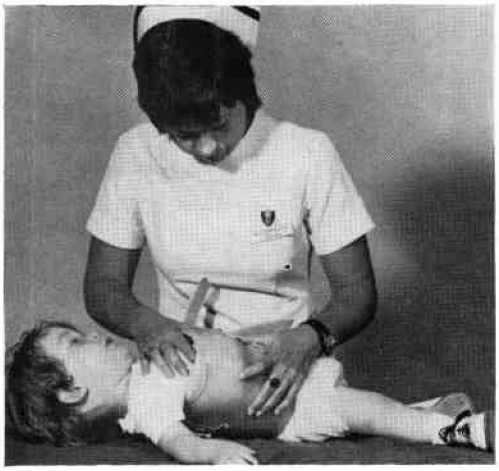

Fig. 12. Application of thoracic distraction orthosis.

Fig. 13. Patient sitting, wheelchair-suspended. Note clearance.

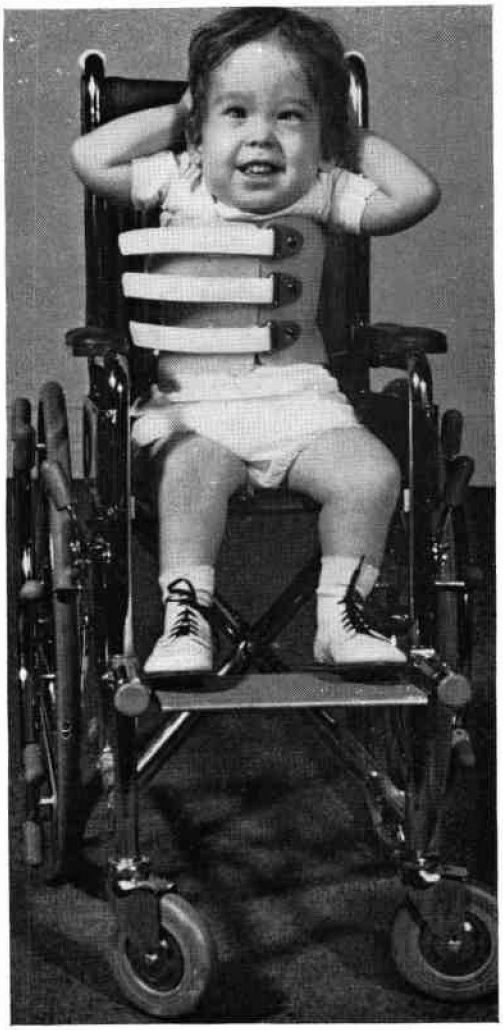

Fig. 14. Patient sitting: anterior view.

an interface material. Such interfacing functions as a cushion and absorbs friction (Figs. 11 and 12).

The encouraging results of initial application resulted in making the thoracic component detachable and interchangeable with wheelchair suspension (Figs. 13 and 14). The patient, now able to sit and stand, benefits from the supportive and corrective features of this relatively new concept of treatment (Fig. 15). No contra-indications were evident. Pulmonary testing demonstrated improved pulmonary function rather than restricted, as seen in other spinal total-contact orthoses.

Upright stability—upright mobility. During early childhood, the patient with spinal problems attempts to become ambulatory. The preparatory orthosis is utilized as an early testing mechanism to determine ambulation potential. The child progresses to a definitive ambulatory device or is identified as a young wheelchair user. The patient with a non-critical spinal curvature is placed in a total-contact spinal orthosis as a separate unit from the lower-limb orthosis (Paul, 1971), (Figs. 16a, 16b, 16c and 16d). This is not the case in patients requiring a thoracic distraction orthosis. In those cases, the lower-limb orthosis is utilized as a floor-contact mechanism and, therefore, attached to the spinal orthosis.

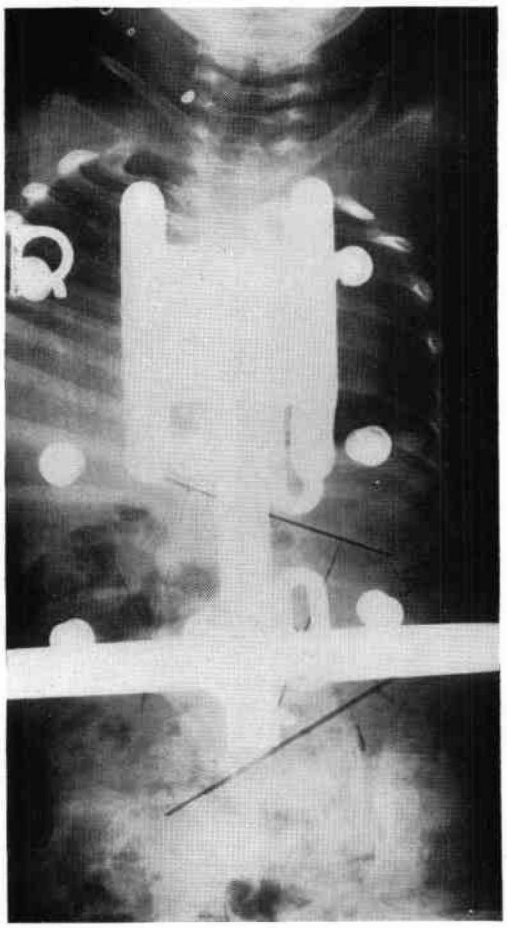

Fig. 15. X-ray of patient in thoracic distraction orthosis: anterior view.

The formative years of the myelomeningocele patient bear all the typical phases of psychological conflict that confront a paraplegic patient. The patient with spinal problems, however, needs to be better prepared for this period of life. It is now that a compromising body height has been reached and spinal-stabilization surgery, such as Harrington instrumentation or Dwyer procedure, can be performed. Surgery of such magnitude requires protective body casting and, thereafter, a total-contact spinal orthosis to be worn until the fusion can be considered mature (Paul, 1971). Spinal problems of the adolescent myelomeningocele patient, if treated from infancy, should not vary from other paraplegic curves.

Developmental years are also decisive for the ambulatory status of these patients. Obesity and indifference, complicated by effects of extensive hospitalization and varying degrees of mental incompetence, create the breaking point where the patient either continues as an effective functional ambulator or is resigned to household ambulation or wheelchair use (Curtis *et al.*, 1972). If, for reasons beyond the control of the clinic team, a patient does not benefit from preventive, supportive, or corrective care, certain alternative procedures are suggested.

Figure 17 illustrates an untreated myelomeningocele patient, aged 17, with sacral agenesis and fixed-flexion deformities of the lower limbs. This patient now functions in a wheelchair with a seating device.

The second patient, diagnosed as having uncorrectable deformities of both lower limbs

Fig. 16a. Patient wearing total contact spinal orthosis and definitive lower-limb orthosis.

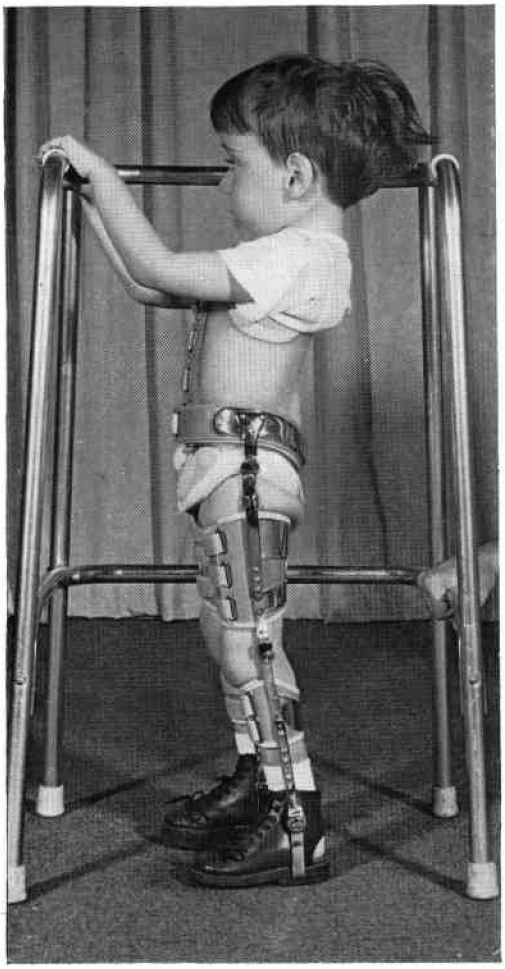

Fig. 16b. Same patient, lateral view.

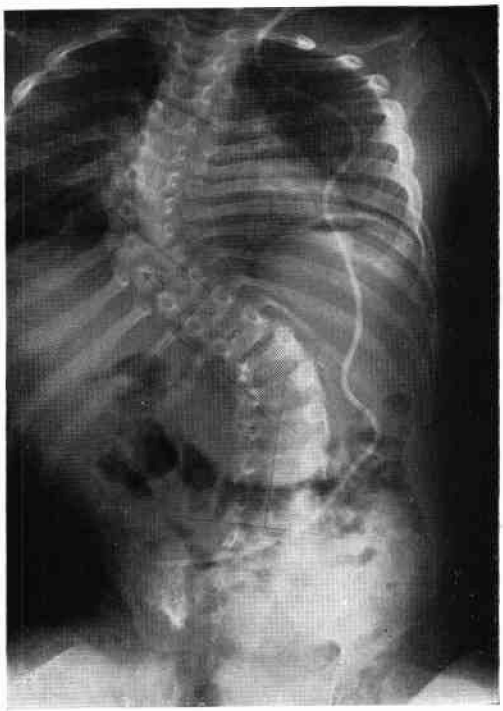

Fig. 16c. Patient sitting unsupported.

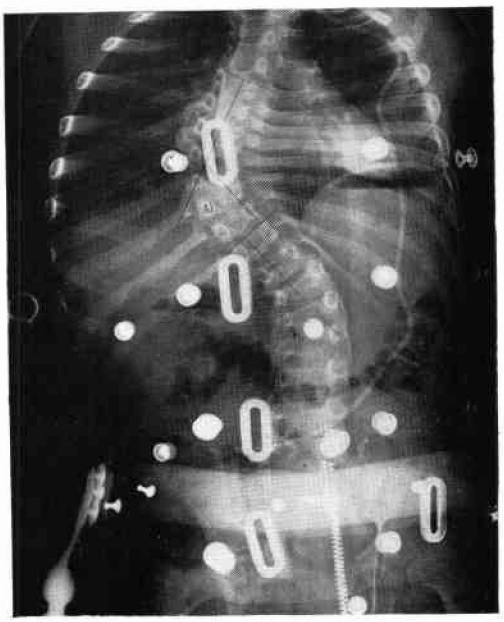

Fig. 16d. Patient standing with total-contact spinal orthosis applied.

and spinal deformities (Figs. 18a to 18d), required bilateral subtrochanteric amputation and fusion of the lower spine. He now ambulates in a bilateral, modified, Canadian-type hip-disarticulation orthosis (Fig. 18e). The prosthetic socket features spinal distraction and the scoliosis has not increased. This patient, capable of all activities of daily living, attends a regular school.

Summary

The concept of treating spinal problems in myelomeningocele during childhood is discussed. An "orthotic" approach is identified not only as a supportive and corrective system

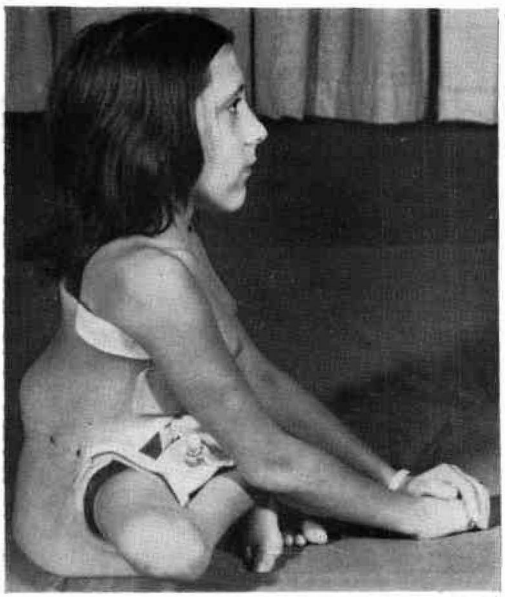

Fig. 17. Patient in seating device, lateral view.

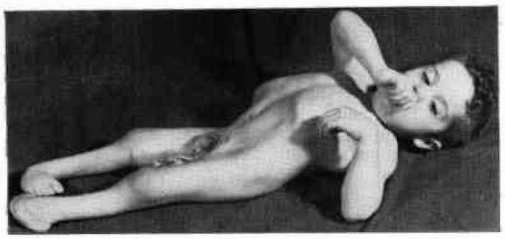

Fig. 18a. Severely deformed patient.

but as a preventive one. The primary objectives are to maintain functional positioning of the spine and, in those cases of spinal anomalies resulting in severe deformity, to maintain the body positioning until surgical procedures can be performed.

The methods discussed are also utilized as methods of postoperative care which have proven most beneficial, particularly in cases of incontinency. The various orthotic devices described represent an effective approach, not only to spinal control in the myelomeningocele, but to any paralytic conditions resulting in spinal curves. In particular, the thoracic distraction orthosis, utilized either as a wheelchair or lower-limb orthosis-connected device, has resulted in the prevention of deformity and the restoration of pulmonary control. The severely deformed patient was able to use a wheelchair effectively and was better able to perform routine daily activities.

