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A review of the consensus conference on appropriate prosthetic technology in developing countries

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The conference

Sixty-three individuals, representing 37 agencies and units, together with 16 resource persons, accepted invitations to attend and these were joined by 15 professionals working in prosthetic units in Cambodia — making a total of 94 participants from 27 countries. Those agencies and units providing prosthetic service had been asked to present a paper describing their service provision in terms of:

- the numbers of amputees and levels of amputation fitted;
- staffing levels, including grades and training;
- fitting and prosthetic technology used;
- unit costs, durability and repairability;
- evaluation of service;
- and arrangements for transfer to local providers of service.

Others were invited to speak on component availability, assessment and evaluation of programmes and education and training.

Most participants arrived in Phnom Penh on Sunday 4th June 1995 in time to attend a welcome reception in the Cambodia Sharaton hotel attended by the US Ambassador. The conference was held in the conference centre of the National Paediatric Hospital, and was formally opened on Monday 5th June by His Excellency Dr. Hong Theme, Under Secretary of State for Social Affairs, Labour and Veterans Affairs of the Kingdom of Cambodia. Other speakers in the opening session were Mr Robert Porter, US Embassy Deputy Chief of Mission: Mr Loyd Feinberg, Manager, War Victim's Fund of USAID; Mr Joel Vanderburg, Cambodian Office of the World Health Organisation (WHO); and Dr Seishi Sawamura, President of ISPO.

The first day continued with presentations by USAID, WHO and six of the main agencies together with a literature review of rehabilitation of the amputee. All these were discussed in plenary session.

Tuesday started and ended with syndicates considering such topics as — the factors to be considered in defining appropriate technology, or in setting up a prosthetic project, and what different features might apply in an emergency situation. In the first session the syndicates were also asked to identify topics on which they hoped the meeting would reach a consensus. In the main part of the day a further 15 presentations by agencies were heard and discussed.

Wednesday started with reports from the rapporteurs of Tuesday's syndicates followed by discussion in plenary sessions. Mid-morning the meeting divided into four groups to be taken to various facilities in the Phnom Penh area. These included the Camodia Trust facility and The National School for Prosthetics and Orthotics (NSPO), the International Committee of the Red Cross (ICRC) factory and the Foundation for the Support of the United Nations (FSUN) project, the Kien Khleang Rehabilitation Centre and the Handicap International (HI) foot factory. Everybody was able to visit each of these centres.

Thursday morning's session concentrated on components, with presentations from four manufacturers/agencies in the developing world together with an overview of components and systems manufactured in the developed world specifically for the developing world. Other

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papers dealt with the possibilities of technology transfer, quality control and the use of nails as roller bearings in joints. The afternoon was devoted to syndicate work dealing with:

- the sustainability of projects;
- methods of displaying the cost of prosthetic supply;
- the definition of acceptable socket fit and any permissible compromises;
- the suitability of CAD CAM systems in the developing world;
- and the specification of acceptable durability.

Friday morning was largely devoted to evaluation, with commissioned papers on needs assessment — evaluation of projects — and medical/rehabilitation evaluation. In addition there were a number of submitted papers giving results of assessment and evaluations of various projects in Cambodia. At the end of the morning, and in the early afternoon, plenary sessions listened to, and discussed, the reports of Thursday's syndicates. Further syndicates then discussed:

- the factors to be considered in performing needs assessment;
- criteria when evaluating on-going projects;
- performance indicators/and outcome measures;
- the role of Community Based Rehabilitation.

After this a short session on education contained commissioned papers on ISPO education policy, the NSPO in Cambodia, and medical education in developing countries. It was felt by the Organising Committee that this vital subject had already been aired thoroughly in previous meetings and publications. Saturday started with the reports and discussion of two small syndicates which had examined the results of earlier syndicates in order to identify points on which a consensus could be reached.

Small groups were then chosen to consider other syndicates results in order to identify points of consensus. Meanwhile the main meeting continued with a wide ranging discussion of matters which had arisen during the conference. Finally a plenary session considered the work of the small groups.

In all some 44 papers were presented at the conference, and the remainder of this paper attempts to review these with the exception of the two literature reviews of Staats and Cummings which are re-printed in this issue of the journal.

