Original article

An evaluation of the first year's experience with a low-cost telemedicine link in Bangladesh

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Summary

In July 1999, the Swinfen Charitable Trust in the UK established a telemedicine link in Bangladesh, between the Centre for the Rehabilitation of the Paralysed (CRP) in Dhaka and medical consultants abroad. This low-cost telemedicine system used a digital camera to capture still images, which were then transmitted by email. During the first 12 months, 27 telemedicine referrals were made. The following specialties were consulted: neurology (44%), orthopaedics (40%), rheumatology (8%), nephrology (4%) and paediatrics (4%). Initial email replies were received at the CRP within a day of referral in 70% of cases and within thee days in 100%, which shows that store-and-forward telemedicine can be both fast and reliable. Telemedicine consultation was complete within three days in 14 cases (52%) and within three weeks in 24 cases (89%). Referral was judged to be beneficial in 24 cases (89%), the benefits including establishment of the diagnosis, the provision of reassurance to the patient and referring doctor, and a change of management. Four patients (15% of the total) and their families were spared the considerable expense and unnecessary stress of travelling abroad for a second opinion, and the savings from this alone outweighed the set-up and running costs in Bangladesh. The latter are limited to an email account with an Internet service provider and the local-rate telephone call charges from the CRP. This successful telemedicine system is a model for further telemedicine projects in the developing world.

Introduction

Telemedicine is a process in which expert medical advice from afar is provided using telecommunications technology. The system chosen depends primarily on the needs of the user, but must also take account of the available finances and technical resources. This is particularly relevant in the developing world.

Telemedicine based on store-and-forward email techniques has become increasingly affordable in the last few years with the advent of high-quality yet inexpensive still digital cameras and easy access to the Internet[1].

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Many civilian and military organizations in the industrialized world now have experience of telemedicine. The United States military medical services have been developing and using telemedicine systems in support of their forces overseas since the early 1990s[2–4]. Their initial focus was on the use of realtime videoconferencing links, but emphasis is now shifting towards the use of email with still images, which is cheaper and simpler[5]. This is partly as a result of British military experience with this method.

In January 1998, the British Defence Medical Services (DMS) set up their first telemedicine link, between a field hospital in Bosnia and specialists at the Royal Hospital Haslar in the UK[6]. The DMS system relied on the transmission of still images attached to email messages containing clinical information. The success of this simple and cheap system led to its rapid adoption by other British military medical units worldwide[7–9]. These features also make it suitable for telemedicine projects in the developing world.

Centre for the Rehabilitation of the Paralysed

The Centre for the Rehabilitation of the Paralysed (CRP) is a 100-bed hospital at Savar, near Dhaka, in Bangladesh. The CRP has grown from humble beginnings in 1979 to become one of the best management and rehabilitation centres for patients with spinal cord injuries in South Asia (Fig 1). It is the only such centre in the whole of Bangladesh (whose population is in excess of 120 million) and the majority of its patients are extremely poor. The CRP provides services for disabled people in a hospital setting and in the community[10]. It is fully accredited by the government of Bangladesh. The CRP clinical staff consists of one full-time consultant orthopaedic surgeon, one resident medical officer and two medical officers. There are three visiting neurosurgeons and one visiting urologist. There are 20 physiotherapy staff, 12 occupational therapy staff and 23 nursing staff, in addition to administrative and domestic staff.

The Swinfen Charitable Trust

The Swinfen Charitable Trust (SCT) was set up in the UK in 1998 with the aim of assisting poor, sick and disabled people in the developing world[11]. The Trust's policy is to do this by helping to establish telemedicine links between hospitals in the developing world and specialists who generously give free advice by email. The simple telemedicine protocols used are modelled on those of the DMS system[1,6–8] (see below).

The CRP telemedicine link

In November 1998, Olympus UK donated two digital cameras (C-1400XL, Olympus) and accessories, two tripods and a laptop computer to the SCT in order to establish a telemedicine link at the CRP. Two SCT administrators delivered this equipment to the CRP in July 1999. They trained a small team of local staff in its use and how to send email referrals, and provided them with an initial list of specialists and their email addresses. Most of the staff had no previous experience of using computers.

Fig 1 Centre for the Rehabilitation of the Paralysed, Bangladesh.

Equipment and software

The CRP

To be suitable for telemedicine, a digital camera has to produce images of sufficient resolution for a clinician to give a confident second opinion on the images and clinical details alone. The Olympus C-1400XL digital camera (known as the D620L in the USA) fulfilled this requirement. It was the highest-resolution digital camera available commercially until mid-1999. It is still widely used by the DMS (although it is now being superseded by the Olympus C-2500). Two Olympus C-1400XL digital cameras, two 6 V AC power adaptors, two sets of rechargeable batteries and rechargers, and two tripods were procured for the CRP (thus allowing some redundancy to prevent disruption of the telemedicine service should any single component fail).

A laptop computer was used (ThinkPad 365XD, IBM) with a standard modem (19.2 kbit/s).

The digital camera was supplied with basic image manipulation software (C-W95, Olympus). This was used to import, display, crop, compress and store images in the laptop. No other image software was required at the CRP.

The CRP took out an email subscription with Bangla-net Dhaka. An ordinary telephone line (not an ISDN line) was used at the CRP for the connection.

The SCT

Individual specialists and the staff at the SCT used a variety of laptop or desktop computers, choosing their own communication and image manipulation software. It was not usually necessary to enhance images on receipt.

Telemedicine protocols

Image capture at the CRP

The camera was usually used on a tripod to photograph clinical images or electrocardiograms; 'macro mode' was used for close-ups. For radiographs or magnetic resonance or computerized tomography images, the camera was used in self-timer mode, on a tripod, in a darkened room, with the radiographs or scans illuminated by a viewing box, at a distance of 40 cm

Fig 2 Digital camera in use at the CRP by Shamsun Nahar Begum, the operating theatre nurse.

from the camera (Fig 2). Images were taken in 'high-quality mode' (1280 × 1024 pixels) for maximum definition. The images were then downloaded into the computer using a Fuji floppy path adaptor (this method was faster than using the serial adaptor cable provided with the camera). The images were automatically compressed as JPEG images (Joint Photographic Experts Group algorithm) and cropped as necessary. This resulted in file sizes of 30–200 kByte, depending on whether the image was saved in 256-level greyscale (for radiographs) or 24-bit colour format.