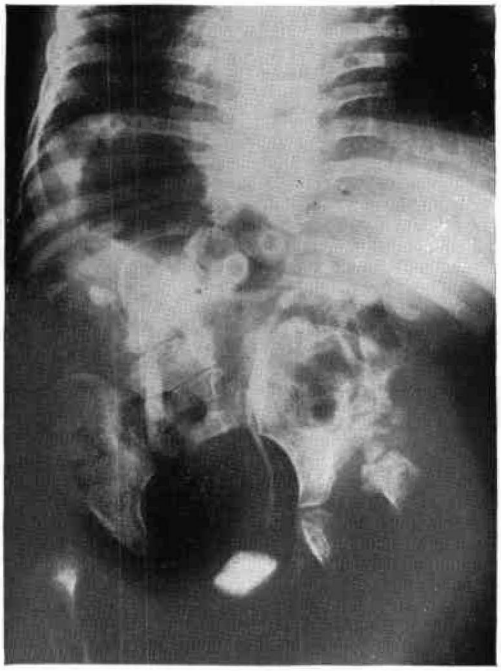

Fig. 18b. Same patient, preoperative X-ray.

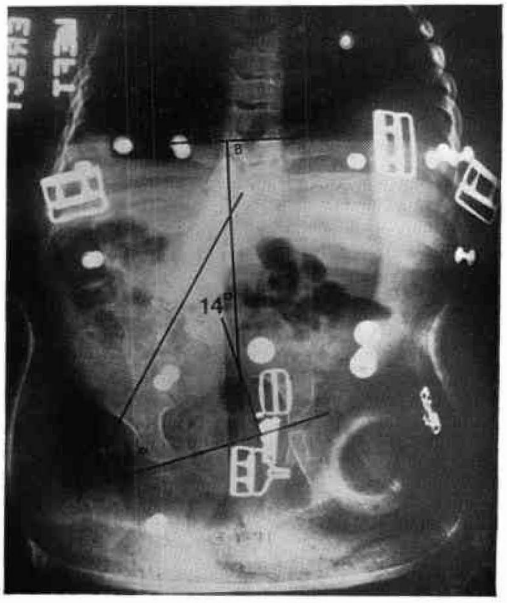

Fig. 18c. Same patient, postoperative X-ray.

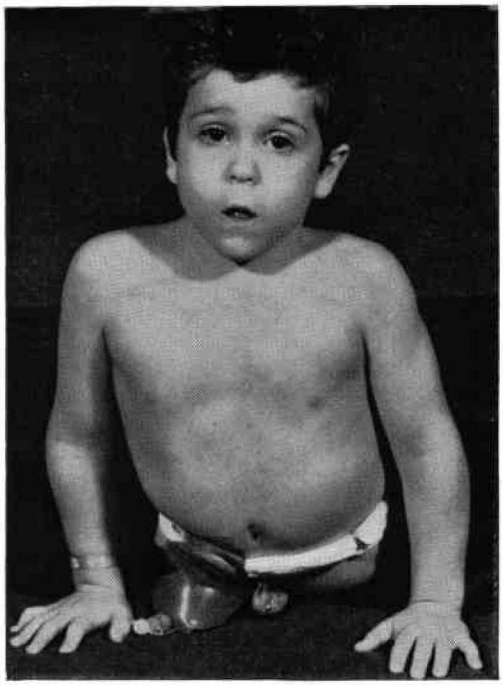

Fig. 18d. Patient sitting, postoperative.

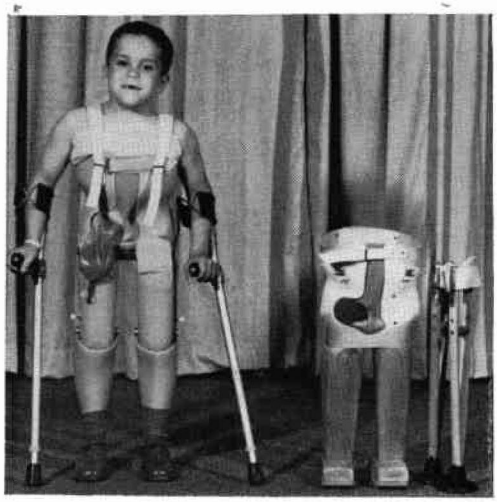

Fig. 18e. Patient standing in permanent prosthesis, training prosthesis shown on right.

Prophylactic application of the principles of treatment described will diminish the problematic spinal deformities which, in the past, frequently resulted in hopeless situations.

ACKNOWLEDGMENT

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The orthotic management of spina bifida children present status—future goals

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All spina bifida children should have functional goals established for them. These goals will vary with the severity of the motor and sensory deficit, and with the child's developmental threshold. In establishing such goals it is convenient to group the children according to neurosegmental level: thoracic, upper lumbar, lower lumbar, and sacral.

Children with spina bifida tend to be delayed in their developmental landmarks: (a) head control, (b) creeping, and (c) ambulation (National Academy of Sciences, 1973). They should be reared in a milieu which is intellectually and physically challenging. Every effort should be made to "normalize" their lifestyle. These children benefit from a sense of achievement. Mobility is essential if the child is going to attain social maturation and educational, vocational and avocational goals. Goal-orientated programming requires a co-ordinated team effort, with the patient the most important member of the team.

From birth to head control, the goals are to correct deformities, avoid contractures, encourage development through mobility and protect anaesthetic skin.

The goals from the time of head control to creeping are to achieve a sitting balance, prevent deformities, protect anaesthetic skin, encourage the use of hands bilaterally, improve eye-hand co-ordination, improve upper-limb strength, improve interaction with a broadened environment and improve mobility.

As regards ambulation, spina bifida children can be classified by functional level into non-ambulators, nonfunctional ambulators, household ambulators and community ambulators (Hoffer *et al.*, 1973).

"Nonambulators—These patients are wheelchair-bound but usually can transfer from chair to bed.

"Nonfunctional ambulators—Walking for these patients is a therapy session at home, in school or in the hospital. Afterwards they use their wheelchairs to get from place to place to satisfy all their needs for transportation.

"Household ambulators—These patients walk only indoors and with apparatus. They are able to get in and out of their chair and bed with little if any assistance. They may use the wheelchair for some indoor activities at home and school, and for all activities in the community.

"Community ambulators—These patients walk indoors and outdoors for most of their activities and may need crutches or braces, or both. They use a wheelchair only for long trips out of the community."

In a study of 68 spina bifida children aged 12 and over, De Souza and Carroll (1974), found that the eventual ambulatory status was primarily dependent on (1) the neurosegmental level of the lesion, (2) the motor power within a given neurosegmental level, (3) the extent and degree of the orthopaedic deformities, (4) age and stature, (5) the design and effectiveness of the orthosis, (6) intelligence, (7) motivation, (8) spasticity, (9) obesity, and (10) possibly sex.

The goals for a child with a thoracic neurosegmental level who has progressed to the point where he is ready to ambulate are (1) good sitting balance, (2) ambulation at least during first decade, (3) ability to do transfers, (4) wheelchair propulsion, (5) self-care, (6) social acceptability, (7) schooling, (8) access to environment. As an adult, the patient should learn to drive an automobile.

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The goals for a child with an upper, lumbar, neurosegmental level who has progressed to the point where he is ready to ambulate are similar to the goals for a child with a thoracic neurosegmental level. However, one would hope that the child with the upper, lumbar, neurosegmental level would learn to be a household ambulator.

One of the goals for a child with a lower, lumbar, neurosegmental level is to make him a community ambulator. He should be capable of crutchless standing and self-care; he should be able to go to a regular school; and he should be motivated to be self-reliant.

The child with a sacral level, neurosegmental lesion should become a community walker with minimal bracing.

The spina bifida programme at the Ontario Centre for Crippled Children includes an information class for the parents of preschoolers, a multidisciplinary clinic, and an orthotic clinic. In the information group parents are taught how to avoid contractures, to encourage development through mobility, and to protect anaesthetic skin. The spina bifida clinic is conducted with a neurosurgeon, an orthopaedist, and a urologist in attendance. The orthotic clinic is attended by an orthopaedic surgeon, an orthotist, orthotic technicians, physiotherapist, occupational therapists, nurses, and social workers. A child is presented at the orthotic clinic when he requires orthoses to help him achieve the next developmental threshold. Most of the children are 10 to 18 months old. The child's specific functional loss is determined, goals are established for the present and future, and decisions are made as to the role of physiotherapy, surgery and orthoses in his programme.

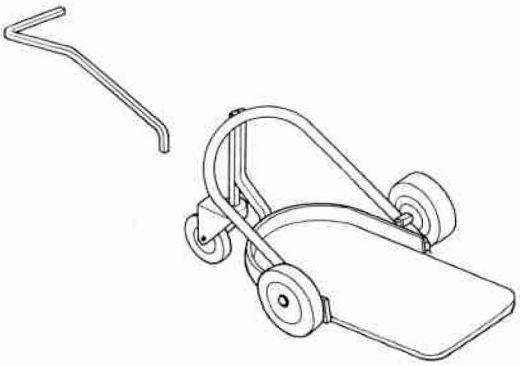

Fig. 1. Caster Cart.

A child with a thoracic or upper lumbar lesion may have difficulty in dragging himself from point A to point B. We frequently prescribe a prebracing mobility aid called a Caster Cart (Fig. 1) for such a child (Carroll, 1974). The Caster Cart makes it easy for the child to move about and explore his environment. He learns to use his hands to manipulate the wheels. His skin is protected.

When a child with a thoracic or upper, lumbar, neurosegmental level demonstrates that he is frustrated with sitting and that he wants to stand, we prescribe a Standing Brace as shown in Figure 2 (Carroll, 1974). This is an

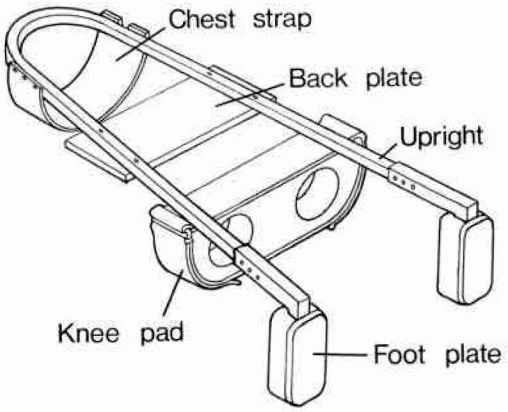

Fig. 2. Standing Brace.

inexpensive prefabricated orthosis which gets a patient upright without delay. It is made of a tubular frame to which parts are riveted. The fitting can be completed in under two hours and the patient can stand without crutches. He can move without crutches by pivoting. He can use crutches to achieve a swing-to or swing-through gait. As a preliminary device it enables the clinic team to assess the child in standing.

We believe that these children should stand and walk even if later in life they will give up their orthoses for wheelchairs. When they stand, their horizons are broadened, their lower limbs are less osteoporotic and they have fewer fractures, their bladders drain better, bowel function is improved and their cardiovascular system is stimulated by the increased physical activity. Upper-limb strength is increased.

Some of the children with an upper, lumbar, neurosegmental level have been fitted with a Reciprocating Gait Brace (Carroll, 1974). This

device, by means of a gearbox, harnesses the power of hip flexors on one side to produce hip extension on the opposite side. With the assistance of crutches, a reciprocal gait is possible by activating one hip flexor at a time. Swing-through gait is achieved by activating both hip flexors at the same time to keep the legs rigid. This orthosis is aligned so that it allows crutchless standing. It is hoped that dynamic stretching of the hip flexors will prevent progressive hip-flexion contractures. We have experienced gearbox maintenance problems with this orthosis.

Children with a total paraplegia, i.e. thoracic neurosegmental level, progress from the standing brace to a Parapodium (Fig. 3), (Carroll, 1974).

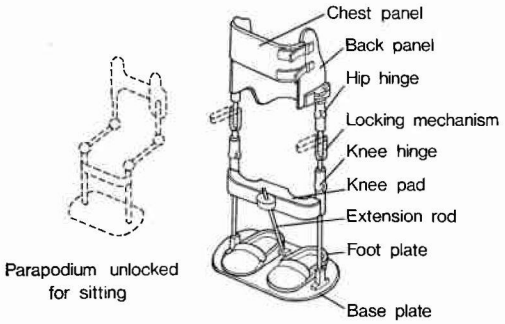

Fig. 3. Parapodium.

This device supports the spine during both sitting and standing and is aligned so that the child can stand without crutches. A swing-to or swing-through gait can be achieved by the use of crutches. The Parapodium is constructed from a prefabricated kit which has the following design features: stability, low weight, adjustability for growth, quickness of assembly, ease of alignment, ease of maintenance. With the Parapodium the shoe is "part of the child," not part of the brace. Crutchless walking can be facilitated by attaching a pivot-walker or swivel-walker platform to the footplate. Special-purpose attachments can be designed and mounted easily. Crutchless standing makes it easier for the paraplegic child to engage in activities such as tossing a ball, dialing a telephone, reading from a book in front of a class, opening a bottle, or pounding a nail at a workbench.

In the last couple of years we have been making more and more use of polypropylene. Practically all our children with instability of the ankle-foot complex are fitted with a vacuum-formed polypropylene insert (Carroll, 1974). If knee stability is a problem, a polypropylene insert can be attached to a polypropylene thigh support by means of side hinges.

Orthoses in the research and development stage at the Ontario Centre for Crippled Children are as follows:-

Plastazote shoes—to protect deformed insensitive feet.

Trunk-suspension systems—to prevent scoliosis, pelvic obliquity, and ischial pressure sores.

Curb-climbing wheelchairs—to broaden the nonambulator's environment.

Stand-up wheelchairs—to enable a nonambulator to assume and maintain a standing position.

Early in this paper, goals were listed for children with varying neurosegmental levels. How often are these goals attained? De Souza and Carroll (1974) found that in the second and third decades, community ambulation was achieved by 53 per cent of children with a sacral neurosegmental level, 30 per cent of children with a lower lumbar level, 10 per cent of children with an upper lumbar level, and no children with a thoracic level. Our great challenge for the future is to have these children continue to ambulate when adult, not just during the first decade.