Scale of the problem

Various estimates were given of the number of amputees in developing countries, 30,000 in Cambodia (Hong Theme), 10,000 in El Salvador (Snelson) 60.000 in Afghanistan (Berhane), and estimates for Vietnam of 200,000 (Kieffer). These figures, however, have been derived, they are estimates rather than based on factual assessments.

The American Red Cross has carried out three "needs assessment" surveys in Camodia. These covered 17% of the population but can be extrapolated to the whole country, although the author warns that as the provinces surveyed were not in high conflict areas, the true national amputation figure is likely to be higher. The report suggests that there are some 21,200 amputees and 100,000 other handicapped people in a total population of 8.8 million (Blatti).

Cause and level of amputation

War injury has been the most common cause of amputation in those countries which have been the scene of conflict (Table 1). However the passage of time from the cessation of conflict means that the number of war injured presenting for treatment now may not be as high, except in those countries where there are large numbers of land-mines and other ordnance whose explosion continues to cause amputations. There is evidence of increasing road traffic accidents (RTA); in Hanoi compound fractures of the lower limb increased 400% from 1990 – 1991 due to the increased use of motor cycles. The number of amputees in Vietnam is increasing at the rate of 3-4% per annum since the end of the conflict (Boone). All papers showed a preponderance of amputations at the trans-tibial level, though the providers of service are quoting the levels which present to them. This may not be the same as the proportion of various levels in the amputee population.

Socket fitting and fabrication technique

The choice of fitting and fabrication technique used in a particular service or provision centre depends not only on the availability of materials but also on other factors, including the training level of the staff employed and the objectives of the organisation.

Table 1. Numbers and levels of amputation

	War	Other trauma	Disease	Trans-tibial level	Author
India		80%	20%	78%	Sethi
Cambodia	94.6%	4.5%	1.15%		Alton
				66%	Nother
				77%	Ludowyk
				75-80%	Hansen
Vietnam	Was 75%				Pomatto
	Now 48%	RTA increased 400% 1990/91			Boone
Armenia	52%				Feinberg
Uganda		40% RTA			Hunter
Zimbabwe	65%	25%	10%	50%	Madonko
El Salvador				77%	Snelson
Afghanistan				60%	Berhane
Yugoslavia (former)				50%	Nummelin
Mexico				77%	Snelson

Trans-tibial amputation

In the vast majority of service units a plaster wrap cast is taken and a modified plaster model used to fabricate a plastic patellar-tendon-bearing (PTB) socket. This requires the skill of a trained prosthetist, usually an expatriate, or a trained orthopaedic technologist (Berhane; Hansen; Hunter; Ludowyk; Madonko; Nother and others). CAD CAM in which the negative cast is digitised and a modified model produced by a computer controlled carver is in use by one provider in Vietnam (Boone), who claims that the use of a software programme to control the modification of the cast increases the productivity of the trained prosthetist, or indeed allows the use of appropriately trained technicians.

Polypropylene is the most commonly used material for socket fabrication, though laminated polyester is used in parts of Vietnam (Lamine; Pomatto) and in Zimbabwe (Madonko). Leather is preferred in some areas of China where there is high humidity (Heim).

Three methods of producing PTB sockets without casting were described, all of which were designed to satisfy particular situations.

a) A socket may be made (as part of the shank) of aluminium sheet beaten by a trained metal worker, who repeatedly tries it on the patient (Sethi; Nagels). This method is claimed to be appropriate particularly in those countries which have a large patient load and a considerable number of skilled metal workers,
b) Selection of the best fit by trained expatriate prosthetists, from a range of preformed polypropylene sockets enables the first fitting of large numbers of amputees attending camps (Snelson). The whole process takes about 45 minutes and 200-250 patients are fitted during a three day camp. The intention is that appliances will be replaced by conventionally made prostheses later and that this latter programme will be sustainable.
c) Direct forming of a thermoplastic material on the stump (Nummelin) was chosen by the Finnish Red Cross as a suitable method to fit large numbers of war victims in the former republic of Yugoslavia.

