Telemedicine and Rural Health Care Applications

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ABSTRACT

Telemedicine has the potential to help facilitate the delivery of health services to rural areas. In the right circumstances, telemedicine may also be useful for the delivery of education and teaching programmes and the facilitation of administrative meetings. In this paper reference is made to a variety of telemedicine applications in Australia and other countries including telepaediatrics, home telehealth, critical care telemedicine for new born babies, telemedicine in developing countries, health screening via e-mail, and teleradiology. These applications represent some of the broad range of telemedicine applications possible. An overriding imperative is to focus on the clinical problem first with careful consideration given to the significant organisational changes which are associated with the introduction of a new service or alternative method of service delivery. For telemedicine to be effective it is also important that all sites involved are adequately resourced in terms of staff, equipment, telecommunications, technical support and training. In addition, there are a number of logistical factors which are important when considering the development of a telemedicine service including site selection, clinician empowerment, telemedicine management, technological requirements, user training, telemedicine evaluation, and information sharing through publication.

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For people living in the rural areas, the distance to main metropolitan centres often places restrictions on access to essential services, including specialist healthcare. Telemedicine provides one possible answer. Many different terms such as telehealth, telecare, online health and E-health have been used but they all have a common meaning, i.e. the use of information and communication technologies to deliver health care services at a distance.

The motivation for investigating the use of telemedicine for different clinical problems include large distances between patients and specialists, isolated health professionals requiring specialist support and/or education, and situations where there is no other alternative, for example space flight or patients at sea, as well as the pervasive and pragmatic issue of cost. Are health care dollars better spent on sending the clinician to the patient, bringing the patient to the clinician, or by facilitating the consultations using telemedicine?

Modern advances in information communication technologies have seen developments in the different mechanisms available for conducting telemedicine, from Morse code to the ordinary telephone and more recently the Internet. The different telecommunication networks required to support these communication technologies have also advanced. The plain old telephone system (POTS) is widely available in both industrialised and developing countries, cheap, well known and can support ordinary telephony, video telephony and Internet access. Newer digital networks such as the integrated services digital network (ISDN) and broadband technologies are becoming more widely available and more affordable for rural telemedicine.

In this paper we describe a range of telemedicine applications used in Australia as well as internationally with emphasis on health services which benefit people in rural areas. We also explain some of the principal logistical factors which should be considered during the conception of a new telemedicine service.

Reasons for doing telemedicine

The purpose for which telemedicine is used may be categorised as one or a combination of the following: clinical, educational and administrative.

For clinical services, sessions generally include interaction between clinicians (and may include or exclude the patient). For example, a primary health care provider could telephone a specialist to discuss appropriate clinical management of an unusual case. Alternatively, a digital image of an X-ray could be sent via email to a specialist to assist with diagnosis.[1]

For education, sessions may include the delivery of lectures and workshops to multiple sites using techniques such as videoconferencing, teleconferencing and web-casting.[2,3] In Queensland for instance, most videoconferencing equipment is currently used by hospitals for educational purposes.[4] Educational sessions may involve the delivery of a pre-recorded lecture (videotape or DVD) to a group of students at a remote site, or an interactive workshop conducted via videoconference involving several different sites simultaneously.

For administrative applications, communication between different sites for management meetings, interviewing interstate/international candidates for position vacancies, and keeping in contact with regional sites are all different types of telemedicine activity.[5]

In all cases, telemedicine is used to facilitate a service or activity for which the parties would normally have to travel.

Types of telemedicine

Regardless of the purpose, there are two main methods of conducting telemedicine, i.e. real-time and store and forward (Table 1). The choice of method depends on what information needs to be transmitted, the availability of the appropriate telecommunications resources and the urgency of the reply.[6]

Real-time

Real-time telemedicine allows participants to send and receive information almost instantly with negligible delay. A common example of real-time telemedicine is a discussion about a patient over the telephone. Videoconferencing is another example although it requires more expensive equipment. Videoconferencing has the added benefit of being able to view live video images. The advantage of real-time telemedicine is that decisions may be made immediately at the time of the session, and if additional information is required, the clinician can request it immediately. Real-time telemedicine can be valuable when a patient in a remote location is linked up to their specialist via videoconference for a clinical consultation.

Store and forward applications

The alternative to real-time telemedicine is "store and forward" telemedicine whereby information is encapsulated and then transmitted to the recipient for subsequent reply. This method is generally cheaper and more convenient. Examples include correspondence via E-mail, fax or the post. The main advantage of this form of telemedicine is that the recipient of the information can examine the material at their convenience. A common example of pre-recorded telemedicine is teleradiology, in which a digital X-ray image is transmitted to a radiologist for reporting.