The third most important factor in determining ambulatory status is the extent and degree of the orthopaedic deformities (De Souza and Carroll, 1974). It is incumbent on the orthopaedic surgeon, therefore, to ensure that the spina bifida child under his care has the spine balanced over the pelvis and hip, the hip balanced over the knee, and the knee balanced over a plantigrade foot. Our orthoses must have the following design characteristics: they must be effective, comfortable, lightweight, low in cost, durable, cosmetically acceptable, easy to manufacture, easy to maintain and adjust for growth, easy to apply and remove, and they must uot impede any of the activities of daily living (Carroll, 1974).

Through research we must develop a means of avoiding abduction, flexion and external rotation contractures of the hip, while still

maintaining a position favouring hip stability. We need better trunk supports. As yet we do not have good multiaxial hip joints. We must develop a means of maintaining directional stability for limbs that are in below-knee braces.

The fourth most important factor in determining ambulatory status is the age and stature of the patient. As yet we do not have a satisfactory means of getting a tall, heavy paraplegic from a sitting to a standing position. We need urinary-collecting devices for both males and females. We must assess the feasibility of externally powered braces for ambulation. We need suitable stair-climbing aids. Our architects need to be educated so that environmental barriers are removed from the community. We need total mobilisation of medical, paramedical, engineering and community resources to meet these challenges.

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Multichannel functional electrical stimulation—facts and expectations[1]

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Functional Electrical Stimulation (FES) was started with the simple and ingenious idea of Liberson *et al.* (1961) of lifting the drop-foot of a hemiplegic patient with a portable electronic stimulator. For the past ten years rather intensive research has been conducted in this area to test further possible applications of functional electrical stimulation. It was obvious that technological and cosmetic improvements of the single-channel peroneal brace could not be the ultimate goal of functional stimulation. Therefore we tried to visualize some possible long-range goals of FES from the beginning of our research.

Thus, we have always felt that the potential of FES lay in complex multichannel-systems which could provide much more than simple dorsiflexion of the foot. In this paper we attempt to show some results of these investigations.

Expectations of Multichannel FES

When our group started systematic work in this area about ten years ago, we had well-defined, long-range goals in the field. In spite of the fact that our initial expectations were rather high and sometimes naive, it is interesting to note that our goals were realistic. Thus, for example, in 1965, the senior author visualized multichannel stimulation of lower limbs with closed-loop control of each joint (Fig. 1) at a conference in Brighton (Vodovnik, 1966). At about the same time, we published (Vodovnik and McLeod, 1965) our "science fiction" expectations regarding multichannel stimulation of the upper limbs (Fig. 2). In this instance we

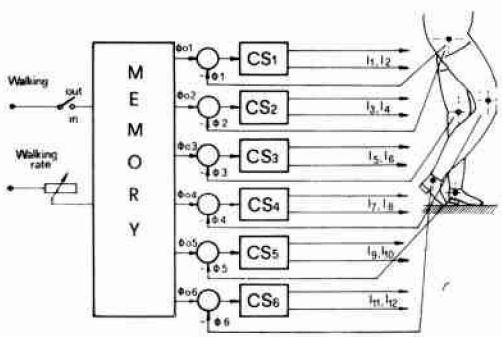

Fig. 1. Multichannel stimulation of paretic legs as visualized in 1965.

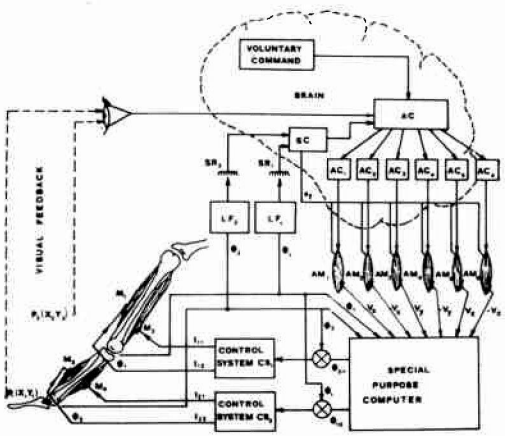

Fig. 2. Multichannel stimulation of paretic arms as visualized in 1965.

expected that the patient would control only the end-point velocity vector of the arm, and the special-purpose computer would find the optimal reference angles for all joints and produce adequate stimulation sequences for the muscles involved. For improved control we suggested local feed-back loops through the

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skin to improve the precision of the control signals.

It is a sobering thought that neither of these two proposals have been realized completely after ten years. The reasons lie both in engineering and in medicine. Our technology is still not advanced enough to enable well co-ordinated control with miniaturized implanted stimulators using radio-frequency operation. There do not exist as yet adequate position, force, or pressure transducers which can be attached easily and cosmetically to the body to send information to the elctronic processors. The influence of electrical stimulation on the remaining reflex mechanisms in patients is still not well understood. These problems, however, should not completely cloud with pessimism, the picture of multichannel stimulation. In the next paragraphs we shall show some rather advanced and exciting, though not ideal, results in this field.

Present Status in Multichannel Stimulation

In 1971 Kralj and his associates developed the first three-channel stimulator which was intended for the control of the swing phase in hemiplegic patients (Fig. 3). A stimulation sequence of three muscle groups on the leg could be pre-set and triggered by a signal from a heel switch. With the use of this stimulator the gait of patients was markedly improved and to date about 50 hemiplegics in Ljubljana have been using it quite successfully. The system, however, is still too large and complicated for the patient to use at home. Therefore, walking with this stimulator was performed only at the Rehabilitation Institute under the supervision of the physiotherapist. Several modifications of this stimulator have been designed or suggested by Kralj *et al.* (1971), Kralj (1975), Kralj and Vodovnik (1977), Jeglič (1973), Stanič *et al.* (1974) and Acimović *et al.* (1976).

Another outgrowth of three-channel stimulation for the lower limbs is a project to make a paraplegic stand or perhaps ultimately walk by FES. Kralj and Grobelnik (1973) introduced a multichannel stimulation programme to train the atrophied muscles of paraplegic patients. After several weeks the muscle power improved to such an extent that the first attempt to make a paraplegic stand up by electrical stimulation was successful (Fig. 4). We are still far away from making a paraplegic walk, in spite of some preliminary attempts at Rancho Los Amigos

Fig. 3. Three-channel stimulation of a hemiplegic patient during the swing phase.

Hospital and at the University of Virginia but there exists reasonable hope that within the next few years paraplegic patients also might have some chances for locomotion. These chances are even increased if some success is achieved in the development of hybrid actuators combining electrical stimulation and external power.

Regarding the hand or arm, the facts are even farther away from the expectations shown in Figure 2. Until now we have not succeeded in much more than obtaining relatively crude two-

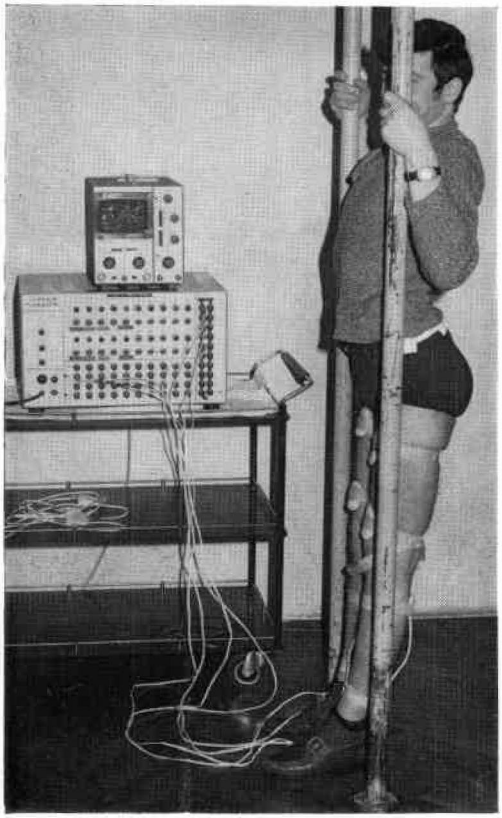

Fig. 4. Multichannel stimulation of a paraplegic patient in order to make him stand up.

channel stimulation of the hand. Merletti *et al.* developed a two-channel stimulator for the arm of hemiplegic patients. The most important muscle groups to be stimulated were the finger extensors and the m. triceps (sometimes combined with m. deltoideus). With two independent position transducers controlled by both shoulders the patient could perform manual tasks (such as picking up and transferring a bottle) which otherwise would be impossible (Fig. 5). The major problems with stimulation of the upper limb are the control sites. Except for minor "subroutines", not much can be programmed for movements of the upper limb. Therefore each paralysed muscle group has to be under voluntary control through one control site and for more than two channels the learning problems for the patient become almost insurmountable. One of the major efforts in future research for upper limb multichannel stimulation will be directed towards the development of training procedures, including biofeedback,

Fig. 5. Two-channel stimulation of a hemiplegic patient to improve hand function.

and finding adequate control sites to ensure the patient independent control of several muscle groups.

Conclusion

Clinically applied multichannel stimulation was visualized in the very beginnings of FES. A short survey of existing multichannel systems was taken and compared to initial expectations. While much still remains to be done to get multichannel stimulation out of the research environment and into the clinical routine, the results obtained so far are encouraging enough to continue work in this area with increased effort.

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Rancho flotation bed

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Physicians and nurses responsible for the management of immobile patients have long been aware of the problems caused by pressure and shear forces over the bony prominences of the body. Although research groups have had great difficulty in attempting to quantify the destructive level of shear forces, several studies (Landis, 1929), (MacLennan, 1942), (Kosiak, 1961) have indicated that pressures of *20 to 30 mm Hg over extended periods* will tend to result in pressure sores.

The phrases "extended periods" and "20 to 30 mm Hg" have been *italicised* because these phrases are the keys to the prevention of pressure sores. There is a relationship between time and pressure such that high pressures can be allowed for short periods of time, lower pressures for longer periods of time, and low pressures for extended periods of time (Lindan, 1965), (Rogers, 1973).

Because of this relationship, it can be stated that pressure sores are preventable. On any ordinary hospital bed, when the patient is moved from one body surface to another repeatedly at not more than two-hourly intervals, ischaemia will not develop. Bridging bony prominences or other susceptible areas with pillows can help to reduce the required turning frequency (Lowthian, 1971).

The major difficulties associated with the turning techniques are the time and physical effort required of the nursing team and the constant need for training in its importance. The cost for all this is substantial but is small when compared to the monetary cost ($5,000–$10,000) and human misery and threat to life of spending several months in a hospital bed to heal a large pressure sore.

Physicians and nurses have resorted to various mechanisms to reduce the manual labour involved in turning the patient and to provide better control of body alignment. Examples are the Roto-Rest (Keane, 1970), the Foster-Stryker turning frame (Ascoli, 1970) and the Edgerton-Stoke Mandeville bed. Many of these mechanisms, however, are complex, resulting in training, reliability and safety problems, and most still require extra nursing time.

Another approach to the prevention of pressure sores is the use of various devices to distribute the pressure in such a way that the resulting lower pressures can be withstood over long periods of time. When a patient is lying on an ordinary bed, the mattress is unable to accommodate the various contours of the body; thus, much of the weight of the entire body is borne by the tissues over the bony prominences. In order to reduce the pressure applied to the bony prominences, devices using such things as sectional foam pads and floating plastic balls (Schetrump, 1972) have been tried.

An ideal distribution of pressure is achieved when the patient is supported by purely hydrostatic forces, i.e. when the patient literally floats in a fluid. If a membrane separating the patient from the fluid is sufficiently thin, the fluid can accommodate all of the body contours. In addition, hydrostatic forces act perpendicular to the surface of the body being supported. Thus, the areas surrounding bony prominences are protected from shear forces along the sides if the separating membrane is loose enough to be free to move with the body.

This concept has led to several types of hospital-type water and other media flotation beds (Hargest, 1969), as differentiated from most home-type water beds in which the patient is partially suspended, as in a hammock, by the inelasticity of the water-filled bladder rather than by true flotation.

The water-flotation beds provide acceptable pressure distribution (Grahme, 1973), (Pfaudler, 1968) however, because the density

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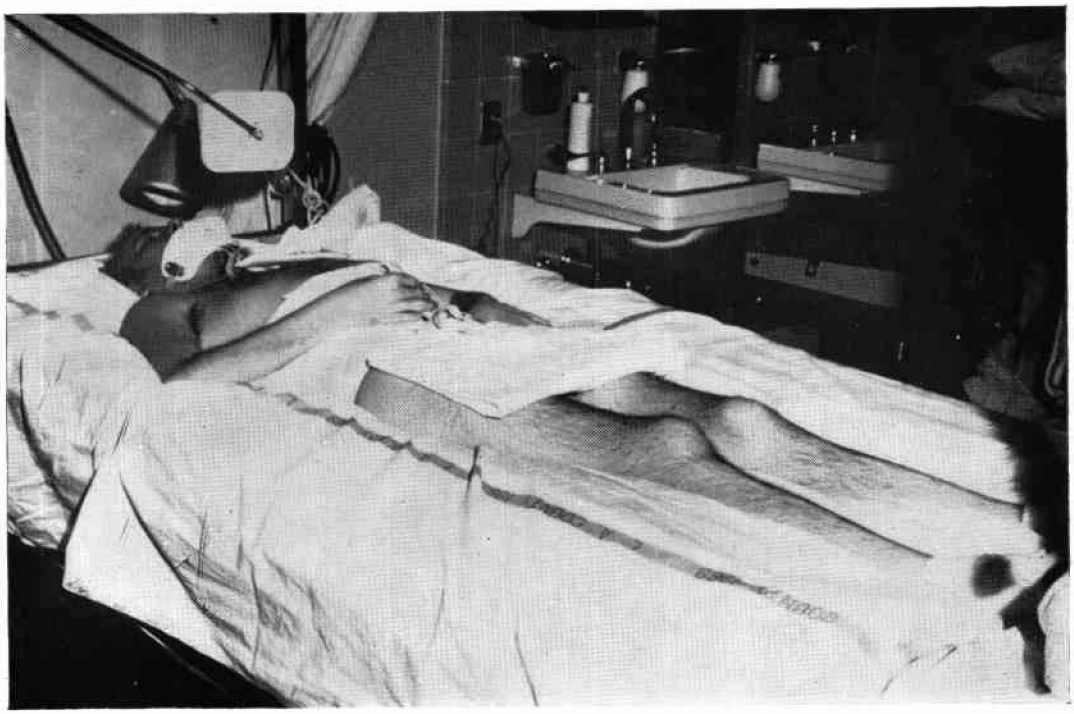

Fig. 1. Original prototype MUD bed built at Rancho Los Amigos Hospital. The photograph was taken during initial trials under actual conditions and shows the first patient to benefit from this device.