The images were then attached to an email containing the necessary clinical information and appropriate subject header (as described below).

Patient confidentiality

Patient confidentiality was ensured by the use of a sequential number for each patient (e.g. CRP 001 was the first referral) and the avoidance of any mention of details that could identify the patient. There was therefore no need for encryption software. The patient's consent was obtained beforehand for telemedicine referral.

Email subject header

The subject header for each referral was written in the following format: *Tmed xxxx CRP nnn.*

(1) *Tmed* identified the email as a telemedicine referral;
(2) *xxxx* identified the specialty whose opinion was being sought, such as neuro for neurology, orth for orthopaedics, rheum for rheumatology, xray for radiology and so on;
(3) *CRP* identified the referring site;
(4) *nnn* was the sequential patient number.

Thus Tmed orth CRP 007 identified the seventh telemedicine referral from the CRP, requesting an orthopaedic opinion.

Email transmission

Each email referral was sent to a specialist's own email address and copied (for coordination and evaluation) to two further SCT addresses. The specialists' replies were sent to the CRP and also copied to the SCT. The SCT thereby built up a central database of all referrals and replies. The SCT administrator or a deputy logged onto the Internet to check for email referrals three or four times a day throughout the evaluation period, including at weekends, and occasionally telephoned consultants to notify them of the more urgent referrals. The SCT also sought the aid of different specialists as required to cover for absences on leave, or if a referral to a new specialty was required.

Methods

The evaluation period lasted from the date of the first telemedicine referral from the CRP on 19 July 1999 to the completion of the first telemedicine referral for July 2000, the study ending on 20 July 2000. All email referrals, replies and follow-up email messages were copied to the SCT (as described above, or after a reminder in the few early instances where either the CRP or the specialist inadvertently omitted to send copies). At the end of the study period the email traffic was analysed to determine the specialties involved, speed of initial reply, time to completion of each consultation, number of email messages for each referral, number of images and size of files, and the frequency of referrals. Only email messages directly relating to patient management were included in the evaluation. Email copies were excluded.

The neurologist graded the difficulty of his consultations as 'difficult' or 'straightforward'. The lead clinician at the CRP documented what benefits accrued to the patient or to the referring doctor as a result of telemedicine. Clinical staff at the CRP evaluated the outcomes of telemedicine interventions in relation to the likely outcome if a telemedicine service had been unavailable. The set-up and ongoing costs of the telemedicine service were compared with the potential or actual savings to assess the cost-effectiveness of the link.

Table 1 Telemedicine referrals from the CRP during the study period

Patient	Specialty	No. of email messages	First reply	Completion	Diagnosis	Telemedicine result	Benefit
CRP 001	Orthopaedics	4	< 1 day	< 1 week	Tetraplegia (see Appendix)	Management endorsed	Flight avoided
CRP 002	Orthopaedics	5	< 1 day	< 1 day	Paraplegia	Pain management refined	Travel avoided
CRP 003	Orthopaedics	6	< 3 days	< 3 days	Pathological fracture	Local management endorsed	Reassurance
CRP 004	Orthopaedics	4	< 3 days	< 3 days	Vertebral tumour	Local management endorsed	Reassurance
CRP 005	Orthopaedics	9	< 3 days	< 3 weeks	Tuberculosis, cord compression	Local management refined	Reassurance
CRP 006	Neurology	7	< 1 day	< 3 weeks	Neuropathy (see Appendix)	Differential diagnosis clarified	Flight avoided
CRP 007	Rheumatology	4	< 1 day	< 2 weeks	Juvenile chronic rheumatoid arthritis	New management plan	Management changed
CRP 008	Orthopaedics	15	< 1 day	< 3 months	Paraplegia, cause?	Diagnosis established	Reassurance
CRP 009	Neurology	10	< 1 day	< 7 months	Chronic inflammatory demyelinating peripheral neuropathy (see Appendix)	Diagnosis established	Management changed
CRP 010	Medicine	3	< 1 day	< 1 day (died)	Tetraplegia, renal failure	n/a	No benefit
CRP 011	Orthopaedics	5	< 3 days	< 1 week	Leg injury (see Appendix)	Management options clarified	Reassurance
CRP 012	Rheumatology	2	< 3 days	< 3 days	Rheumatic fever	Management plan clarified	Reassurance
CRP 013	Neurology	4	< 3 days	< 3 weeks	Stroke	Management plan clarified	Management changed
CRP 014	Neurology	6	< 1 day	< 3 weeks	Abnormal posture	Differential diagnosis clarified	No benefit to patient
CRP 015	Orthopaedics	3	< 1 day	< 1 day	Paraplegia	Local management endorsed	Reassurance
CRP 016	Orthopaedics	4	< 1 day	< 3 days	Congenital hip dislocation (see Appendix)	Management plan clarified	Surgery avoided
CRP 017	Neurology	5	< 1 day	< 3 weeks	Early-onset dementia	Diagnosis established	Reassurance
CRP 018	Neurology	4	< 1 day	< 3 days	Parkinson's disease	Management plan clarified	Management changed
CRP 019	Neurology	2	< 3 days	< 3 days	Stroke	Management plan clarified	Reassurance
CRP 020	Neurology	2	< 1 day	< 1 day	Cerebral palsy, spasms	Management plan clarified	Management changed
CRP 021	Neurology	13	< 1 day	< 3 months	Neurological deterioration	Differential diagnosis, management options	No benefit to patient
CRP 022	Paediatrics	7	< 3 days	< 3 weeks	Osteogenesis imperfecta	Management plan clarified	Travel avoided
CRP 023	Neurology	3	< 1 day	< 3 days	Stroke	Management plan clarified	Management changed
CRP 024	Neurology	2	< 1 day	< 1 day	Depression	Management plan clarified	Management changed
CRP 025	Orthopaedics	2	< 1 day	< 1 day	Ankylosing spondylitis	Management plan clarified	Surgery avoided
CRP 026	Neurology	4	< 1 day	< 3 weeks	Neurological deterioration	Differential diagnosis clarified	Reassurance
CRP 027	Orthopaedics	2	< 1 day	< 1 day	Ankylosing spondylitis (see Appendix)	Management plan clarified	Surgery avoided