Many authors asserted that end contact in sockets is contra-indicated because the terminal soft tissue cover of many stumps was inadequate in amount or quality (Berhane; Boone; Ludowyk; Nother; Sethi). In such cases plastic sockets are deliberately lengthened to avoid such contact, and many are fitted as hard sockets without a liner (Boone; Ludowyk, Pomatto) particularly when some time has elapsed between amputation and fitting. Others preferred the use of a soft liner (Berhane; Hunter; Nother). The commonest type of suspension was by means of a thigh cuff, though most authors used polypropylene sockets in a supracondylar or patellar-tendon supracondylar (PTS) configuration for short stumps (Berhane; Nagels; Sethi).

Trans-femoral amputation

The quadrilateral socket shape is used in

almost every case, most commonly being obtained by hand casting, but sometimes by the use of brims (Hunter). The most popular socket material seems to be polypropylene often fabricated by "wrap" draping with a welded seam. The "bubble" drape method is considered to produce a stronger socket (Nother).

CAD CAM, allowing centralised socket production from measurements transmitted by fax from distant units is undergoing trial in China (Heim). Preformed quadrilateral sockets are used as part of a complete prosthetic system (Nummelin) and the metal quadrilateral socket previously used in Jaipur is being superceded by the ISNY (Icelandic-Swedish-New York) flexible type with a rigid frame (Sethi). Again most authors avoid terminal contact because of the inadequate soft tissue cover of many stumps. Suspension is usually by Silesian belt or pelvic band; self suspension, or "suction" sockets, are not common particularly when the polypropylene socket has been seam welded.

Other levels of amputation

A small number of lower limb amputees at other levels are fitted, often using imported modular components (Nother). Upper limb amputees are seldom fitted as most can manage their lives better without a prosthesis, though the value of the Krukenburg procedure was mentioned (Sethi).

Staffing

Hughes indicated that ISPO recognises four categories of worker:

- Category I is the Prosthetist/Orthotist who has had three years formal training leading to a University degree (or equivalent);
- Category II, the Orthopaedic Technologist (or equivalent term) who has had three years formal training to a lower level than that of Category I.
- Category III, Prosthetic/Orthotic Technician who has been trained on the job and is involved in construction;
- Category IV Technician who has no formal training.

The majority of those agencies which have prosthetic programmes in developing countries provide their service using expatriate Category I prosthetists together with local staff of varying levels. This works out in several ways. Cambodia Trust employs 6 Category I expatriate prosthetists who do all the patient care backed up by 11 local category IV technicians who have had "on the job" training (Nother). Sandy Gall's Afghanistan Appeal (SGAA) takes a different course in employing 1 Category I expatriate prosthetist plus 2 local Category II orthopaedic technologists, 20 Category III and 10 Category IV technicians (Berhane).

On a much larger scale ICRC, worldwide, employs 26 expatriates (20 prosthetists, 5 physiotherapists, and 1 doctor) together with 336 local prosthetists, physiotherapists, doctors, nurses and trainees plus over 500 local technical personnel (Garachon and Gehrels).

As an example of sustainability, the service in Harare which once used expatriate prosthetists, now runs with 11 Category II orthopaedic technologists, 7 of whom were trained at the school in Tanzania (Madonko). On the other hand the CAD CAM project of the Prosthetics Outreach Foundation (POF) operates with 1 orthopaedic technologist and 3 trainees.

Prosthetic components and construction

Prosthetic feet

The prosthetic foot/ankle unit is particularly important in developing countries. It is the durability of this component which really determines the durability of the whole prosthesis.

Almost all the feet used are variations of the SACH (solid ankle cushioned heel) type, and may be locally made conventional design types (Hunter; Madonko), or imported (Boone; Nummelin; Snelson). In many cases the foot has to withstand climatic extremes, often being immersed in water, and provide a large range of dorsiflexion to allow squatting. This led to the design of the Jaipur type, which has no keel and incorporates variable density blocks and an external capsule (Sethi) and to the Handicap International foot (Simon) and the Veterans International Cambodian (VIC) foot which has short plastic keel (Nagels).