(mass per unit volume) of the human body is approximately the same as water, the patient must float almost totally submerged. This has been known to cause hallucinations owing to the feeling of weightlessness and respiratory problems (Pfaudler, 1968) probably due to the "hunching" of the shoulders which usually occurs when the body is submerged. Lying prone is impossible and catheterisation over the tub side may be difficult. Also, experience at Rancho Los Amigos Hospital has indicated that hip and knee flexion contractures may form more easily in submerged paralysed individuals because the stronger flexor muscles tend to dominate when the body is submerged.

In order to overcome these problems, the Rancho Flotation Bed was developed at Rancho Los Amigos Hospital (Reswick, 1972). It is basically a flotation bed, similar to a water flotation bed, but using a fluid of density 2 (twice as heavy as water). Thus, it provides all of the advantages of a water flotation bed, but since the human body weighs only one half as much per unit volume as the fluid in the bed, the patient floats half submerged. The patient being well above the edge of the bed can see around him and gravity acts with the fluid to keep the body in horizontal alignment. Catheters drain well, having only a down-hill path. Hip and knee flexion contractures as well as the possible cause for the respiratory problems encountered on the water flotation bed are avoided. The fluid is contained in a vacuum-formed plastic tub covered by a thin, oversized plastic sheet. It is heated to a temperature of 85-90 degrees Fahrenheit, by an electric unit on the underside of the tub. Figure 1 shows the first patient, a recent quadriplegic, in the original prototype bed built at Rancho Los Amigos Hospital.

The fluid which makes this possibe is a colloidal suspension of pulverised Bayrite and water which is kept homogeneous by the addition of a thixotropic clay called Bentonite. The mixture is similar to oil-well drilling mud, which leads to the nickname, "MUD Bed". The relatively few other chemical solutions which have a density of 2 tend to be either too reactive (harmful to the skin) or to have other undesirable properties.

The first prototype bed was placed in a ward in Rancho Los Amigos Hospital three years

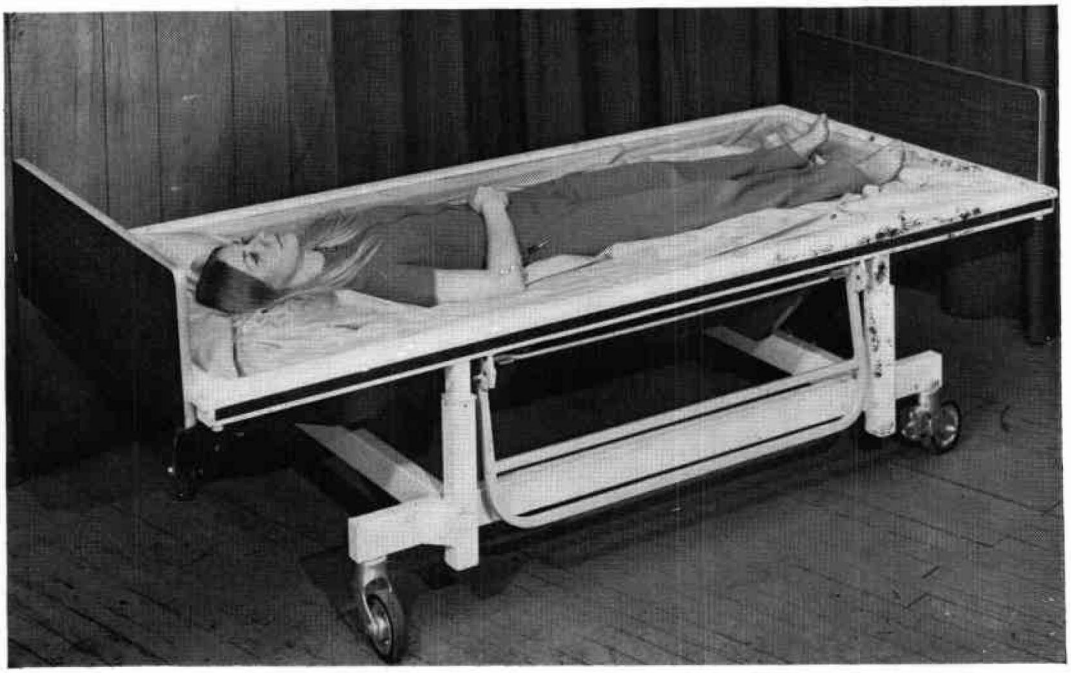

Fig. 2. Production model of the MUD bed manufactured by Gaymar Industries, Buffalo, N.Y. and marketed as the HDF(R) Bed.

ago. As of this writing fifteen such beds are being used in the Spinal Injury Service, the Burn Service and the Spinal Injury Readmission (Pressure Sore) Service. The beds are now being manufactured commercially[1] and a number are currently in use in other hospitals. Figure 2 shows the commercially available bed.

Clinical Experience

Over 200 patients, with the majority presenting severe pressure sores at time of admission, have been treated on Rancho Flotation beds at Rancho Los Amigos Hospital with no occurrence of new pressure trauma and with general improvement of existing ulcers. The case records of two of these patients may serve as examples of the use to which these beds have been put:

Case No. 1: L. G. is a 19-year-old male who sustained a gunshot wound on 12 July, 1971 leaving him a complete T8 paraplegic. He was treated at a local hospital for his spinal injury and for lacerations of the liver, jejunum and oesophagus. His post-injury course included a bronchial-pleural fistula and required a gastrostomy and a feeding jejunostomy. He was transferred to Rancho Los Amigos Hospital on 12 November, 1971. Upon arrival, several of his operative wounds and drain wounds were still unclosed superficially and he had a left anterior chest wound that was granulating but the depth of which could be observed. He had a large sacral pressure sore, a large right trochanteric pressure sore, and a smaller left trochanteric pressure sore. He also had a peno-scrotal fistula. On 23 November, 1971 he was taken to the operating room where he had closure of his sacral and right trochanteric pressure sores and skin grafts applied to the clean granulating areas in his left trochanteric pressure sore. After surgery, he was initially treated in a standard bed with bridging and turning, but this proved unsatisfactory as his left anterior chest wound began increasing in size and depth and he developed an oedematous, swollen scrotum. An urgent call was made for

[1] HDF(R) Bed, Gaymar Industries, 701 Seneca Street, Buffalo, N.Y. 14210.

the Rancho Flotation Bed on 6 December, 1971. He was placed on the bed the same day, lying supine on his recently closed sacral pressure sore and was not turned at night. His worsening condition stabilized and he was nursed on the MUD bed until 16 February, 1972, at which time his sores had healed such that a more needy patient could be put on the bed. His skin was totally healed by 30 June, 1972.

Case No. 2: C. W. is a 16-year-old who had a motor-cycle accident on 15 April, 1973, leaving him with a fracture dislocation at T7-T9 and a dislocation with complete spinal injury at T12. He also suffered from a cerebral contusion with coma, a possible cardiac contusion, a right pneumo-thorax and a left haemo-thorax. He was treated in an acute hospital and was put into halo-femoral traction on 11 May, 1973. The initial traction of 50 pounds was later reduced to 15 pounds at either end. He was transferred to Rancho Los Amigos Hospital on 30 May, 1973 and placed on a standard bed with 20 pounds traction on the halo and 30 pounds on the femoral pins. Upon admission he had a sacral pressure sore which was approximately 3.3 cm diameter and 0.9 cm deep. Because of the difficulty in caring for his skin while in traction, he was placed on a MUD bed on 5 June, 1973, lying supine, directly on the sacral ulcer. By 17 July, 1973 his sacral ulcer had healed to approximately 0.5 cm diameter and 0.1 cm deep. Since his spine had now stabilized and his traction been removed, he was removed from the MUD bed on 20 July, 1973 so that a more needy patient could use it.

Discussion

Much clinical experience with the beds has been gained. Perhaps the most significant aspect of experience has been that patients, admitted with sacral pressure sores, have had these sores heal while they lay supine directly on the ulcer without the need for turning. Not having to lie prone has a tremendous effect on the morale of the patient and on the time and energy required to provide the nursing care needed for any sore to heal. When dressings must be changed, the patient can easily be turned by one nurse (since his centre of gravity and the long axis of his body are at the level of the surface of the fluid). When the patient is turned on his side, a sacral sore can be completely exposed for nursing care. Also, since the patient is not totally submerged, he can be easily laid prone when desired.

Features of the bed design which one might envisage to be troublesome have generally caused few problems. The thin polyvinyl-chloride (PVC) membrane covering the fluid is occasionally punctured causing the fluid to leak slowly, however leaks can be patched permanently using standard surgical tape found on the ward. No completely ideal cover material has yet been found. Even though PVC has a low rate of water vapour transmission, the large surface area does allow sufficient evaporation to require the occasional addition of water followed by hand mixing of the mud to keep it a uniform fluid consistency. Because the fluid is twice as heavy as water, the bed is heavy, weighing approximately 1200 pounds. On a hard level surface however, one nurse can handle the bed on its smooth castors. Additional help is needed only for ramps, door sills or carpeted areas. The fluid basis of the bed, while preventing shear forces, also prevents the use of unilateral traction, although 5 to 7 pounds of uncounter-balanced traction have been used with no problem. Above that level, the traction simply tends to pull the patient to that end of the bed. Patients with counter traction are, however, much more easily cared for in a flotation bed than in a standard bed as turning is not required. The Trendelenburg position for providing opposing traction force or positioning for respiratory drainage is not possible as gravity will always keep the fluid surface horizontal. Since the bed cannot be "rolled up" for sitting, foam bolsters or pillows are used to prop the patient up when needed.

Summary

The Rancho Flotation Bed provides hydrostatic support with maximum pressures over bony prominences of 15 to 25 mm Hg (measured with a pneumatic pressure transducer). This is generally below the levels normally quoted as conducive to the development of ischaemia. Clinical experience has shown the bed to be a successful aid to nursing by eliminating the need to turn the patients for pressure reasons, allowing patients with pressure sores to remain in a position which is more comfortable and more suitable for other nursing care. It also makes it easier for nurses to handle patients in order to care for the pressure sores.

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Education in prosthetics and orthotics

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Historically most of the truly competent people who have become skilled in all phases of the prosthetics and orthotics field have achieved this position by self-study, reading and discussion, participation in meetings, and a varied clinical experience; all of which was preceded by a vigorous and stimulating apprenticeship during their early formative years which contributed to these desirable patterns of work and study. Others, however, have been less fortunate in their personal attributes and preparation; consequently, they have few significant contributions to make in any area of prosthetics and orthotics and in fact do not provide acceptable service.

Variation in ability between people engaged in a profession is to be expected and is a good thing, but in the field of prosthetics and orthotics there is far too much difference between the capabilities of various practitioners. This disparity may be attributed to the fact that there has been a lack of orderly, organized, systematic training and educational opportunities in which all prosthetist-orthotists could participate prior to their entry into this field. Consequently, the level of a person's professional ability is more dependent upon chance exposure to various experiences than on a planned educational programme designed to transmit efficiently the cumulative knowledge of the profession.

One of the major purposes of institutionalized training in the field of prosthetics and orthotics is to minimize this variation in professional abilities and to assure that every qualified prosthetist-orthotist displays a minimum competency in all phases of his profession.

Before discussing a programme for the education and training of the professional prosthetist-orthotist, it would be well to review the responsibilities and functions of such individuals. In summary terms, the three pervasive responsibilities of the professional prosthetist-orthotist are:

1. To serve as a co-equal member of the clinic along with the physician or surgeon and therapist providing consultative advice; to participate in discussions and share in decisions regarding prescription, evaluation, and formulation of the prosthetic-orthotic treatment programme.

2. To provide prosthetic-orthotic service to patients, which implies all of the necessary intellectual and manual skills (design, measure, cast, fit, align, etc.) required to supply an appliance of excellent quality.

3. To be aware of, and contribute to, the progress and growth of the profession through such means as research and development activities, participating and exercising leadership in professional associations, and recruiting and training new entrants into the field.

It is indeed difficult to summarize all of the skills, capabilities, knowledge and understanding that a professional prosthetist-orthotist should have in order to satisfactorily fulfill these responsibilities. As we consider the matter, it seems that there are six areas of skill and knowledge which are indispensable:

(a) Physical sciences, including mathematics
(b) Biological sciences
(c) Psychological sciences
(d) Mechanical skills and crafts
(e) Communication skills
(f) Personal and cultural qualifications.

Physical Sciences

A mechanic may be defined as someone who performs manual work in the fabrication of some structure or device. As such, the prosthetist-orthotist has functioned as a mechanic for hundreds of years. The shortcoming in this approach is that the mechanic (or technician),

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not being exposed to many of the relevant principles evolving from the physical sciences, is taught to reapply the techniques he has learned in all situations with minimal variation.

Basic physics and chemistry, mechanics (the branch of physical science that deals with forces and energy and their effect on bodies), and properties of materials are the particular areas of concern to the prosthetist-orthotist. Fundamental principles derived from such studies are requisite to the design and production of prosthetic-orthotic devices.