Results

Twenty-seven telemedicine referrals were sent during the first 12 months (Table 1), relating to both inpatients and outpatients. Twenty-three referral messages (85%) contained images, the number ranging from one to seven, apart from one referral containing 13 images. Apart from this one referral, the total file size was always less than 500 kByte. The file transfer times (i.e. the length of time it took to send the email with attachments from the PC to the ISP) were less than 2 min. There was no loss of definition in transmitted images.

Five different specialties were consulted (Table 1). Rheumatology referrals were sent to a British rheumatologist working at the Patan Hospital in Nepal, which illustrates the feasibility of referrals between two developing countries.

The frequency of referrals gradually increased, reaching a maximum of six in two separate months.

Twice as many referrals were sent on a Monday than on any other day of the week. The Bangladeshi weekend starts on Thursday afternoon, with Friday being the main holiday. Saturday and Sunday are normal working days, and the pattern of referrals reflected this. There was a tendency for a slight delay before reply to Sunday referrals, probably because Sunday is a holiday in the UK and there is a 5 h time difference between the UK and Bangladesh. Paradoxically, the one Sunday referral that received a reply on the same day was sent on Boxing Day (26 December 1999), a public holiday in the UK. The day of referral did not otherwise affect the time before a reply was received.

Initial email replies were received at the CRP within a day of referral in 70% of referrals and within three days in 100% (Table 1).

The number of email messages per referral ranged from two (in the most straightforward cases, i.e. a referral and a reply) to 15 (in a combined orthopaedic and neurological case), the mean being five email messages per referral. There was no significant difference between specialties in the number of email messages per referral (Table 1).

Telemedicine consultation was completed within one day in seven cases overall (26%), within three days in 14 cases (52%), within a week in 16 cases (59%) and within three weeks in 24 cases (89%). Of the remaining three cases, two were completed within three months and in the last, a complicated neurological case, the correspondence lasted seven months. The time to completion of the telemedicine consultation was significantly longer for neurology referrals than for orthopaedic referrals. Thus the respective figures for completion within one day were two out of 12 neurology cases (17%) and four out of 11 orthopaedic cases (36%). For completion within three days the figures were five out of 12 neurology cases (42%) and seven out of 11 orthopaedic cases (64%), and at one week the figures were still five out of 12 for neurology (42%) but nine out of 11 for orthopaedics (82%). By three weeks after initial referral most consultations were finished, with 10 out of 12 neurology cases (83%) and 10 out of 11 orthopaedic cases (91%) being completed.

Notwithstanding the difference between specialties, this short time overall compares very favourably with standard (non-telemedicine) outpatient referrals (even between hospital specialists) within the UK, especially for orthopaedics and neurology.

Of the 12 neurological referrals, eight were graded as 'difficult' and four as 'straightforward'. The cases therefore represented a highly selected and difficult patient population. The UK neurologist considered this method of email consultation to be sufficient in the four straightforward cases but stated that he would have preferred video-consultation to email in the other eight. Nonetheless, the CRP staff perceived benefit to the patient and/or to the referring clinician in six of the eight complicated neurological cases.

Telemedicine referral was judged by the CRP staff to be beneficial to the patient in 24 cases (89%), the three exceptions being a patient who died very shortly after referral (CRP 010), one who probably had a psychiatric disorder (CRP 014) and one with a rapidly progressive complex neurological condition (CRP 021). The benefits included establishment of the diagnosis, reassurance to the patient and referring doctor, and a change of management. These results do not take into account the considerable educational benefits to the referring doctor and his colleagues at the CRP — and indeed to the specialists — even in those few cases where no benefit accrued to the patient.

Four patients (15% of the total referred) and their families were spared the considerable expense and unnecessary stress of travelling abroad for a second opinion. They had expressed the intention of travelling before the telemedicine referral, but changed their minds on receipt of the replies.

The cost to the patients for the telemedicine service was a nominal Tk1000 ($18 — Tk1 is $0.018, EU0.020), paid to the CRP to partially defray the cost of the email subscription. This fee was waived for two patients.

Discussion

There has been little practical experience with telemedicine of a direct clinical kind in the developing world, which contains 80% of the world's population. In the 45 poorest countries, it is estimated that only 50% of the population has access to health services[12]. Arguably, it is those same countries that stand to gain most from a simple and cheap telemedicine system, on the principle that it could improve access to health-care and specialists, and enhance research and the education of local health-care workers[13]. However, the fundamental assumption — that telemedicine in a developing country is cost-effective — can be proved only by carrying out pilot projects[14]. The potential for telemedicine to play a useful role in the developing world has been the focus of attention for several years[15–21]. The dearth of formal evaluations of the cost-effectiveness of telemedicine projects and the almost complete lack of evaluations of the outcomes of telemedicine interventions have unfortunately militated against the wider use of telemedicine[21]. The

International Telecommunication Union has reviewed the telemedicine experience of various countries and published its recommendations for the development of telemedicine services in developing countries[17,18]. A major recommendation was that developing countries should undertake pilot projects in order to identify the most cost-effective telemedicine solutions, especially for the provision of health-care to people living in remote and rural areas.

It has been suggested[14] that the logical steps to determine the place of telemedicine in the developing world would include:

(1) identifying potential telemedicine projects;
(2) establishing one or more pilot projects in order both to demonstrate technical feasibility and to measure the benefits to the health-care system;
(3) calculating the cost of large-scale deployment.