Real-time telemedicine applications

Telepaediatrics

Telemedicine can be very useful for the delivery of specialist paediatric services, hence the use of the term telepaediatrics. The best known examples of telemedicine services for children are in cardiology,[7-9] fetal medicine[10-13] and psychiatry.[14,15] In terms of general telepaediatrics, i.e. encompassing all paediatric sub-specialties, the work conducted in Queensland represents the largest body of work reported in the literature to date.[16]

Since 2000, we have established and evaluated a novel telepaediatric service in Queensland, Australia (Figure 1). Queensland is the second largest state in Australia with a population of about four million people.[17] Given the large distances in Queensland and that the majority of specialist health services are located in the far south-east corner of the state, patients living in non-metropolitan areas must travel up to 2000 km for their specialist appointment. This usually requires hours of driving by car or expensive travel by rail or air. If patients must travel to see a specialist, the health department in Queensland provides funding to subsidise the costs associated with transportation and accommodation. These costs amount

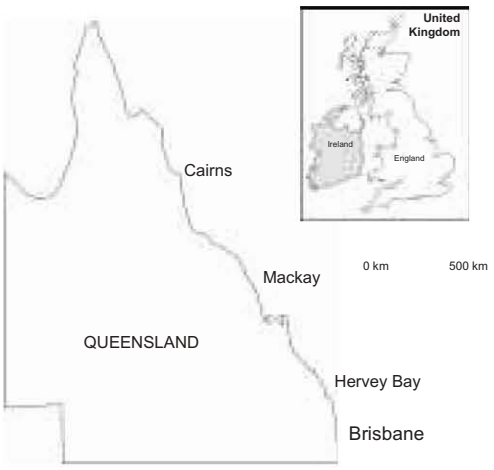

Figure 1: Queensland Map showing distances

Table 1: Telemedicine examples: store and forward and real-time

Purpose	Store and forward	Real-time
Clinical	Digital images may be sent via email direct to the specialist for diagnosis and management advice, e.g. teledermatology, teleradiology.	Videoconferencing may be used for clinical consultations involving the patient, primary care provider (General Practitioner) and specialist at a tertiary hospital.
Educational	Educational material can be sent by mail in the form of tutorial notes, audio or video resources.	Lectures can be transmitted via videoconference to multiple sites simultaneously.
Administrative	Memo and meeting notes may be mailed by post or fax for perusal at a time that is convenient for the recipient.	Telephone conferencing may be used for interactive discussions between participants.

to more than $25 million per annum.[18]

The telepaediatric service provides convenient access to specialist paediatric services. Referrals are easily made by calling a single (toll-free) telephone number, a direct link to the telepaediatric service. The referral is coordinated and a guaranteed response made to the referring clinician within 24h. More urgent cases have been responded to by specialists within one hour of referral (e.g., cardiology).[19]

A range of communication technologies are used - including email, telephone correspondence and videoconferencing. Around 85% of all referrals, result in a consultation via videoconference.[20] Consultations 'at a distance' are delivered via dedicated digital telephone lines (ISDN) at a preferred bandwidth of 384 kbit/s using standard videoconferencing equipment. The telepaediatric service enables clinicians, children and their families to 'link up' via videoconference with specialists at the Royal Childen's Hospital (RCH) in Brisbane (Figure 2).

We have conducted over 3000 consultations for children living in regional and remote areas of Queensland. More than 35 different paediatric sub-specialties are offered, including burns (Figure 3), cardiology, diabetes, ENT (ear, nose and throat), nephrology, neurology (Figure 4), oncology, orthopaedics, psychiatry and surgery.

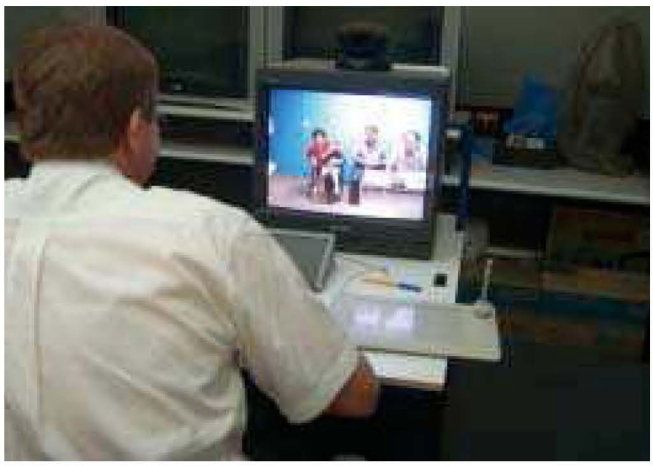

Figure 2: Discussion via videoconference between family and paediatrician (on screen) and specialist