Other components

Other components and systems include:

- the ICRC polypropylene system (Gehrels) which is used by many of the service providers (Berhanu; Hansen; Heim; Ludowyk; Nother). This system is produced by ICRC workshops in a number of countries;
- locally made components (Berhane);

- traditional PTB shanks using wood or Pedilen (Hunter; Madonko);
- a formed metal shin as an extension of the socket (Sethi; Nagels);
- traditional metal, leather and wood methods (Lamine; Pomatto);
- locally cast aluminium alignment device (Nother);
- glass reinforced plastic pylon tubes (Snelson);
- prefabricated prosthesis kits (Nummelin);
- imported endoskeletal components designed for the project (Boone).

Three papers dealt with component manufacture in developing countries.

1. The ICRC system (Gehrels), using recycled polypropylene comprises:
   a) the polypropylene Colombia alignment system (PPCAS) which is used to connect the socket to the foot in the trans-tibial prosthesis, and is used in the shank and above the knee in the trans-femoral prosthesis;
   b) the Debra Zeit knee unit, for the trans-femoral prosthesis, which can be used as a "free" or as a locked knee;
   c) the poypropylene single axis joint (PP SADA joint) which can be used for knee and hip disarticulation;
   d) a crustacean polypropylene cosmetic cover.
2. ALIMCO in India produces a range of components for sale originally in the prosthetic centres in its own country, but it is now exporting to a number of countries in Asia, Africa and the Middle East (Kherwa). Many of these are prefabricated "set-ups" intended for incorporation in a laminated cover, though the use of laminated plastics is increasing.
3. The Shaanxi Centre in China, is not only a major supplier in China, but is now exporting components and endoskeletal systems to some countries, particularly in SE Asia (Shang).

To compare some component prices:

- the ICRC knee unit made in Ethiopia is priced at US$ 12.3;
- ALIMCO market a knee/shin assembly with constant friction swing phase control for approximately US$ 20;
- the Shaanxi centre quotes a price of US$66 for a 4 bar modular knee.

A review of prosthetic components manufactured in the industrialised world for use in the developing world (Quigley) stated that some major manufacturers have now started to develop components specifically for this market. As might be expected most of these tend to be "low tech" solutions, although one manufacturer's philosophy is to use high manufacturing and design technology to produce cheaply in quantity. Although all these components and systems are cheaper than those designed for their home market, it remains to be seen whether they can be produced at a low enough price to be suitable for the developing countries.

The whole question of technology transfer is complex. Sometimes the industrialised world sees the attraction of supplying simple prostheses using "traditional" methods and materials. Sometimes in developing countries a few centres offer "blurred Xerox copies" of the prostheses of the industrialised world to a few urban dwellers. The need is to ensure that the benefits of technology transfer reach the mute majority, and that the products should be appropriate to the culture and environment of the people, who can develop self reliance rather than suffer from over dependency (Sethi).

Durability

However and wherever components are manufactured, quality control and compliance with manufacturing standards is essential (Kherwa; Nakagawa) to ensure consistency. There is also a need for physical testing using standardised test methods and the relation between the new International Standards Organisation standard (ISO 10328: Prosthetics-structural testing of lower limb prostheses) and local standards (Nakagawa). Physical testing is necessary to avoid the unsatisfactory method of waiting to see how long a component or prosthesis lasts in amputee service. This latter can be particularly inappropriate in developing countries where the patient may live too far away from the service provider to return when a component breaks. Almost all speakers agreed that the foot was the component with the shortest life, with estimates varying from 3 – 9 months for a SACH foot (Berhane; Pomatto), 12 – 18 months for a Cambodian (HI) rubber foot (Ludowyk; Nother), to 2 – 5 years for a Jaipur foot (Berhane; Sethi)

Cost

This has to be divided into two parts, the cost of the prosthesis and the cost of transport to,

and accommodation at the fitting centre. Some presenters quoted the cost of prostheses for the trans-tibial and trans-femoral levels and these are displayed with comments in Table 2, but the absence of any standardisation in the method of calculating the costs makes it very difficult to obtain proper comparisons. This table also displays information concerning the number of prostheses fabricated per year.

The cost of transport and accommodation may be as great or greater than the prosthetic cost. The cost of travel and accommodation at Wuhan for an amputee living in Xiangfan equals 85% of the cost of a trans-femoral prosthesis (Heim). In Vietnam these costs may be more than twice that of the prosthesis (Boone). This element, usually payable by the patient, affects not only the first fitting process but also subsequent refitting or repair.