Various concerns have been raised regarding the use of telemedicine in the developing world[14]. The following questions are pertinent:

(1) Can health workers do anything on the basis of the advice they receive?
(2) Is telemedicine an appropriate use of resources?
(3) Can the difficult organizational and administrative problems be overcome in a developing country? (In telemedicine projects in the industrialized world it has been shown that success depends on much more than the delivery of the right equipment to the user.)
(4) Are neurological consultations based on still images and store-and-forward email effective? (It has been shown that this specialty can safely be carried out using video-consultation[22,23].)

In addition, there are particular logistical concerns in attempting to set up a telemedicine project in the developing world[24]. These include:

(1) delivering the equipment;
(2) doing the initial user training;
(3) supporting the project afterwards.

These questions can be answered only on the basis of experience with telemedicine in the developing world[14].

The establishment of the CRP telemedicine link followed the logical strategy outlined above and sought to determine whether telemedicine in the developing world could be cost-effective and therefore whether it ought to be more widely employed.

Identification of a suitable site for a telemedicine project

The CRP is situated in one of the 45 poorest countries of the world and cares for the poorest of the poor. It has a well deserved reputation as a centre for the management and rehabilitation of patients with spinal cord injuries throughout South Asia and yet is handicapped by a lack of specialists in various disciplines. It originally sought advice from the SCT and others about a suitable telemedicine system that would enhance the care it could offer its patients. The Bangladesh Ministry of Health gave its approval to the CRP for telemedicine advice to be sought from overseas.

Choice of telemedicine system

The simplicity and effectiveness of telemedicine based on pictures taken with a digital camera and email had been established by the DMS. This system was deemed to be potentially suitable for the CRP. The equipment requirements were modest and in the event the costs were met through donations.

Evaluation

The results of the first year of the pilot project at the CRP show the technical feasibility of telemedicine based on a digital camera and email in a developing country and show measurable benefits to the patients at the referring institution. The fact that initial replies were received within one day in 70% of referrals and within three days in 100% of referrals demonstrated that store-and-forward telemedicine could be both fast and reliable. Follow-up email messages were equally prompt, resulting in completion of the consultation within three days in 14 cases (52%) and within three weeks in 24 cases (89%). Such results are not often obtained, even for non-telemedicine referrals, within the UK.

Cost of large-scale deployment

The essential elements of the system used at the CRP were a digital camera, computer and email link, one or more coordinators, and a network of specialists. How best to scale up the system to encompass a large number of referring sites — and therefore what the costs of large-scale deployment would be — is a current topic for research.

Can health workers do anything on the basis of the advice they receive?

Our evaluation shows that the telemedicine advice received is useful, so long as common sense is applied

and so long as specialists can be relied upon to reply promptly, with consistently high-quality advice and a choice of management options. The referring doctor then chooses the best option in the circumstances. This worked well in the present study. Specialists soon realized what was feasible locally and tailored their advice accordingly. This is illustrated in the case reports (see Appendix), especially CRP 011, a very difficult case where amputation would probably have been the best surgical option, but parental influence overrode this, so further advice was modified accordingly.

It is essential that specialists always reply promptly to referrals. Only thus will they materially influence patient management and maintain the confidence and trust of the referring doctor. The CRP experience shows that the quality of service (i.e. response time, quality of consultation and the expertise of the consultants) is important in sustaining such a telemedicine link.

Is telemedicine an appropriate use of resources?

In considering the introduction of low-cost telemedicine for the developing world, this question might be better phrased as 'Is telemedicine the most effective use of resources?' and 'What would have happened if telemedicine had not been available?' Can it be shown, for instance, that the funds produce a greater health gain when spent on telemedicine rather than on conventional public health measures? These questions can now be answered on the basis of the CRP's experience.

The main aim of the CRP telemedicine project was to provide access to specialist consultation for the patients at the CRP, often very poor people, at little or no cost. A secondary consideration was to prevent unnecessary and expensive travel for treatment to another country. Both aims were achieved. In four cases, a personal outlay of Tk1000 each saved the patients and respective families the considerable cost of travelling abroad for a second opinion (Table 1). The ongoing costs to the CRP were low, mainly consisting of the email account with an Internet service provider and the cost of local-rate telephone calls. The cost to the CRP for the email account and all telephone bills for the period of the evaluation was about Tk20,000.

Staff at the CRP were asked specifically to evaluate what would have happened if telemedicine had not been available in their assessment of the appropriateness of the use of resources. The results were as follows:

(1) Four patients (15% of the total) would have travelled abroad for a second opinion. Two of them, including a tetraplegic patient, would have travelled, with at least one relative each, by air to the UK and two would have travelled overland to India, accompanied by two relatives each. The expenses saved in these four instances more than made up for the set-up and maintenance costs of the telemedicine project. The costs of travel and treatment abroad would have been fully borne by the patients and families concerned. Instead, this money was available for their care at home in Bangladesh. Both the CRP staff and the patients were delighted with this outcome.
(2) Seven patients (26%) whose management was changed as a result of telemedicine would have suffered longer and might well have undergone inappropriate treatment.
(3) Three patients would not have received a firm diagnosis and would probably have undergone inappropriate investigation and management, and unnecessary stress.
(4) Three patients might have undergone possibly deleterious or unnecessary surgery.
(5) Three patients would have been referred to another hospital in Dhaka for investigation and further management, at significant cost to the patients. One of these, CRP 010, underwent telemedicine referral almost in extremis (without it interfering with his clinical care) and he died shortly afterwards, during transfer to another hospital.
(6) The referring clinician would have missed out on the educational aspects of professional consultation, possibly to the detriment of future patients (see below).