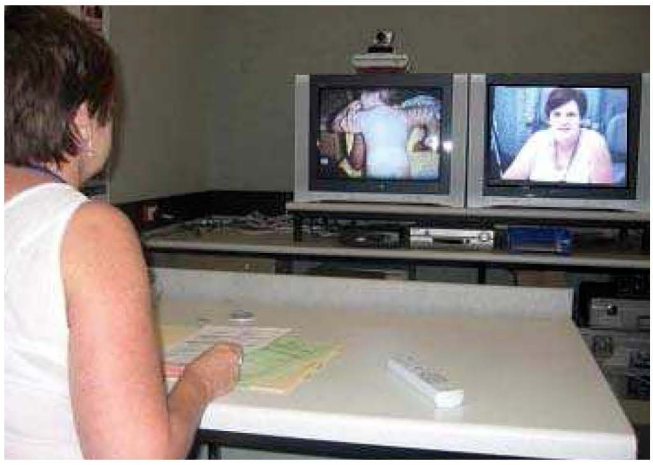

Figure 3: Post-acute burns care via videoconference

In terms of the economics of telepaediatrics, it is likely that substantial savings are made by the health department in the form of reduced expenses associated with reduced patient travel. A preliminary cost analysis showed that during a three year period the total cost of providing telepaediatrics was about $740,000 compared with the estimated cost of almost $1.1 million had all patients been transferred to Brisbane for their appointment.[21]

A study of family costs showed significant savings for families who were able to attend a specialist appointment in their regional hospital (via videoconference), compared to families who travelled to Brisbane to see the specialist in person. Regional families were also saved time, personal expenses and stress associated with having to travel to Brisbane.[22]

The success of the telepaediatric service is most likely due to a number of factors. These include the unique model used to receive and respond to referrals, the role of the telepaediatric

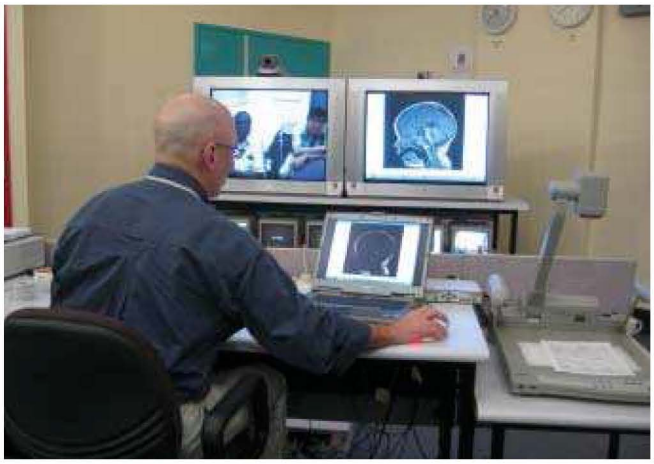

Figure 4: A paediatric neurologist discusses the results of an MRI scan during a telepaediatric consultation

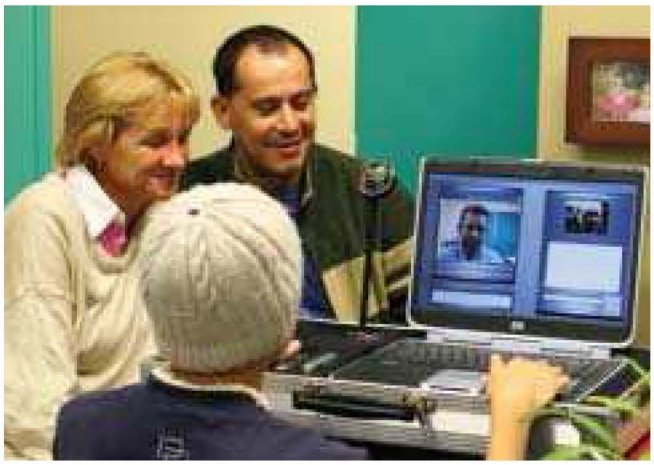

Figure 5: An example of remote consultation via videophone between the family home and a hospital specialist

coordinator who ensures a response by a specialist for each referral, the establishment of videoconference facilities which are suitable and accessible in a venue appropriate for clinical work, the ongoing evaluation and publication of results which provides valuable evidence of cost-effectiveness and for decisions related to funding. The enthusiasm and support of all regional clinicians and specialists involved in the service has no doubt been a key element of the telepaediatric service, and the support of the hospital executive at the RCH and participating hospitals has also been invaluable.