It is also clear that little can be accomplished towards learning and applying these principles without a command of basic mathematics and geometry. Consequently, the study of all of these subjects becomes important.

Biological Sciences

The mechanical product (machine) which the prosthetist-orthotist fabricates must be integrated with a biological entity (the human being). It must be fitted and worn in the closest intimacy to the body of the wearer for the purpose of improving the physical resources of that individual. In view of this, knowledge from the biological fields of anatomy, physiology, and kinesiology is indispensable for the qualified practitioner.

In recent years, we have begun to learn some new things about how the human body functions as a mechanical system. This field of knowledge is called "biomechanics" and the adequacy of efforts at physical restoration is completely dependent upon a grasp of this new science, the principles of which govern the motions of the human body.

Since the patients treated in the prosthetic-orthotic field all have some form of neuro-musculoskeletal disorder, the study of biological science must extend into the areas of pathology and pathomechanics, that is, abnormal as well as normal function.

Psychological Sciences

Since the prosthetist-orthotist creates a product to be worn by a human being, success or failure will be influenced by the opinions, attitudes, feelings, likes and dislikes of that human being. The experienced prosthetist-orthotist knows that in many instances the critical problem in the successful fitting of a prosthesis or an orthosis lies with the psychology of the wearer rather than in any physical or biological problem. The prosthetist-orthotist must, therefore, be capable of understanding and relating to his patients so that he can work constructively with the individual's psychological attributes rather than at cross-purposes. Patients, peers, professional colleagues, and prosthetist-orthotists themselves must be viewed in psychological terms and dealt with in a similar manner.

Mechanical Skills

In spite of the stress placed on the academic and theoretical knowledge required by the prosthetist-orthotist, we do not intend to underestimate the mechanical abilities involved in the fabrication of an appliance. Practitioners must learn the characteristics of the major materials —wood, metal, plastic—and master the manipulative skills which will enable the production of an appliance no less adequate than the one that they are able to conceive.

Communication Skills

The need for adequate abilities in the use of the spoken and written language must not be overlooked. There is no possibility of the prosthetist-orthotist being able to communicate his ideas, opinions and points of view to his patients or to his professional associates without an adequate command of language skills.

Personal and Cultural Qualifications

Lastly, there is the need for the prosthetist-orthotist to be a well-informed, cultured citizen so that in his social and professional behaviour he may be respected as a mature, understanding person in many areas rather than considered a narrowly informed individual.

The personal and personality characteristics of people in professional work are of the utmost significance, since the ability of a patient to accept service is directly related to his opinion of the individual providing the service. It is mandatory, therefore, that the professional prosthetist-orthotist be offered the opportunity for broad educational and life experiences.

We have, then, specified the areas of knowledge from which subject matter should be drawn, and oriented the curriculum content towards the goals represented by the professional responsibilities of the prosthetist-orthotist.

Before turning to the matter of an "ideal" curriculum, several basic assumptions on which the curriculum rests must be mentioned

1. Graduates will practice their profession utilising *prefabricated* prosthetic-orthotic components. Therefore, training in the production of such items as prosthetic feet and orthotic joints need not be offered.

2. The fields of prosthetics and orthotics are not separate and distinct entities. Rather, there is a considerable (and growing) degree of overlap in the knowledge and skill required in both areas. Therefore, the educational programme should offer concurrent training in both specialities.

3. The academic level of the education programme and the value and acceptance of the degree or diploma issued on successful completion of the course of study should be comparable to that of other health professionals (therapists, counsellors, etc.). The training should be offered by an existing, accredited, recognised educational institution at the post-secondary school level.

For some years, we at New York University have been conducting a prosthetics-orthotics education programme to prepare individuals for entry into the field and, because of the considerable thought that has been devoted to it, I will venture to use our own programme as a basis for a suggested curriculum. The courses listed

TABLE 1—SUGGESTED PROSTHETIC-ORTHOTIC CURRICULUM
(4 years)

	Class Hours		
	Lecture	*Lab.*	*Total*
Physical Sciences (including mathematics)			
Algebra and Trigonometry	45	—	45
Introductory Chemistry	45	45	90
Introductory Physics	45	60	105
*Mechanics	45	—	45
*Properties of Materials	30	—	30
	210	105	315 (8%)
Biological Sciences			
Introductory Biology	45	60	105
Anatomy and Physiology	90	30	120
Orthopaedic and Neuromuscular Pathology	30	—	30
	165	90	255 (6%)
Psychological Sciences			
Introductory Psychology	45	45	90
Psychology of the Physically Handicapped	45	—	45
	90	45	135 (3%)
Communication—Personal and Cultural			
English Composition and Speech, Social Sciences, Humanities, Liberal Arts, and other sciences	570 (approx.)		570 (14%)
Manual Skills and Concepts			
Mechanical Drawing	15	75	90
General Metalworking	15	75	90
*Prosthetic and Orthotic Techniques	30	180	210
	60	330	390 (10%)
Professional Specialization			
*Biomechanics	30	—	30
*Above-Knee Prosthetics	40	200	240
*Below-Knee Prosthetics	30	150	180
*Lower-Limb Orthotics	60	90	150
*Upper-Limb Prosthetics	30	105	135
*Upper-Limb Orthotics	15	60	75
*Spinal Orthotics	30	105	135
*Professional Problems in Prosthetics and Orthotics	30	—	30
Clinical Affiliations (supervised practical experience)	—	1440	1440
	265	2150	2415 (59%)
Totals	1360 (33%)	2720 (67%)	4080 (100%)

*These courses are offered in our own facility by our own faculty—remaining courses are given by other departments in the University.

in Table 1 comprise a four-year programme of 131 academic credits with a total of 4,080 hours of classroom instruction (1,360 hours of lecture and demonstration, and 2,720 of laboratory experience). Upon successful completion of the curriculum, the student is awarded the degree of Bachelor of Science.

It is important to note that the last group of courses entitled "Professional Specialization" accounts for approximately 60 per cent of the total number of instructional hours. When the additional 10 per cent devoted to "Manual Skills and Concepts" instruction is added one approaches 70 per cent of the total class contact hours for the specialized prosthetic-orthotic training. This reflects the considerable amount of time required to develop the necessary prosthetic-orthotic skills. However, even with this substantial time allocation, we find it necessary to be very selective and to limit the variety and types of prostheses and orthoses fitted and fabricated by the students so as to assure their unquestioned understanding of basic principles and procedures.

Space will not permit any further discussion of the detailed content of the specialized prosthetic-orthotic courses. It will suffice to point out that considerable agreement regarding the topics to be covered in these specialized courses was achieved at the International Study Week on Prosthetic-Orthotic Education sponsored by the University of Strathclyde, Glasgow in July, 1974 and outlined in the associated publication (Hughes, 1976).

In conclusion it may be of interest to mention briefly that long-term training opportunities are available in prosthetics and orthotics throughout the world. Detailed information on fourteen institutions offering such programmes was identified at the International Study Week. Six of the institutions were in North America, five in Europe, two in Asia and one in the Middle East. There is reason to hope and expect that this number will increase in the years ahead.

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Rehabilitation engineering—a developing specialty

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Introduction

Recent estimates made by the Social Security Administration (SSA) and the Swedish Institute for the Handicapped (National Research Council, 1976) indicate that between 10 and 12 per cent of the population are handicapped. Using the lower figure and estimating on the conservative side means that there are approximately 20 million handicapped individuals in the United States. The SSA figure also indicates that about 8 million are able to work either normally or in a limited capacity and 7½ million are unable to work at all. By deduction, the remaining 4½ million must be comprised of those from the young and geriatric populations. The loss of productivity plus the financial burden borne by federal and state programmes are estimated to be in the billions of dollars. Of course, these financial burdens are in addition to personal losses suffered by physically handicapped individuals resulting from their inability to participate in many aspects of life—losses that cannot be measured in dollars.

A conservative estimate is that technology can be potentially beneficial to at least 50 per cent of the physically handicapped population (10 million people in the United States). Prosthetics and orthotics have been the primary source of technology for physically handicapped over the years. Recent studies conducted by the Committee on Prosthetics Research and Development—National Academy of Sciences (le Blanc, 1973) indicate that approximately 4 million individuals benefit directly from prosthetic and orthotic services. This means that a remaining 6 million individuals stand to benefit from additional types of technology that are presently unavailable to them.

Recent experience with this latter population indicates that judicious application of technology can have beneficial effect by increasing the independence of individuals, thereby reducing cost of care and increasing their involvement in productive job activities. At present only a very small fraction of the capabilities of modern technology are being effectively utilised to aid this population.

Traditionally, engineers in the field of rehabilitation have been involved largely on the periphery undertaking research and development projects in areas such as prosthetics and orthotics, but rarely becoming involved directly with patients. That is, very few engineers have become truly integrated into the clinical setting as functioning members of clinic teams. As a result, engineering has remained merely as a desirable supplement to clinical treatment rather than becoming an integral component in the rehabilitation process.

Throughout the 1960s attempts were made to transfer sophisticated technology developed by NASA and the computer industry and other space-age technical spinoffs into the clinical setting. This effort was abandoned after eight years as no significant success had been achieved. The major difficulty stemmed from an inability of the involved disciplines to communicate effectively; and from the fact that there was not a mechanism within the clinical environment that could integrate the technology in a manner that was acceptable to patients. A more realistic approach has placed engineers, physicians, and related professionals together in a clinical setting to work directly on patient problems. This approach has been termed Rehabilitation Engineering, and distinct from their biomedical or bioengineering research-oriented "half-brothers", the new breed of engineers in this subspecialty are becoming known as rehabilitation engineers.

The Role of the Rehabilitation Engineer

The broad objective of rehabilitation engineering is to enhance the lives of the physically

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handicapped through the clinical application of a total approach to rehabilitation; combining medicine, engineering and related science and technology. The prime function of the rehabilitation engineer is to bring an organized approach to patient problem solving, through problem definition, analysis, synthesis, and application of solution.

It is evident that the scope of rehabilitation engineering must be broader than the traditional focus of prosthetics-orthotics in order to be responsive to the needs of all aspects of a handicapped individual's life, i.e. education, vocation, daily living, recreation and creativity. It is conceivable that rehabilitation engineering activities can be carried out anywhere that consumers require the service. Some examples are; rehabilitation hospitals and centres, special public schools, industry, special living environments, research laboratories, insurance companies, vocational rehabilitation departments, consulting services, government health departments, teaching programmes, standards committees, and private charitable organizations. It therefore follows that within the scope of rehabilitation engineering there will be individuals with different interests and job activities. There will be those who prefer to work solely in areas of teaching, research, and development with only limited contact with clinical activity. However, within the rehabilitation process, the unique aspect of the rehabilitation engineer is that he functions as a member of the clinical team, and has the training and experience necessary for the successful delivery of technology to those who require it. Additional functions of the rehabilitation engineer are to: a) be knowledgeable of all potential resources that can be utilised on the behalf of the handicapped, b) assist in identifying and defining the clinical problem, c) develop a procedure for providing a possible solution, d) work with rehabilitation professionals, other engineers, and technicians to provide solutions, e) assume responsibility for eventually finding a solution that is acceptable to the consumer.

It is anticipated that patient needs outside the scope of currently practised prosthetics-orthotics is the main activity area in which the rehabilitation engineer will grow his deepest roots and ultimately make the greatest contribution in terms of direct benefits to patients. Within this sphere of activity the rehabilitation engineer is assuming responsibility for patient case loads, and working directly with doctors and therapists in the management of patients with a wide diversity of rehabilitation problems. The most obvious activity areas are; special seating, pressure sore prevention, mobility, biofeedback training, non-verbal communication devices, transportation, environmental control, and work environment modifications.

Relative to prosthetics and orthotics, it is visualized that the rehabilitation engineer will function in the capacity of technical consultant, particularly related to patient problems that require the application of more sophisticated technology. For example, the engineer may be of valuable assistance to the orthotist or prosthetist on the problems that require the application of materials such as newer plastics and light weight/high strength alloys, advanced electronics, or unique mechanical designs.

In the realm of research, it is the author's opinion that the rehabilitation engineer as described above should not be considered a basic researcher, since his primary interest and charge is the direct application of current technology to patient problems. However, his clinical exposure gives him the unique opportunity to identify and define many complex clinical problems, which can then be transmitted to research scientists for solution. In this capacity the rehabilitation engineer acts as a resource person who is primarily involved in the early definition stage of a research project, and then again in taking the results of research and converting them into practical clinical applications. Therefore, relative to basic research it is important that the rehabilitation engineer maintains an open communication between other professionals within the clinical setting, the patient, and his research colleagues in order to affect the best solution to complex clinical problems.

Relationship with Peer Professionals and Consumers

The practising rehabilitation engineer at one time or another must associate with approximately 15 different peer professionals—and so do without offending those who basically resent the intrusion of Captain Marvel with his black boxes and flashing lights. Within the sphere of the traditional rehabilitation process, the

engineer would function as a member of the clinical team and assume equal status to other professionals on the team—with the physician retaining the ultimate responsibility for patient welfare. As the scope of rehabilitation engineering develops to encompass more areas of activities outside the established rehabilitation process, the engineer may function in a consultant capacity, on a fee-for-service basis, and assume legal and ethical responsibility for the services provided.

Since the field of prosthetics-orthotics has long served as the major contributor of technology for the rehabilitation process, some view the evolution of rehabilitation engineering as an encroachment upon the achievements made or the future developments of the prosthetic and orthotic professions. It must be recognized that all fields have both unique and common areas of contribution to make to the lives of the handicapped. Rehabilitation engineering in no way should supplant or infringe upon the growth of prosthetics and orthotics. Rehabilitation engineers, unless having had certification in prosthetics-orthotics, are not competent to provide prosthetic-orthotic devices to patients. However as mentioned, they can have a technical area of expertise that when combined with a basic understanding of the field of prosthetics-orthotics can serve as a valuable technical resource. If one takes the view that in clinical activities that are basically within the realm of prosthetic and orthotic experience the rehabilitation engineer should assume the role of consultant, and in other technical areas the rehabilitation engineer should assume the primary responsibility for technical delivery and call upon the expertise of the prosthetists-orthotists as consultants—then crossing of boundaries can be done in a spirit of co-operation and goodwill. Of course there will always be "grey areas" and the technical responsibility for an individual patient may bounce back and forth between the disciplines; depending on the type of problem, the course of a patient's improvement, and the point in the time—continuum of the individual's rehabilitation process.