The question about appropriate use of resources has to be placed in the context of the CRP's specialist work, the costs involved in setting up and maintaining a telemedicine link, and the benefits accruing to the staff and patients. In this project, the equipment was donated to the CRP; the SCT transported it, carried out the training, made two subsequent visits (see below) and provided the connection to overseas specialists, who gave their advice free of charge. There was therefore almost no cost to the CRP. The potential outlay for equipment would otherwise have been in the region of £2500 (£1 is $1.49, EU1.57) (for two cameras, accessories, tripods and a laptop computer). The potential outlay for travel (including the follow-up visits) would have been at least £4000 (for two persons and three return journeys each, with economy-class return flight to the UK from Dhaka costing £650 per person).

The main impingement on local resources at the CRP was on personnel, but their work in the local telemedicine team was performed without detriment to other duties. Analysis showed that it took 90–120 min from the time the CRP clinician requested the help of

his telemedicine team with a new referral to the time the email message was sent. The steps and the time involved were:

(1) to obtain patient's consent and contact address form, 10 min;
(2) to compose an email message containing the relevant clinical information, 30–60 min, depending upon the specialty, with non-orthopaedic referrals taking longer (it should be noted that referrals were not being composed in the clinician's native language and that the email was typed by another person, not a clinician, who was also unfamiliar with the English language);
(3) to photograph a radiograph or computerized tomography or magnetic resonance scan, 20 min;
(4) to download images to the computer, 10 min;
(5) to attach the relevant images to the email message, 10 min
(6) to perform a final check and send the referral, 10 min.

On the basis of the results of the referrals, the CRP staff judged this to be time and effort well spent.

Our results show that the minimal expenditure incurred by the CRP in using the telemedicine link significantly improved the service it could provide. The CRP already had ready access to medical supplies, clean drinking water and proper sanitation, so this was not an issue. The CRP management and clinical staff could not identify any alternative health measure locally where such a small expenditure would have had as great or as lasting an effect on patient care, and they were in no doubt that the introduction of telemedicine had been both appropriate and a most effective health measure.

Teleneurology

Can the specialist consulted give appropriate advice on the basis of the transmitted information? This question is particularly pertinent to neurology[22,23,25]. In the industrialized world, teleneurology has concentrated on realtime high-quality video-links, mainly using transmission at 384 kbit/s via ISDN lines because this is what is required to transmit a neurological examination accurately. It had been assumed that store-and-forward techniques would not be sufficient to enable accurate diagnosis and therefore management recommendations to be made. Our results suggest that this may not always be the case. While the neurologist felt that video-consultation would have given him more diagnostic confidence, he was still prepared to provide a reasoned differential diagnosis and suggest further management on the basis of the excellent clinical history and examination findings recorded by an experienced orthopaedic surgeon. The clinical images themselves were less important. What is particularly interesting is that the perceptions of usefulness were so different between the neurologist, who was not happy that he had always made the diagnosis correctly, and the referring doctor, who thought that the neurologist's advice was extremely useful in 10 of the 12 cases. Store-and-forward techniques are not just less expensive to set up than a video-link but also much easier to use, since they do not require the referring doctor and the consultant to be dealing with the patient's problem at the same time. Moreover, a video-link is particularly difficult to organize where there is a substantial difference in time zones between the two sites. Our results indicate that store-and-forward telemedicine for neurology would be of substantial potential benefit to the developing world, where neurologists are scarce. Consequently this technique merits further study.

The logistics of setting up telemedicine

Can the organizational and administrative problems of setting up a telemedicine service be overcome in a developing country? There were different organizational and administrative issues at each end (the UK and Bangladesh) of this telemedicine link, some of which were unique to it, but others which are generally applicable (see below). There were no insurmountable technical, administrative or logistical problems.

Delivering the equipment

Before importing the digital cameras and accessories into Bangladesh, a number of bureaucratic formalities had to be completed. These were done with the aid of the Bangladesh High Commission in London, but still took some months. Two SCT administrators transported the equipment by Emirate Airlines to Dhaka in early July 1999. All went well until they reached Dhaka Airport, where the customs officers initially refused to let the equipment through, despite all the relevant forms having been completed in both Bengali and English. However, obduracy finally paid off and the equipment was allowed through to the CRP.

Initial user training

At the CRP, four personnel were selected for involvement in telemedicine. The same two SCT administrators who had delivered the equipment collaborated with the local team leader in training these staff. They concentrated on teaching them how to use the camera to take the best possible images, and

how to compose email messages to ensure that correct subject headers were used and that referrals were sent to appropriate addresses. Local staff quickly grasped the basics of the system and the unfamiliar technology, even though they were learning through the medium of English, when their native language was Bengali. There were inevitably some amusing incidents during the teaching sessions, with everything said having to be translated into Bengali.

The CRP team leader was a clinician, who was responsible for initiating all telemedicine referrals. Other team members were responsible for taking and downloading photographs, and for the composition and transmission of email messages.

Supporting the network

At the UK end, an SCT administrator or deputy checked the email three or four times a day and followed the progress of each referral, occasionally prompting replies by email or by telephone calls to relevant specialists. New specialists were enrolled as required through personal contacts. The SCT also sent two administrators to visit the CRP on two occasions to monitor its progress during the evaluation period, to encourage local staff, to help in further training and to participate in telemedicine workshops. These two visits (in October 1999 and April 2000) were followed by a significant surge in telemedicine referrals as local staff regained confidence in their skills. Both visits were considered crucial in this regard. The second visit resulted in a sustained level of activity, with the project gaining a momentum of its own. A drop in referrals in May 2000 was due to the referring clinician going abroad on a postgraduate course, and the number of referrals picked up after his return.

At each end of the link, a particular concern was how best to keep track of email messages and images relating to particular referrals, especially as email traffic increased and involved more specialists in different locations. For this reason, the SCT began to assess the free telemedicine software system specially developed for the DMS Telemedicine Unit at the Royal Hospital Haslar for use with the telemedicine protocols described above[26].