Home telehealth

In the previous example the use of relatively high bandwidth telemedicine systems to deliver health services in rural areas has been described. In this case individuals in a rural hospital consult with individuals in a tertiary hospital. With an ageing population and changing health problems there is a growing trend and necessity to treat patients at home. Home health care has been defined by the World Health Organization (WHO) as the "provision of health services by formal and informal caregivers in the home in order to promote, restore and maintain a person's maximal level of comfort, function and health including toward a dignified death".[23] The possibility for telemedicine to be applied to home health care is an area of increasing interest. This is commonly referred to as home telehealth.[24]

There are many examples of investigations into home telehealth in the research literature including asthma,[25] cardiac disease,[26] diabetes,[27] heart failure[28] and smoking cessation.[29] For many of these applications the ordinary home telephone has been used. The telephone is arguably the most readily available, financially attractive and easy to use device for home telehealth. Even when the telephone itself is not used, the home telephone line provides adequate bandwidth for video telephony,[30] transmission of ECGs[31] and other clinical information such blood pressure,[32] and blood glucose levels[33] as well as access to the internet for counselling[34] and other services.[35]

Our own investigations into the use of videophones for the clinical and psychosocial support of children and their families in their homes[36, 37] use readily available technology (personal computers, web cameras, modems and NetMeeting software) and the ordinary home telephone line (Figure 5). Telemedicine does not have to be expensive or complicated. Simple commercially available technology can be used. Like-

Figure 6: Demonstration showing how the videoconference camera and the telephone are used for communication with the specialist

Figure 7: This photograph was sent to an orthopaedic surgeon for advice regarding appropriate clinical management

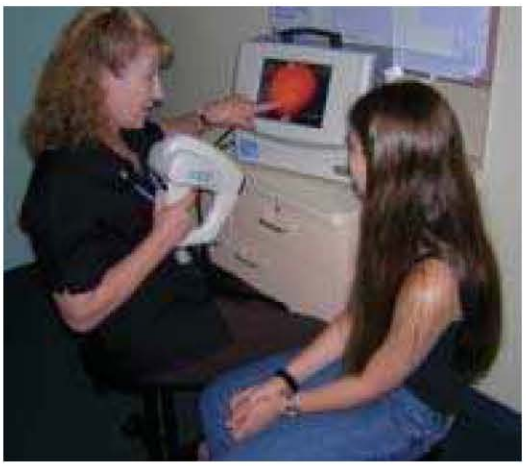

Figure 8: Digital images of the retina can be collected by a trained operator and e-mailed direct to a specialist for assessment

Figure 9: Radiological images are viewed via an image database

wise, the focus does not have to be on hospital-based care but can instead extend directly to the patient's home.

Critical care telemedicine for newborn babies

The increasing availability of broadband networking is permitting the potential transmission of high-quality, real-time video for a range of clinical applications. While, typically, videoconferencing via digital telephone lines (ISDN) has been carried out at bandwidths from 128 to 384 kbit/s, broadband networking has the potential to deliver multi-megabit connectivity at a comparably low cost. [38]

In Queensland, a pilot study is underway to investigate the feasibility and benefits of a telemedicine service for critically-ill children. Depending on geographical location, newborns and younger children with serious health conditions are cared for at one of three main paediatric tertiary facilities. Two of the facilities are in the capital city of Brisbane and the third is about 1400 km north of Brisbane in Townsville. Whilst access to these facilities is very convenient for families living nearby, a substantial proportion of children needing specialist health care live long distances away. As a consequence, these children may require urgent transfer to the nearest paediatric tertiary facility. Transportation may involve road ambulance, fixed wing aircraft and/or helicopter. Neonatal retrieval is a specialised activity with high costs associated with transport, medical and nursing support. For parents and families, the emotional stress of transfer and admission of their baby to an intensive care unit is considerable. When an urgent transfer is being arranged, communication between the rural hospital and specialist facility is typically carried out by ordinary telephone. The condition of the child is discussed as well as an appropriate clinical management plan prior to retrieval by the specialists. The main disadvantage of this process is that the specialists have no way of viewing real-time video images of the baby, medical imaging results or test results.

Preliminary work in the Centre for Online Health (COH) has investigated the use of real-time video to augment the existing telephone communications for urgent neonatal consultations. The telemedicine application is based on a mobile telemedicine cart which may easily be positioned adjacent to an incubator (Figure 6). An IP videoconferencing camera attached to the mobile trolley provides real-time (25 frame/sec at 10 Mbit/s) views of the baby across a computer network. Full remote camera control is available to the specialist in the tertiary hospital. On lower bandwidth links the camera provides similar functionality but at a lower frame-rate directly proportional to the available bandwidth. Initial experiences with both dummy and live patients have been very encouraging with the ability to evaluate chest movements, patient morphology and skin colour. [39] The system has also been successfully used to capture and transmit X-ray and ultrasound images displayed on conventional light box and LCD screens.