Both authors claim that CAD CAM fitting methods reduce these costs by allowing fabrication at a distance or by providing the prosthesis more quickly. WHO has established a service in Eritrea using a main workshop with a number of satellites which are visited regularly by staff from the main shop. They cast patients and fit and deliver prostheses which are made centrally. This project is also linked with Community Based Rehabilitation (CBR) to provide a flow of information between the centre and its clients in both directions (Eklund).

Assessment and evaluation

Needs assessment

Needs assessment has to consider the medical, surgical and prosthetic/orthotic needs of an

Table 2. Prosthetic costs and production

Unit (Author) (Country)	Cost US$ trans-tibial	Cost US$ trans-femoral	Approx number of prostheses p.a.
AFSC (Hansen) (Cambodia)	24	32	650
ARC (Ludowyk) (Cambodia)	25	40	450
CT (Nother) (Cambodia)	37 (1)	34	1200
In the above group the components and feet are supplied free of charge by ICRC and HI respectively. The costs are for materials and do not include labour and overheads. Nother suggests that if they were included a realistic cost would be 230 US$. (1) The CT trans-tibial prosthesis costs more because it uses a locally made alignment device and imported Plastazote for the cosmesis.			
SGAA (Berhane) (Afghanistan)	35	50	2400
BRC (Hunter) (Uganda)	40	60	300
Jaipur (Sethi) (India)	30	100	3000 (1982)
WRF (van Rolleghem) (Armenia)	55	—	200
Harare (Madonko)	82	185	340
In this group SGAA uses mostly local materials: BRC uses some local, some imported but is changing to ICRC polypropylene technology: Jaipur claims costs are low because of the use of locally available materials and because the wage bill for the locally trained limbmakers is much less than would be required by qualified prosthetists (Sethi).			
Wings of Calvary (Snelson) (El Salvador)	400	600	750
FRC (Nummelin) (Yugoslavia)	520	1100	800+
Wings of Calvary's fitting costs include the prosthesis and travel, lodging and food for the expatriate prosthetists, but no salary as they are volunteers (Snelson). Some of the prefabricated components of the FRC system can be reused in the permanent version			
POF (Boone) (Vietnam)	—	—	1000
VVAF (Nagels) (Cambodia)	—	—	1200
WV (Pomatto) (Vietnam)	—	—	11,000 (1993)
HI (Simon) (Cambodia)	—	—	1500
ICRC (Garachon) (16 countries)	—	—	15,000 (1994)
HI also is involved in a foot factory in Cambodia. ICRC manufactures polypropylene components in a number of countries. Their factory in Cambodia manufactured over 20,000 components in 1994.			

area. The number needing services has to be identified by pathology, age and location (Stills). This might be fairly easy to carry out in an industrialised country but it is not easy in a developing country for such reasons as poor communications and security problems.

In one district of Cambodia whose population was estimated to be 36,000, interviewers found 3% to be impaired. This rather low figure was assumed to be due to lack of information from some 25% of the area because of security problems. Of the known cases amputation accounted for 12% of impairments (Coren-Willimzik). This means that the incidence of amputation in the population is 0.36%. Another paper describing a needs assessment carried out in another province of Cambodia suggested that the incidence of amputation could be 0.28% (Blatti). The population of Cambodia is 8.8 million (1993 UNTAC census) so the total numbers of amputees could be between 24,000 and 31,000.

The actual "needs" must be balanced against the available facilities, staffing and training (Stills). This is not always the case, as an example, only one state hospital in Panama City has prosthetic and orthotic facilities and treatment of the amputee there depends on the availability of components, so they can treat only 20% of the amputees. In another provincial hospital where 20 amputations were performed in 1994, none were fitted with prostheses (de Saez).

Programme planning

All speakers agreed (Feinberg; Heim; Stills; *et al.*) that, with the possible exception of the emergency or war situation, the intention is to initiate a sustainable operation, and therefore a partnership with the host government is necessary at the planning stage. Goals must be set, the type of technology and personnel to be employed decided and plans made for the training of local personnel. A budget must be prepared, and if necessary, a funding application must be made (Feinberg). The duration of the whole project and its sustainability has to be decided.