Additional benefits of telemedicine

The educational aspects have already been alluded to. For example, two weeks after telemedicine advice was given for better pain management in a patient with cerebral palsy and painful muscle spasms (CRP 020), a similar outpatient presented to the CRP. This new patient was managed successfully according to the same treatment regime, without the need for further consultation.

Two telemedicine workshops were also held during the year, and these generated considerable interest among local Bangladeshi medical consultants, politicians, non-governmental organizations, other interested persons and the local press[27].

The CRP is now developing itself as a centre for telemedicine within Bangladesh, a welcome offshoot of this project. Digital photographs are also being used in teaching local personnel, and the Haslar Hospital library's Website[28] is being used by CRP staff as a portal to medical sites on the Internet. A Web-based presentation on the work of the CRP has been prepared with the aid of the supplied digital cameras and has been published on the 'Good Medicine in Bad Places' Website[10].

Satellite telephones

An Inmarsat-A satellite telephone was donated to the SCT by Nera Satellite Services to provide an emergency backup at the CRP in the event of conventional telephone lines breaking down, which would be most likely during the monsoon season. The satellite telephone was delivered to the CRP by the SCT in July 1999. In practice, the telephone line at the CRP broke down only twice during the study period and these interruptions were overcome by using another line. The satellite telephone itself, on the few occasions it was tried, ran up a prohibitively large telephone bill, so its use was discontinued. On the basis of this experience we hesitate to recommend satellite telephones for telemedicine links in the developing world, primarily because of the cost of the calls.

Unique aspects

The present work has provided invaluable experience in how to set up a successful telemedicine project in the developing world. It has also shown that the most pressing concerns about such projects (the logistical aspects of delivering the equipment, doing the initial user training and supporting the network afterwards) can be overcome by the use of simple yet effective equipment, straightforward protocols and dedicated personnel.

This telemedicine project is also unique in that it was established under the aegis of a new telemedicine charity[11]. This charity donated and transported the relevant equipment to a centre already equipped with email, it helped train local staff and it has continued to support the local staff and supervise the progress of the project. It aims to help establish further telemedicine projects in the developing world[29].

Conclusions

Other health workers have independently confirmed the usefulness of digital cameras and email for telemedicine in the developing world[30,31]. The low-cost telemedicine project described in this article is one of very few clinical projects in the developing world. Evaluation of the project has proven that telemedicine in a developing country is cost-effective. It is simple and can readily be emulated.

Its example is already being followed in similar pilot projects set up by the SCT in two other countries: Nepal (at Patan Hospital) and in the Solomon Islands (Gizo Hospital in Gizo, and Helena Goldie Hospital in New Georgia, Western Province)[32]. The LAMB Hospital, also in Bangladesh, followed suit in late 2000. The CRP digital camera and email telemedicine link is a model for further telemedicine projects in the developing world. In the words of one of the CRP telemedicine team:

> Telemedicine has provided us with tremendous support for our patient management at CRP and in Bangladesh. If this service had not been available, some of our patients would have definitely suffered longer from their disease process and money would have been wasted travelling overseas. Telemedicine has lessened the suffering of our patients, given them assurance too and provided teaching for our consultant.

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References

1 Vassallo DJ. Digital camera telemedicine for British and NATO forces — a simple solution with civilian and humanitarian applications. *Journal of Telemedicine and Telecare* 2000;**6** (suppl. 1):197
2 Zajtchuk R, Sullivan GR. Battlefield trauma care: focus on advanced technology. *Military Medicine* 1995;**160**:1–7
3 Calcagni DE, Clyburn CA, Tomkins G, *et al*. Operation Joint Endeavor in Bosnia: telemedicine systems and case reports. *Telemedicine Journal* 1996;**2**:211–24
4 Zajtchuk R, Gilbert GR. Telemedicine: a new dimension in the practice of medicine. *Disease-a-Month* 1999;**45**(6):197–262
5 Vidmar DA. The history of teledermatology in the Department of Defense. *Dermatology Clinics* 1999;**17**:113–24
6 Vassallo DJ, Buxton PJ, Kilbey JH, Trasler M. The first telemedicine link for the British Forces. *Journal of the Royal Army Medical Corps* 1998;**144**:125–30
7 Scerri GV, Vassallo DJ. Initial plastic surgery experience with the first telemedicine link for the British Forces. *British Journal of Plastic Surgery* 1999;**52**:294–8
8 Vassallo DJ. Twelve months' experience with telemedicine for the British armed forces. *Journal of Telemedicine and Telecare* 1999;**5** (suppl. 1):117–18
9 See http://www.emergency-medical.com/case01_01.htm
10 See http://www.emergency-medical.com/case06_01.htm
11 The Swinfen Charitable Trust. Registered charity no. 1077879 (see http://www.coh.uq.edu.au/swinfen), c/o Dene House, Wingham, Canterbury CT3 1NU, UK (email: swinfen@dene73.freeserve.co.uk)
12 UNDP. *Human Development Report 1996*. New York: Oxford University Press, 1996
13 Mitka M. Developing countries find telemedicine forges links to more care and research. *Journal of the American Medical Association* 1998;**280**:1295–6
14 Wootton R. The possible use of telemedicine in developing countries. *Journal of Telemedicine and Telecare* 1997;**3**:23–6
15 Wright D, Androuchko L. Telemedicine and developing countries. *Journal of Telemedicine and Telecare* 1996;**2**:63–70
16 Wright D. Telemedicine delivery to developing countries. *Journal of Telemedicine and Telecare* 1997;**3** (suppl. 1):76–8
17 Wright D. The International Telecommunication Union's report on Telemedicine and Developing Countries. *Journal of Telemedicine and Telecare* 1998;**4** (suppl. 1):75–9
18 Wright D. Telemedicine and developing countries. A report of study group 2 of the ITU Development Sector. *Journal of Telemedicine and Telecare* 1998;**4** (suppl. 2):1–87
19 Adeyinka MB. Fundamentals of modern telemedicine in Africa. *Methods of Information in Medicine* 1997;**36**:95–8
20 Darkwa O. An exploratory survey of the applications of telemedicine in Ghana. *Journal of Telemedicine and Telecare* 2000;**6**:177–83
21 Hakansson S, Gavelin C. What do we *really* know about the cost-effectiveness of telemedicine? *Journal of Telemedicine and Telecare* 2000;**6** (suppl. 1):133–6
22 Craig JJ, McConville JP, Patterson VH, Wootton R. Neurological examination is possible using telemedicine. *Journal of Telemedicine and Telecare* 1999;**5**:177–81
23 Craig J, Patterson V, Russell C, Wootton R. Interactive videoconsultation is a feasible method for neurological inpatient assessment. *European Journal of Neurology* 2000;**7**:699–702
24 R Wootton, personal communication
25 Craig J, Chua R, Wootton R, Patterson V. A pilot study of telemedicine for new neurological outpatient referrals. *Journal of Telemedicine and Telecare* 2000;**6**:225–8
26 See http://www.bktelemed.com