The rehabilitation engineer should at all times remain sensitive to the needs of patients. He must attempt to gain insight into human behaviour, particularly relative to the pressures experienced by the handicapped in their daily lives, and inject these realities into the technical goal-setting process. He must at all times be cognizant of the intricate balance between cost and real benefits derived, and in some cases be prepared to withhold technology when the cost-effectiveness ratio becomes highly questionable.

The relationships of the rehabilitation engineer must also extend beyond the sphere of the rehabilitation centre. Upon the successful research and development of any new device the rehabilitation engineer has the responsibility to make the development available to all patients who can potentially benefit. This may mean consultant activities with local and international manufacturers and suppliers, involvement in co-operative programmes involving other developmental centres or private facilities; as well as providing support to national and international organizations that may wish to carry out evaluations or educational programmes on a larger scale.

Work Environment

In order to carry out his prescribed role in the clinic team, the rehabilitation engineer ideally should be located in, or adjacent to, a clinically based medical-technical programme which encompasses in-patient and out-patient medical services, therapy, prosthetics-orthotics, engineering services, applied research, teaching, with access to basic research resources as required. As a functioning member of the clinical team with an active caseload, the engineer must have resources at his disposal for designing, fabricating, supplying and maintaining a wide variety of technical devices for patients. In order to carry out his activities effectively, adequate resources must be available in terms of mechanical and/or electronic fabrication facilities located in reasonable proximity to the clinical setting. Naturally, the extent of the support resources are dependent upon the types and numbers of patients being served. Generally, a rehabilitation engineer should have 3 to 4 support technicians plus secretarial assistance, so that most of the devices can be fabricated or modified on site without excessive time delays.

It is felt by some that in addition to the researcher, prosthetist-orthotist, and rehabilitation engineer there is need for another level of individual—a rehabilitation engineering technologist. It has been proposed that this person

would essentially be "the hands" of the engineer working directly with patients under his direction. However, this view has not been supported in general on the basis that it is neither necessary nor desirable to have a technician acting as the interface between the engineer and the patients since direct patient contact should remain the primary responsibility of the engineer. Also, the support skills usually required are already available in the form of machinists, electronic technicians, draftsmen, etc.

Education and Certification

Establishment of educational programmes that will meet immediate and future manpower needs remains as a priority goal in the systematic evolution of the field. A recent workshop (University of Tennessee, 1976) has generated guidelines for the development of rehabilitation engineering education and certification. The major recommendations of this workshop can be summarised as follows.

First and foremost, it is recommended that the rehabilitation engineer be a competent engineer in a traditional engineering specialty, supplemented by advanced training in the subspecialty of rehabilitation engineering. The advanced training should generally result in a second degree (Master's) which comprises both didactic and clinical experience. The clinical experience (or internship) should involve approximately one-half of the advanced training time in which exposure is gained into activities of other rehabilitation disciplines, plus direct experience with problems of patients involving both children and adults.

In parallel with the development of a formal education programme is the need to develop short-term continuing education courses. These courses would be on a variety of topics depending on the current needs of both engineers and other professionals involved in rehabilitation engineering activities.

Regarding certification, it is recommended that a certification process be instituted in rehabilitation engineering to assure adequate consumer protection and recognition of the qualified rehabilitation engineer. It was felt that individuals should first be licensed as engineers and then obtain certification as rehabilitation engineers after completion of recognized course work plus the appropriate length of practical experience. The existing Biomedical engineering societies should be approached to convene an appropriately constituted committee to consider the details of certification of rehabilitation engineers. In general, it was felt that certification should establish minimum standards or requirements for rehabilitation engineers and that it should imply recognition rather than licensing. It is further suggested that initial examination be required, plus periodic continuing education experience in order to maintain certification.

Summary

Rehabilitation engineering is a new and rapidly developing specialty of medical engineering; with the unique goal of directing advances in technology towards enhancing the lives of physically handicapped individuals. The rehabilitation engineer is an engineer who has acquired specialised training and experience so that he/she may function as an effective member of the clinic team and assume responsibilities for the delivery of engineering technology to patients.

The sphere of activity of the rehabilitation engineer must transverse many of the disciplines and boundaries involved in the traditional rehabilitation process in order to be effective in community based problems such as; transportation, home and work environment modifications, and activities of daily living including recreation and creativity.

The field is only in its infancy stage and many problems remain unsolved. Paramount to the successful evolution of the field is the need for a recognised educational process including certification that will recognise those who have acquired the necessary training and experience. Finally, a delivery system must be developed that will contain the necessary employment opportunities and resources through which the rehabilitation engineer can fulfil his commitment as a technical member of the clinic team.

In recent years, advances have been made in many countries, the most significant being in the United States where strong federal support has been legislated. In most other countries, advancement has been commensurate with the degree to which the public and their elected government representatives have recognised the potential of the field and have appropriated the

required funding. It therefore follows that until rehabilitation engineering is generally accepted as a responsibility of society, identification of adequate financial support will remain as the primary impediment to its growth and development. To this end it is imperative that early clinical successes be achieved within the established programmes in order to demonstrate the value and potential worth to the handicapped population of this new and developing specialty.

REFERENCES

LE BLANC, M. A. (1973). Patient population and other estimates of prosthetics and orthotics in the U.S.A. *Orth. and Pros.*, **27**, 3, 38–44.

NATIONAL RESEARCH COUNCIL (1976). Science and technology in the service of the physically handicapped. Committee on National Needs for the Rehabilitation of the Physically Handicapped; Division of Medical Sciences, National Research Council.

UNIVERSITY OF TENNESSEE (1976). Draft proceedings of workshop on rehabilitation engineering. Held at Knoxville, Tennessee, November 3–5.

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International Society for Prosthetics and Orthotics 1977 World Congress

May 26 - June 2 New York, NY, USA

Congress Sponsorship:

International Society for Prosthetics and Orthotics
P.O. Box 42, DK 2900 Hellerup, Denmark
American Orthotic and Prosthetic Association
1444 N Street, N.W., Washington, D.C. 20005 USA

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President: Anthony Staros, New York, New York
Vice-President: Robert Thompson, Chicago, Illinois
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Congress Affiliations: Ted Thranhardt, Orlando, Florida
Publications: A. B. Wilson, Jr., Philadelphia, Pennsylvania

Collaborating Organizations:

American Orthopaedic Association
American Academy of Rehabilitation Medicine
American Academy of Orthotists and Prosthetists
Rehabilitation International

GENERAL INFORMATION

Secretariat: Before and after the Congress:

Driscoll and Associates
7109 Masters Drive
Potomac, Maryland 20854, USA

During the Congress, starting Thursday, May 26, 1977:

Vendome Room, 3rd Floor, Americana Hotel

Place of Congresss Americana Hotel
7th Avenue and 52nd Street
New York, New York 10019, USA

Congress Languages: For all plenary sessions: English, French, German, Spanish and Japanese. Interpreters will also be made available on a selective basis in some Instructional Courses and other Technical Sessions.

Congress Registration Fees: *Advance Registration* (*Received in Potomac, Maryland before May 1, 1977*):

Member of ISPO, AOPA or employee, or AAOP	$115.00
Non-Member	140.00
Accompanying Family Member	40.00
Student,* Resident,* Intern*	60.00*

On-site registration (*at the Congress*):

(Starts Thursday, May 26, 1977)

Member of ISPO, AOPA or employee, or AAOP	135.00
Non-Member	160.00
Accompanying Family Member	40.00
Student*, Resident,* Intern*	75.00*

Daily Registration

Member of ISPO, AOPA or employee, or AAOP	30.00
Non-Member	35.00
Student,* Resident,* Intern*	15.00*

*Must be certified by a letter of sponsorship from the head of an institution for these fees to be honoured at registration.

Instructional Course Programme: The courses being presented before and after the Congress and those being offered during the Congress are shown. Fees for these courses are also shown.

Requests are being made to AMA, AAOS, ABC, APTA, and AOTA to grant continuing education credits for attendance at these courses. *Since the number of individuals that may be accommodated in each course will be limited, early registration is encouraged.*

Scientific Exhibits and Films: Submitted films will be shown from 2.30 to 5.00 p.m. starting Saturday afternoon, May 28, 1977 and ending on Wednesday afternoon, June 1, 1977. No films will be shown on Monday, May 30, 1977, a free afternoon for Congress registrants.

A limited number of scientific exhibits will be offered by the Congress.

Those interested in presenting a film or a scientific exhibit should contact James Demopoulos, M.D., Director, Rehabilitation Medicine and Medical Center, Hospital for Joint Diseases, 1919 Madison Avenue, New York, New York, 10035. USA.

Commercial Exhibits: The exhibit area (including both commercial and scientific exhibits) will be officially opened at 12.45 p.m. on Saturday, May 28, 1977. The exhibits will be open from 9.00 a.m. to 5.00 p.m. every Congress day except Monday, May 30, 1977 and Thursday, June 2, 1977, when they will be open from 9.00 a.m. to 12.00 noon.

Those interested in presenting a commercial exhibit should contact Mr. Robert Miller, Vice-President, Camp International, Inc., 109 West Washington Street, Jackson, Michigan 49201 USA.

Scientific programme

FRIDAY, MAY 27, 1977	8.00 a.m.– 5.00 p.m.	**Instructional Courses**
SATURDAY, MAY 28, 1977	8.00 a.m.–10.00 a.m.	**Instructional Courses**
	10.30 a.m.–11.30 a.m.	**Opening Plenary Session**
	11.30 a.m.–12.30 p.m.	**Plenary Session** The Knud Jansen Lecture: Above-Knee Prosthetics Charles Radcliffe, U.S.A.
	2.30 p.m.– 5.00 p.m.	**Submitted Papers, Symposia, and Workshops**
SUNDAY, MAY 29, 1977	8.00 a.m.–10.00 a.m.	**Instructional Courses**
	10.30 a.m.–12.30 p.m.	**Plenary Session** Amputation Surgery and Postoperative Care Tor Hierton, Sweden J. E. Lescoeur, France Below-Knee Prosthetics Erik Lyquist, Denmark Carlton Fillauer, U.S.A.
	2.30 p.m.– 5.00 p.m.	**Submitted Papers, Symposia, and Workshops**

MONDAY,	8.00 a.m.–10.00 a.m.	**Instructional Courses**
MAY 30, 1977	10.30 a.m.–12.30 p.m.	**Plenary Session**
		Lower-Limb Orthotics Melvin Stills, U.S.A. Jacques van Rolleghem, Belgium
		Self-Help Devices and Technical Aids Karl Montan, Sweden Edward Peizer, U.S.A.
	2.30 p.m.– 5.00 p.m.	**Afternoon—free**
TUESDAY,	8.00 a.m.–10.00 a.m.	**Instructional Courses**
MAY 31, 1977	10.30 a.m.–12.30 p.m.	**Plenary Session**
		Spinal Cord Injuries and Orthotics Paul Meyer, U.S.A. André Bähler, Switzerland
		International Assistance Programmes and Policies Robin Hindley-Smith, Pan-American Health Organisation; Panel Chairman
	2.30 p.m.– 5.00 p.m.	**Submitted Papers, Symposia, and Workshops**
WEDNESDAY,	8.00 a.m.–10.00 a.m.	**Instructional Courses**
JUNE 1, 1977	10.30 a.m.– 1.00 p.m.	**Plenary Session**
		Prosthetics and Orthotics Education Wilfred Krieger, West Germany John Hughes, Scotland
		National Prosthetics-Orthotics Programme Administration George Robertson, Scotland Panel Chairman
	2.30 p.m.– 5.00 p.m.	**Submitted Papers, Symposia, and Workshops**
THURSDAY,	9.00 a.m.–10.30 a.m.	**Plenary Session**
JUNE 2, 1977		Upper-Limb Orthotics Yasoma Challenor, U.S.A.
		Upper-Limb Prosthetics Eichiro Kato, Japan Heinz Pfau, West Germany
	10.30 a.m.–12.00 noon	**Submitted Papers, Symposia, and Workshops**
	12.00 noon–1.00 p.m.	**Closing Plenary Session**

Simultaneous translation services into English, French, German, Spanish and Japanese will be provided at *all plenary sessions*, as well as one series of instructional courses each morning. The submitted papers, symposia and workshops will be conducted in any one of the five official Congress languages with informal translation services provided wherever possible.

Congress instructional courses—Friday, May 27

Instructional courses will be scheduled from 8 a.m.–12 noon and from 1–5 p.m. on Friday, May 27. Registration charge is $15.00 for a four hour course and $25.00 for an eight hour course.