Interim and final evaluation

One or more interim evaluations are required, to monitor the operation and determine whether or not the programme is on course to achieve its goals, or whether changes are needed (Heim; Stills). The final evaluation must establish whether or not the goal was met, and whether there should be a renewal or a different project. The German Agency for Technical Cooperation (GTZ) uses a goal oriented planning instrument from the start, which is designed to operate throughout the programme (Heim).

Funding agencies may not possess "in house" prosthetic expertise and therefore use independent evaluators, and it is desirable that these use a standardised evaluation protocol such as the USAID/ISPO form (Stills).

Sustainability

Any prosthetic programme can only survive the departure of the initiating agency and its funding, if its goals, technology and use of resources, both human and financial, were planned in collaboration with the host government (Feinberg). A problem can arise when more than one agency is operating using different technologies in the same country. It was interesting and encouraging to see that there is now collaboration between the various agencies providing services and training in Cambodia, extending to the use of similar technology e.g. the Handicap International (HI) foot and ICRC polypropylene components.

Outcome

Two papers were presented on "prosthetic outcome" in Cambodia. One carried out by the Coren-Willimzik for American Friends Service Committee (AFSC) interviewed 347 amputees, of whom 97% suffered amputation as a result of war, 92% from land-mine injury. Some 60% had amputations below, and 30% above the knee. At the time of interview about 80% had a prosthesis and of these 62% claimed to use their prosthesis "all the time", 18% regularly, 16% sometimes and 4% never. The paper provides considerable information about patients' occupations and their preferences for different types of prosthesis.

The basic figures are confirmed in the paper by Alton who reviewed the Cambodia Trust records of 1725 amputees. Some 94.6% were as a result of war, 90% from land-mine injury of these 66% had amputations below, and 28% above the knee. It also analysed the repair incidence (or at least those who attended for repair, a service for which there is an increasing demand).

Although these papers and that of the Prosthetics Outreach Foundation (POF) (Boone) suggested that most found their prosthesis highly desirable, Neff examined other evaluations which showed that in many cases the subjective worth of the prosthesis (as perceived by the patient) was greater than the objectively observed poor fit and condition of the device. But he also showed that as many as 30% were not worn. Hotchkiss made the point that many successful prosthetics wearers also require wheelchairs, and this is probably the best form of mobility for the bilateral trans-femoral amputee in many environments

Education

NGOs and agencies employing expatriate prosthetists to provide services in developing countries can never satisfy the enormous demands (Shangali). Education and training of sufficient prosthetists and technicians in the developing countries is the only longer term solution. Such training must take into account the local needs, abilities, culture, availability, economy and the possibility of licensing or certification (Harsha). ISPO, recognising four categories of worker, appreciates that Category I training in developing countries does not exist, but considers that some supervisory personnel should be trained to this level, in order to direct the locally trained Category II technologists (Hughes). The need for local schools to train technologists who will provide the majority of clinical services was recognised many years ago. GTZ uses its fitting services to provide clinical training in the schools for orthopaedic technologists which have been set up with their collaboration in many countries (Heim). The National School of Prosthetics and Orthotics in Cambodia was set up in 1994 by the Cambodia Trust with the assistance and co-operation of other agencies working in the country and with the blessing of the Government. This is a formal three year course, with a supervised clinical placement in the final year, and there is an associated Category III training course (Harte).

Conclusion

This was an excellent conference in which many views and opinions were aired and discussed, and there is no doubt that it will prove helpful to those who provide or fund the provision of prosthetic services in developing countries. The exchange of information must have been helpful and valuable to everyone who attended. Many agencies are so busy providing service that perhaps it is not easy for them to find time to stand back and look at what they are doing and report it.

It, is of course, inevitable and right that a conference entitled "appropriate prosthetic technology" should concentrate on prosthetic rehabilitation. However it should not be forgotten that the rehabilitation of an amputee does not begin or end with the supply of a prosthesis, and this reviewer, as a doctor specialising in amputee rehabilitation, would like to see further discussion about the rehabilitation process, and its evaluation, of the amputee as a person and member of society, including whether or not providing a prosthesis (even though correctly fitted and aligned) is necessarily the best rehabilitation. The use of techniques of "clinical audit" should not be confined to the industrialised world.

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