27 Swinfen P. Telemedicine service. *The Independent* (Bangladesh), 9 May 2000
28 See http://www.medical-bookmarks.org.uk
29 See http://www.coh/uq.edu.au/swinfen/
30 Corr P, Couper I, Beningfield SJ, Marss M. A simple telemedicine system using a digital camera. *Journal of Telemedicine and Telecare* 2000;**6**:233–6
31 Fraser HS, McGrath SD. Information technology and telemedicine in sub-Saharan Africa. *British Medical Journal* 2000;**321**:465–6
32 Vassallo DJ. Telemedicine kept simple. *Images in Paediatric Cardiology* 2000;**3**:1–14. Also available on line at http://www.magnet.mt/health/impaedcard/issue/issue3/vassallod/vassallod.htm#top, or go to http://www.medical-bookmarks.org.uk then click on Telecommunication (including Telemedicine) and go to electronic journal article 'Telemedicine kept simple'

Appendix. Case reports

Patient CRP 001 (orthopaedic)

Referral

I would be most grateful if you would look at this email and its attachments. This patient is a complete tetraplegic, neurological level C5. A male aged 18 years. His tetraplegia developed following a road traffic accident in December 1998. He is now rehabilitated in a wheelchair, suffering frequent attacks of vertigo, probably due to postural hypotension. He has bladder and bowel incontinence, and is using a clean intermittent rubber catheter. This patient's relatives are convinced that he needs further treatment, and they are thinking seriously of travelling to the UK with him, in order to obtain it. We therefore need an opinion as to whether he has any chance of improvement if he should undergo further treatment, by surgery or any other means. Attached are two cropped magnetic resonance images.

Reply (same day)

The replying consultant endorsed the local management regime, and advised that useful neurological recovery was highly unlikely and that the only benefit obtainable by travel overseas would be for aid in occupational therapy. The patient and his family were persuaded that the local doctor's management was appropriate and that they would gain little from overseas travel. They were therefore spared the expense of overseas travel. The patient's quality of life improved slightly afterwards.

Result (four emails total)

There were significant cost savings to patient and family.

Patient CRP 006 (neurological)

Referral

A 38-year-old man attended the CRP outpatient department with gradual weakness in his upper limbs for the last one and a half years. For the last couple of months he has noticed wasting in the right arm and hand. He has also noticed weakness of the left upper limb. For the last seven years he has been suffering from sexual dysfunction (loss of desire, delayed erection and rapid loss of erection). His attending physician on that visit detected that he had some weakness in the left side of his face. Functionally he is unable to perform fine hand functions such as buttoning his clothes and eating with his right hand. Now he has tremor (coarse) in both hands and is unable to extend the fingers of his right hand. Gradually all the motor symptoms are progressing but his sensory function remains normal. . . . The neurophysiological studies reveal chronic active denervation confined to both upper limbs. . . .

Initial reply

Thanks for the case history which is really difficult! I'm going to discuss the magnetic resonance images with a neuroradiologist colleague but meanwhile answers to the following questions (if they're available) would help. . . .

Further reply after supply of answers

This is extremely difficult! As part of the Royal College of Physicians Membership Examination there are tests called 'grey cases' which are easy compared with this. I will run through my thought processes. First this appears to be a problem with the lower motor neurone system because. . . . I don't think I've been much help to you and I'm still concerned we haven't got a perfect diagnostic fit. This has reinforced my prejudice that teleneurology is best dealt with by realtime ISDN-6 connections (but I realize that this is not always possible!) . . . I look forward to future challenges which I hope will be easier!

Result (seven emails total)

The neurologist's differential diagnosis and expected outcome of the likeliest two diseases (differing mainly in their rate of progression) were thoroughly explained to the patient by the CRP physician. The patient had initially reacted by suggesting that he would travel abroad to try to ascertain the exact diagnosis, but on reflection he decided against this. He accepted that, as there was no effective treatment in either case, he would gain little by doing so.

Patient CRP 009 (Boxing Day referral) (neurological)

Initial referral (when patient was confined to a wheelchair)

A 48-year-old lady, non-diabetic, normotensive, right-handed housewife. Presented with the following complaints: (1) Gradual weakness of both lower limbs since nine months ago. (2) Pain in both calves nine months ago. . . . On examination. Lower limb: All the tendon jerks are absent, muscle tone reduced, muscle power grade III proximal and grade II in distal group of muscles. . . . Disease process [Fig 3] is slowly progressive. . . .

Initial reply

This lady seems to have a motor peripheral neuropathy. The likely cause is chronic inflammatory demyelinating peripheral neuropathy (CIDP). If you have access to nerve conduction velocities these should be slow. Your investigations seem to have excluded myeloma and also diabetes; the other condition that needs to be excluded is lead poisoning. CIDP should respond well to steroids — prednisolone 60 mg daily is what I would use. . . .

Further email

Following your advice, I started prednisolone . . . after one month of the course I found she was improving.

Result (10 emails)

The diagnosis was established, the management changed and the patient fully recovered, walking unaided.