EIGHT HOUR COURSES

8 a.m.-5 p.m.	8 a.m.-5 p.m.	8 a.m.-5 p.m.	8 a.m.-5 p.m.
ADVANCED LOWER-LIMB ORTHOTICS (F-1) Melvin Stills David Condie	ELECTRICALLY POWERED PROSTHETIC & ORTHOTIC SYSTEMS (F-2) Dudley Childress Carl Mason	A SYSTEM OF CLASSIFYING GAIT DEVIATIONS (F-3) Jacquelin Perry	WHEELCHAIRS AND ELECTRONIC TECHNICAL AIDS (F-4) Karl Montan, Edward Peizer Ronald Lipskin, Heiner Sell

FOUR HOUR COURSES

8-12 noon	8-12 noon	1-5 p.m.	1-5 p.m.
PRINCIPLES OF SPINAL ORTHOTICS (F-5A) Norman Berger Jeanne Compton Ralph Lusskin	ORTHOSES FOR THE FOOT & ANKLE (F-6A) J. Demopoulos Melvin Jahss James Pugh John E. Eschen	SCOLIOSIS MANAGEMENT: BOSTON APPROACH (F-5P) Bill Miller Hugh Watts	ABOVE-KNEE SOCKET-CASTING PROCEDURES: NYU, UCB, VAPC (F-6P) Richard Hanak Robert Klein Kenneth LaBlanc

Congress instructional courses—Saturday through Wednesday

Instructional courses will be scheduled each morning from 8–10 a.m., Saturday, May 28th through Wednesday, June 1. Saturday-through-Wednesday courses consist of a variable number of two-hour units, each of which may be registered for separately, except for the six-hour course on Amputation Surgery and Post-operative Care. Registration charge is $10 for the first two-hour course, and $5 for any additional two-hour period to a maximum of $30.00 for the entire ten hours of instruction.

SATURDAY, MAY 28 8-10 a.m.	SUNDAY, MAY 29 8-10 a.m.	MONDAY, MAY 30 8-10 a.m.	TUESDAY, MAY 31 8-10 a.m.	WEDNESDAY, JUNE 1 8-10 a.m.
BELOW-KNEE PROSTHETICS*				
BIOMECHANICS (BK-1) John Hughes John Paul	PRINCIPLES OF FIT AND ALIGNMENT (BK-2) Norman Jacobs John Taylor	DESIGN VARIATIONS: PRESCRIPTION CRITERIA (BK-3) John Taylor George Murdoch	A THERMOPLASTIC STRUCTURAL & ALIGNMENT SYSTEM (BK-4) Herbert N. Shalant Joseph N. Lupo	ULTRALIGHT PROSTHESES (BK-5) A. B. Wilson, Jr. Michael Quigley Charles Pritham
UPPER-LIMB ORTHOTICS				
ANATOMY AND BIOMECHANICAL CONSIDERATIONS (UL-1) Joan Edelstein H. R. Lehneis	COMPONENTS AND FITTING PRINCIPLES: IRM-NYU, RANCHO (UL-2) H. R. Lehneis Herbert Marx	COMPONENTS AND FITTING PRINCIPLES: TIRR (UL-3) Thorkild Engen	EVALUATION PRINCIPLES: MANAGEMENT OF HAND TRAUMA (UL-4) Joan Edelstein Leonard Goldner Bert Titus	SPECIAL DESIGNS AND CASE PRESENTATIONS (UL-5) H. R. Lehneis Samuel Sverdlik Yasoma Challenor

*Simultaneous translation into French, German, Spanish, and Japanese will be provided at all sessions of this course.

UPPER-LIMB ORTHOTICS	AMPUTATION SURGERY AND POSTOPERATIVE CARE				UPPER-LIMB ORTHOTICS
PROSTHETIC TREATMENT OF CONGENITAL DEFICIENCIES (CD) Leon Kruger	AMPUTATION LEVELS AND SURGICAL TECHNIQUE: WOUND ENVIRONMENT: EARLY PROSTHETIC TREATMENT AND TOTAL CARE PROGRAMME (AS) Ernest Burgess, Robert Thompson, Robin Redhead, William Wagner, Michael Quigley, George Murdoch				FRACTURE BRACING PROCEDURES (FB) Vert Mooney
ANKLE, KNEE, AND HIP DISARTICULATIONS		**GENERAL TOPICS**			
SURGICAL CONSIDERATIONS: SYME'S PROSTHETIC PROCEDURES (AKH-1) René Baumgartner, Fred Hampton	KNEE AND HIP DISARTICULATION PROSTHETIC PROCEDURES (AKH-2) Fred Hampton, Erik Lyquist	FLUID-CONTROLLED KNEE UNITS (FC) Malcolm Dixon, Bert Goralnick	AIDS FOR HANDICAPPED DRIVERS (HD) L. F. Bender, David Harden, Joe Wanchik	MAINTENANCE OF PROSTHETIC-ORTHOTIC DEVICES (DM) Bo Klassen	
SPINA BIFIDA			**CEREBRAL PALSY**		
STANDING PARAPODIUM (SB-1) C. A. McLaurin	ORTHOTIC APPLICATIONS (SB-2) John Glancy, Melvin Stills	CARE OF THE SEVERELY INVOLVED (SB-3) G. K. Rose, J. Stallard	TECHNICAL AIDS (CP-1) Raphael Levine, Douglas Hobson, Maurice LeBlanc, Wallace Motloch	BIOFEEDBACK DEVICES (CP-2) C. Wooldridge	
HEMIPLEGIA		**LOWER-LIMB ORTHOTICS**			
GAIT PATTERNS & TREATMENT METHODS (H-1) Robert Waters	ELECTRONIC AIDS TO CONTROL PARALYSED LIMBS (H-2) Franjo Gracanin	KNEE ORTHOSES FOR RHEUMATOID ARTHRITIS (RA) James Foort	CLUBFOOT ORTHOSES (CFO) Erik Lyquist	THE SHOE AS COMPONENT OF ORTHOSES (OS) Gustav Rubin	

Pre- and post-congress courses

In addition to the instructional courses being offered during the 1977 World Congress on Prosthetics and Orthotics, several institutions in and around New York City will offer comprehensive courses on selected subjects for Congress registrants before and after the Congress. The courses, to be conducted in English, will be held at the addresses indicated.

VETERANS ADMINISTRATION PROSTHETICS CENTER

PC 1 ORTHOPAEDIC SHOES—3 days, May 23–25, 1977, Tuition $100.00.

Demonstrations and laboratory experience in measuring and casting for orthopaedic shoes. Last and pattern design will be presented and samples of each will be fabricated. Cork and toe fillers will also be constructed. Upper fabrication and lasting, soling, and finishing will be undertaken by each participant under supervision of VAPC orthotists.

This course is designed for orthotists and orthopaedic footwear specialists. German, Italian, and Spanish language assistance will be available during laboratories.

PC 2 COSMETIC RESTORATIONS—3 days, May 23–25, 1977, Tuition $100.00.

Demonstrations and laboratory experience in fabrication and fitting of plastic eyes, cosmetic limb restorations including gloves, and ear-nose-face restorations. Mould making, sculpturing, fabrication, and tinting will be emphasized, with student participation undertaken under supervision of VAPC restoration prosthetists.

This course is designed for doctors, technicians, and prosthetists. Spanish language assistance will be available during laboratories.

These courses will be offered at the Veterans Administration Prosthetics Center, 252 Seventh Avenue, New York, NY 10001.

PROSTHETICS & ORTHOTICS—NEW YORK UNIVERSITY

PC 3 LOWER-LIMB PROSTHETICS—5 days, May 23–27, Tuition $150.00.

This is a basic introductory course to lower-limb prosthetics which includes normal locomotion, biomechanics, prosthetic components, fitting, alignment, suspension of above- and below-knee prostheses, and prescription principles. Major emphasis is on the quadrilateral socket and on the patellar-tendon-bearing prosthesis and its variants. Fluid-controlled mechanisms, prostheses for children and for hip-disarticulation, bilateral, and Syme's amputations are also covered.

PC 4 LOWER-LIMB ORTHOTICS—5 days, June 6–10, 1977, Tuition $150.00.

This is a basic introductory course to below- and above-knee orthotics, which includes normal locomotion, pathomechanics, shoe modifications, orthotic components and materials, alignment and fitting, prescription, and evaluation of orthoses as applied to the management of lower motor neuron disorders, hemiplegia, spinal-cord injuries, cerebral palsy, arthritis, fractures, haemophilia, and muscular dystrophy.

These courses will be offered at Prosthetics & Orthotics NYU Post-Graduate Medical School, 317 E. 34th Street, New York, NY 10016.

INSTITUTE OF REHABILITATION MEDICINE—NEW YORK UNIVERSITY

PC 5 PLASTIC LOWER-LIMB ORTHOTICS MANAGEMENT—2 days, May 25–26, 1977, Tuition $75.00.

This course will emphasize the use of newly developed plastic ankle-foot, knee, knee-ankle, and hip-knee-ankle orthoses. In addition to fitting and fabrication principles, the biomechanics and pathomechanics of gait will be included as well as principles of prescription, checkout, and training. A number of case presentations are also planned.

This course will be offered at IRM, NYU Medical Center, 400 E. 34th Street, New York, NY 10016.

TEMPLE UNIVERSITY

PC 6 CLINICAL GAIT ANALYSIS AND AMBULATION TRAINING—3 days, June 6–8, 1977, Tuition $100.00.

This course will describe the use of new tools designed to assist in gait analysis under clinical conditions. Instruction in ambulation training, using sensory augmentation will also be in-

cluded. Faculty will be drawn from Rancho Los Amigos Hospital, University of California, Berkeley, as well as Temple University.

This course will be offered at the Krusen Research Center, 12th and Tabor Road, Philadelphia, PA 19141.

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Although attendance at the Veterans Administration Prosthetics Centre courses is limited to the professions indicated, the Temple and New York University courses are open to *all* professional disciplines attending the Congress (physicians, surgeons, therapists, prosthetists, orthotists, engineers, etc.).

SOCIAL PROGRAMME

(Included in Registration Fee)

Friday, May 27, 1977

7.00 p.m.—Welcoming Reception. *Georgian Ballroom A-B.*

Sunday, May 29, 1977

7.00 p.m.—Presidents' Reception. *Georgian Ballroom A-B.*

Monday, May 30, 1977

4.30 p.m.–7.30 p.m.—Boat Ride—Circle Line Tour around Manhattan.

TICKET FUNCTIONS

Tuesday, May 31, 1977

12.30 p.m.–2.30 p.m.—Rehabilitation International Luncheon with a speaker from United Nations (Room to be designated). $12.00 per person.

Wednesday, June 1, 1977

7.00 p.m.—Congress Reception and Dinner. *Imperial Ballroom A.* $35.00 per person.

Additional Functions and Social Events will be Scheduled

1. Luncheons of Collaborating Societies.
2. New York Neighbourhoods and Landmarks Tour with Lunch.
3. United Nations Seminar with Lunch.
4. Lincoln Center Tour with Lunch.

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Calendar of events

13 April, 1977
International Society for Prosthetics and Orthotics.
United Kingdom 5th Scientific Meeting. To be held in conjunction with British Orthopaedic Association Spring Meeting. Liverpool University Hall of Residence, Carnatic Hall.
Information: John Williams, Secretary, U.K. National Society ISPO, Trustees Office, Queen Mary's Hospital, Roehampton, London SW15 5PL.

14–16 April, 1977
Spring Meeting, British Orthopaedic Association, Liverpool.
Information: Miss M. Bennett, Honorary Secretary, B.O.A., Royal College of Surgeons, Lincolns Inn Fields, London WC2A 3PN.

20–24 April, 1977
Association of Bone and Joint Surgeons, Annual Meeting, Point Clear, Alabama.
Information: David B. Stevens, M.D., Secretary, 2116 North 122nd Street, Seattle, Washington 98133.

May, 1977
11th Congress of the Latin Group on Sports Medicine, Nice, France.
Information: (President of the organising committee) Dr. Commandri, 23 Bd. Carabacel, 06000, Nice, France.

6–8 May, 1977
European Symposium on the Evaluation and Prospects of European Physiotherapy, Utrecht, Netherlands.
Information: Royal Netherlands Industries Fair, Special Events Department, Jaarbeursplein, Utrecht, The Netherlands.

9–13 May, 1977
NC 102 Course on Lower Limb Orthotics for Physicians and Surgeons.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

12–16 June, 1977
Canadian Orthopaedic Association, Annual Meeting, Kingston, Ontario, Canada.
Information: R. L. Cruess, M.D., Secretary, 687 Pine Avenue, West, Montreal 112, Quebec, Canada.

26 June–1 July, 1977
4th International Congress of the International League of Rheumatism, San Francisco, California, U.S.A.
Information: ILAR, P.O. Box 149, CH-4010, Basle, Switzerland.

27–30 June, 1977
American Orthopaedic Association, Annual Meeting, Boca Raton, Florida.
Information: Richard E. King, M.D., Secretary, 430 North Michigan Avenue, Chicago, Illinois 60611.

July/August
World Conference of the International Council for Education of Visually Handicapped, Paris, France.
Information: World Council for the Welfare of the Blind, 57, Avenue Bosquet, 75007 Paris, France.

10–16 July, 1977
6th International Seminar on "Rehabilitation—Professional Training and Practice", University of York, England.
Information: Cmdr. Ian Henderson, British Council for Rehabilitation, Tavistock House, Tavistock Square, London WC1H 9LB, England.

11–14 July, 1977
4th International Congress of Biomechanics, Copenhagen, Denmark.
Information: Kurt Jorgensen, International Congress of Biomechanics, August Krogh Institute, Universitetsparken 13, DK 2100, Copenhagen, Denmark.

21–24 September, 1977
Autumn Meeting, British Orthopaedic Association, Eastbourne.
Information: Miss M. Bennett, Honorary Secretary, B.O.A., Royal College of Surgeons, Lincolns Inn Fields, London WC2A 3PN.

1–5 October, 1977
Western Orthopaedic Association, Annual Meeting, Colorado Springs, Colorado.
Information: H. Jacqueline Martin, Executive Secretary, 1970 Broadway, Suite 1235, Oakland, California 94612.

5–8 October, 1977
American Academy for Cerebral Palsy, Annual Meeting, Atlanta, Georgia.
Information: James E. Bryan, Executive Secretary, 1255 New Hampshire Avenue, Northwest, Washington, DC 20036.