Fig 3 Wasting of intrinsic hand muscles in CRP 009.

Patient CRP 011 (orthopaedic)

Referral

A young man, 20 years old, had a road traffic accident two months ago and had a closed comminuted fracture of the left tibia and fibula. He was initially treated at the district hospital conservatively and developed compartment syndrome. Four days after the accident he was referred to me. On examination, the left foot was found to have loss of sensation and motor function on dorsum of the foot and anterior compartment of the leg. We immediately did a fasciotomy but after seven days we found necrosis of the anterior and lateral compartment muscles. Finally we performed debridement of the necrotic tissue and subsequently good granulation tissue has formed and the fibula has healed well. However, the fracture area of the shaft of tibia was exposed and had become necrotic; this we removed [Figs 4, 5]. Now the flexor muscle of the leg and foot has normal power. The patient is very much interested

Fig 4 Extensive leg wound of CRP 011 (after excision of necrotic tibial shaft and necrotic muscles).

Fig 5 Radiographs of CRP 011 after excision of necrotic tibial shaft.

in saving his leg. I need your opinion at present as to what should be the line of treatment.

Initial reply

This is a dreadful case. This would be an appallingly difficult case even in a major trauma unit; I do not envy you. To save the leg, the first essential is skin cover. The extent of the defect is such that only a free flap, probably latissimus dorsi, is the only way to get cover. To deal with the bone defect, there are two options. First an external fixator at anatomical length and once there is good skin cover do an Ilizarov-type bone transport, from proximal to distal. The alternative is to trim the bone ends at the time of the free flap, externally fix and oppose the bone ends and then distract as it starts to unite — risky, but it might work. However, if that were one of my sons (three) I would recommend a below-knee amputation. Otherwise, it's going to be multiple procedures, prolonged period under care, and a far from guaranteed result. Looking at the pictures, you should be able to get a long posterior flap of good skin, so it should be a reasonable stump. Sorry to be so nihilistic, but I think it would be for the best.

Reply from CRP

Thank you for your detailed explanation. I explained the possibility of amputation but the parents of the patient do not accept this owing to social prejudice. They want to keep the leg even if it is totally inactive. I have removed all the necrotic bone; now the wound is infection free and a good granulation tissue has formed with a big area of bone loss from the tibia. I am planning for skin grafting very soon. After skin grafting I will send you a picture and X-ray of the foot.

Further reply from UK

If amputation is not an option, there is one rather old and forgotten technique you might consider. The Papineau method for treating infected non-unions was very good at filling in bony defects, even with poor skin cover. If you put on an external fixator to hold anatomical position and to allow the limb to be supported clear of the bed, pack the defect with fine autogenous bone graft, and leave open, and then a continual gentle irrigation with saline over a period of weeks. If you wish, I could dig out some references, though it might take a few days.

Follow-up after five months

. . . the leg wound is now healed except a tiny point anteriorly lower end of tibia. He is walking with axillary crutch and AFO. He needs bone grafting for an area of 1 cm in the shaft of the tibia.

Result (five emails)

The management options were clarified and modified according to local circumstances, and moral support was provided for the referring clinician.

Patient CRP 016 (orthopaedic)

Referral

A four-year-old boy presented to me at the CRP outpatient department with the complaints of huge swelling of both thighs, shortening of both thighs and unable to walk without support. The boy is quite normal in his other functions and system. He looks very short for his age: height is 70 cm and the diameter of each mid-thigh is 28 cm. It seems that both thighs are short in comparison to his legs and trunk. I did not find any other abnormalities in the boy or any other congenital anomalies in his family. I attach X-rays of both femurs and pictures of his thighs [Figs 6, 7].

Fig 6 CRP 016 — neglected congenital dislocation of both hips.

Fig 7 Radiographs of CRP 016.

Reply (same day)

I think it is possible he has bilateral congenital dislocation of the hip. That said, on the basis of the photos it is a very severe case. The Canadian experience suggests that leaving them is probably best with late presenters.

Further reply (next day)

I showed these films in Edinburgh today [at an orthopaedic meeting]. No real consensus, but the absence of the femoral head epiphysis was noted . . . with the acetabular deficiency, I don't feel you have much prospect of getting an anatomical hip joint. My feeling is leave alone for fear of making it worse.

Result (four emails)

The diagnosis was established, the management plan clarified and no surgery undertaken.

Patient CRP 027 (orthopaedic)

A 22-year-old boy attended the CRP outpatient department with severe stiffness of both hips and knees. He is unable to bend his spine forward and chest expansion is only 0.5 cm. His blood ESR 106 mm in the first hour (Westergreen). Plain X-ray of both hips shows complete fusion and both knees are dislocated, deformed and have lost contour of the articular surfaces [Figs 8, 9]. His upper limbs and hand functions are normal but both legs have severe disuse atrophy with equinus deformity of both ankles. He is a case of ankylosing spondylitis and now he is pain free and receiving active physiotherapy and NSAID (ibuprofen). At this stage, what could I do for his mobility? What kind of surgery of hips and knees would be helpful for his mobility? Would you please give me a management plan for this patient?

Reply (same day)

Firstly, let me say that with a chest expansion of only 0.5 cm any surgical intervention would be fraught with danger. As he is pain free his ankylosing spondylitis is largely burnt out although I note his high ESR. I think the most important thing is to strengthen his upper limbs and shoulder girdle so that he can transfer from his wheelchair unaided. If he is able to sit reasonably comfortably I would not recommend any surgical interference. In view of the general state of his lower limbs I feel any surgery to provide mobility of his ankylosed joints would be doomed to failure. I know that people argue that spinal anaesthetics do not interfere with breathing but that is not my experience here. The respiratory effects are just as severe and surgery is to be avoided unless absolutely necessary.

Fig 8 Pelvic radiographs of CRP 027 (ankylosing spondylitis).

Fig 9 Knee radiographs of CRP 027.

Result (two emails)

The management plan was clarified and surgery was avoided on the basis of the advice received.