12–14 October, 1977
Clinical Orthopaedic Society, Annual Meeting, Cincinnati, Ohio.
Information: Mack L. Clayton, M.D., Secretary-Treasurer, 2045 Franklin Street, Denver, Colorado 80205.

17–21 October, 1977
American College of Surgeons, Annual Clinical Congress, Dallas, Texas.
Information: C. Rollins Hanlon, M.D., Director, 55 East Erie Street, Chicago, Illinois 60611.

24–28 October, 1977
4th Conference and Exhibition on Bio-Engineering, Budapest, Hungary.
Information: Scientific Society of Measurement and Automation, 1372 Budapest V, Kossuth Lajoster 6–8, Hungary.

January, 1978
Second International Conference on Legislation Concerning the Disabled, Manila, Philippines.
Information: Rehabilitation International, 122 East 23rd Street, New York, N.Y. 10010, U.S.A.

13–17 March, 1978
7th Congress of the World Federation of Occupational Therapists, Tel Aviv, Israel.
Information: (President of the organizing committee) Mrs. M. Clyman, 65 Aloof David Street, Ramat-Gan, Israel.

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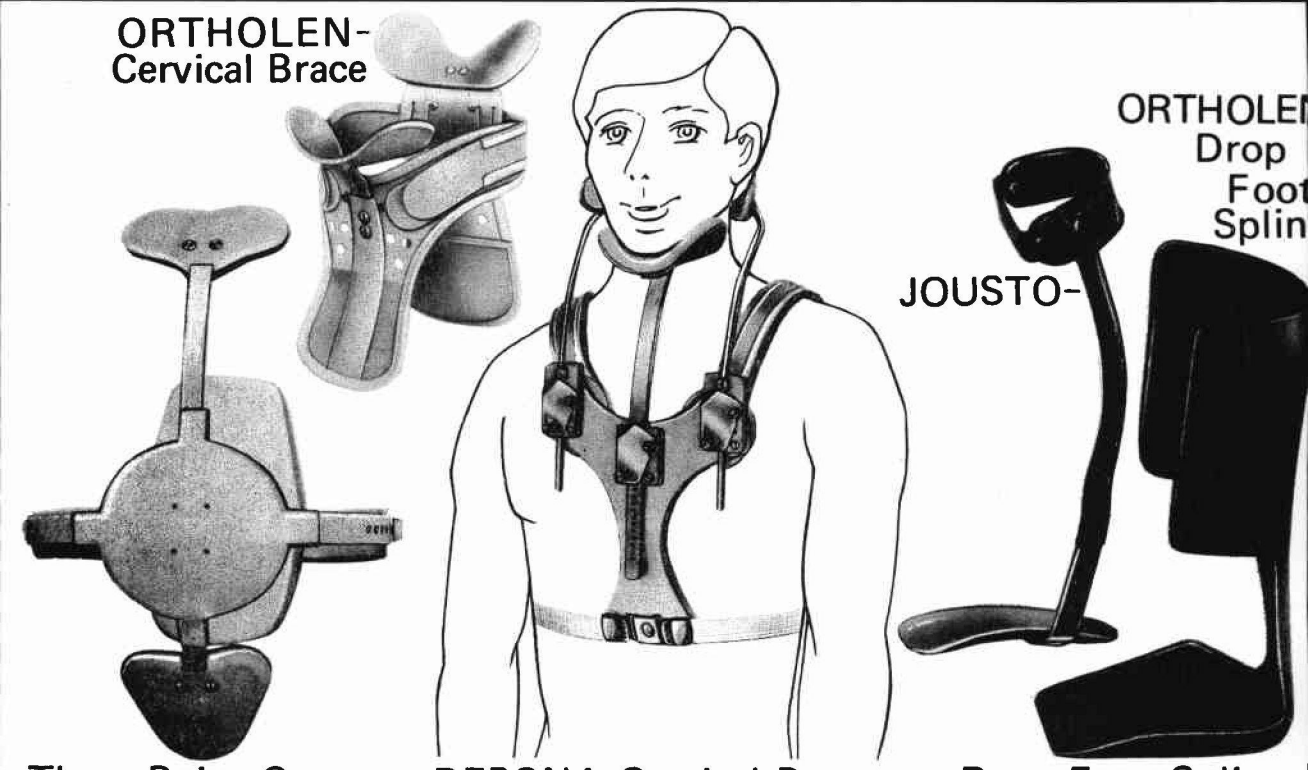

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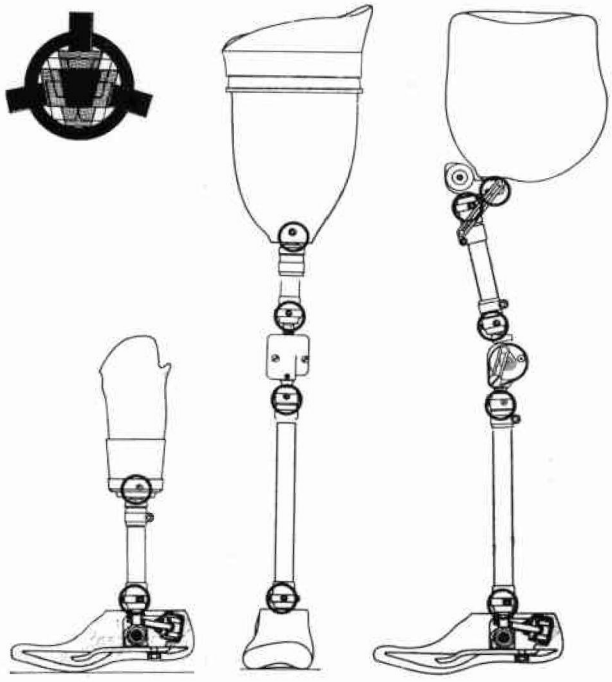

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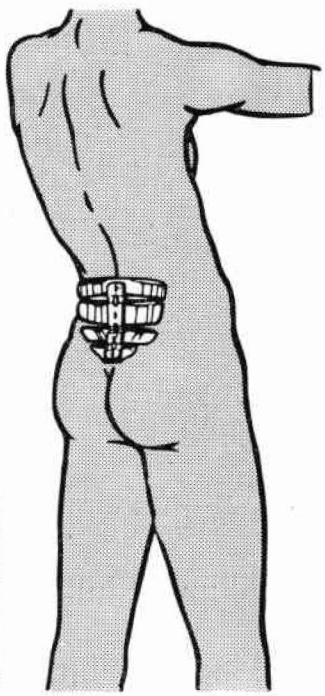

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References to articles in books should include author, year of publication, article title, book title, edition, editor (if different from author), first and last pages, publisher and place of publication. For example, Hughes, J. (1975). Recent developments in prosthetics and orthotics. Recent Advances in Orthopaedics (2) Ed. McKibbin, B., 196–216, Churchill Livingstone, Edinburgh.

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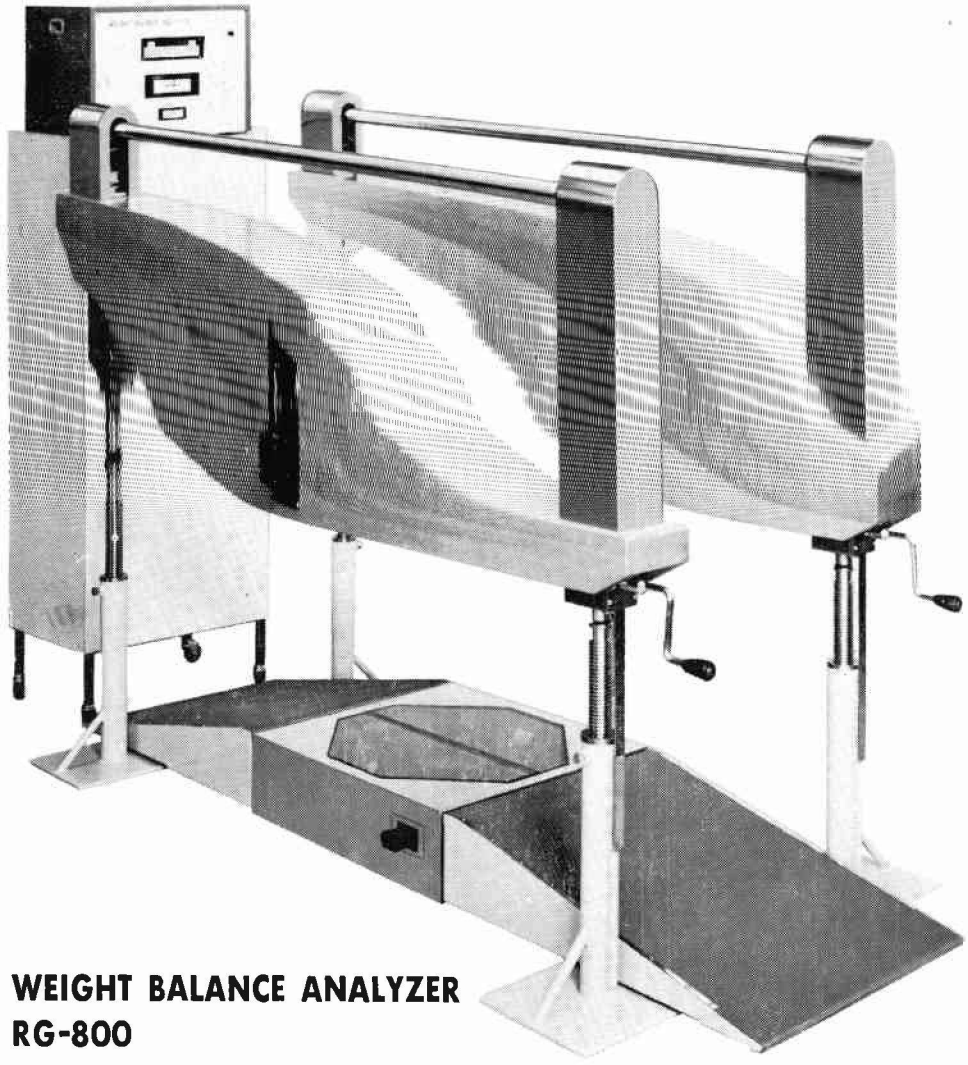

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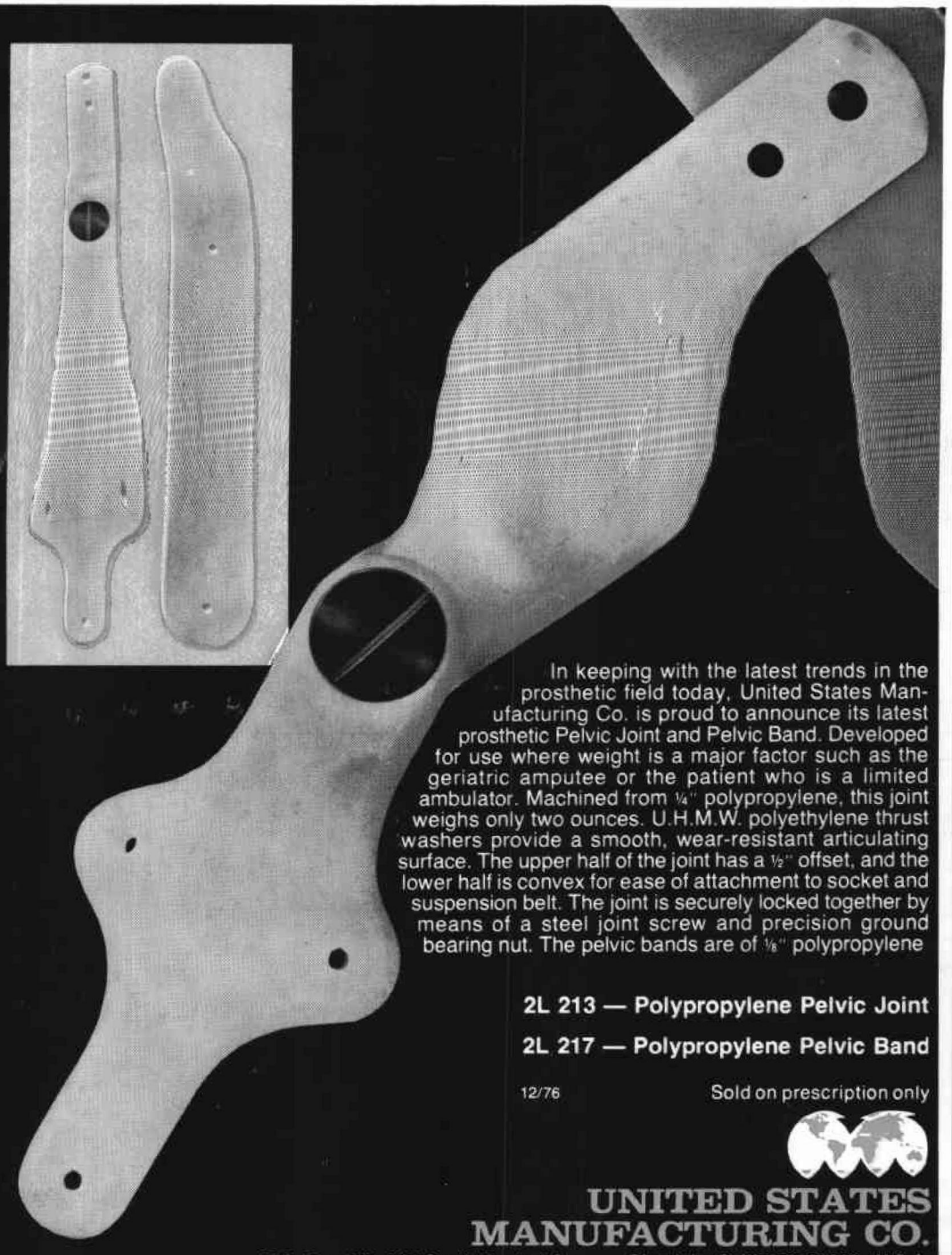

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