Store and forward telemedicine applications

Despite the obvious advantages that real time consultation provides it may not be appropriate in all situations. Store and forward techniques may provide a viable alternative when, for example, consulting individuals are not available at the same time.

Telemedicine in developing countries

Despite suggestions that telemedicine will offer great hope in developing countries there is only limited published evidence to support this claim. One good example of telemedicine which has proven feasible and useful in developing countries is the service founded and operated by the Swinfen Charitable Trust (SCT).[40,41] Since 1999, this service has provided free medical advice to doctors and other health professionals working in about 20 countries including Bangladesh, Bolivia, Ethiopia, Iraq, Nepal, and the Solomon Islands. Technological requirements for the service include a standard digital camera and a computer with access to e-mail via the Internet.[42,43]

Referrals to the SCT are made by sending an E-mail direct to a single email address. All e-mails sent to this address are managed 24 h per day by administrators based in the UK (London) and Australia (Brisbane). E-mail messages sent to the SCT may include attachments such as digital photographs to support the cases being presented. Depending on the cases referred, e-mail referrals are directed to an appropriate specialist registered on a database set up by the Trust. (Figure 7) is an example of a digital photograph sent to the SCT as part of a referral and subsequently forwarded to an orthopaedic surgeon for advice. The SCT is supported by an international contingent of about 180 volunteer specialists representing more than 60 different specialist fields.

Since the service began in 1999, more than 1000 cases have been dealt with via e-mail. The considerable growth in the service has prompted the development of automatic message handling software (AutoRouter) to manage some of the administrative tasks associated with the coordination and monitoring of referrals. [44] The AutoRouter is particularly useful for ensuring that dialogue between the referring doctor and the specialist is routed appropriately, and for alerting the administrators when a response is not received within a reasonable period of time.

Retinopathy screening via e-mail

Telemedicine can also be valuable for the screening of chronic health conditions such as diabetes and related complications such as diabetic retinopathy (DR). DR is a leading cause of vision impairment and blindness in all people who have diabetes. This specific microvascular complication is asymptomatic in its early stages. Routine eye screening, accurate diagnosis and intervention can reduce the risk and the progression of DR.[45] A common problem in most countries is that specialist ophthalmology services are generally located in the capital cities and major regional towns. This limits access for those people with diabetes who live in rural and remote communities, especially indigenous communities who have a higher prevalence of diabetes and related to diabetes complications.[46]

A number of studies on diabetic adults in rural and remote communites have been undertaken using store and forward techniques and a non-mydriatic digital retinal camera.[47,48] The

results have shown that this technique is applicable to retinal screening and assessment that in turn facilitates access to appropriate eye care services for rural and remote people with diabetes.

We have established a telepaediatric diabetic retinopathy screening program for selected rural areas in Queensland.[49] The program is staffed by a registered nurse specially trained in the use of the retinal camera and she is responsible for doing screening in the clinics in the rural communities (Figure 8). Images are stored and sent by e-mail to a paediatric ophthalmologist who makes an assessment. Although a non-mydriatic retinal camera can be used by a non-medical person, an appropriate level of training in the use of the camera is required in conjunction with regular training updates.

Teleradiology

Teleradiology is the electronic transfer of radiographic images from one location to another. Teleradiology may be used to provide radiology services to an underserved community, but can also be used to provide specialist medical opinions regarding the treatment and management of patients in these communities. One study found that when Computed Tomography (CT) scans of brain-injured patients were reviewed by a neurosurgeon via telemedicine, unwarranted patient transfers to a tertiary centre were reduced by 21% and adverse events, such as hypoxia and hypotension during transfer, were reduced by 24%.[50] The latter resulting from appropriate advice from the neurosurgeon prior to the transfer.

Teleradiology via e-mail

Teleradiology can be implemented by attaching a digital camera image to an e-mail. The image is obtained by photographing an X-ray film on a light box. In a South African study the accuracy of this form of telemedicine was measured. The results of this study showed that in 94% of cases the reports made via telemedicine were comparable to the reports made on the original film.[51]

Dedicated teleradiology systems

Dedicated teleradiology systems can be purchased from numerous vendors. These systems vary in cost, complexity and image quality. A teleradiology system consists of the following components:

- Image acquisition modalities.
- Image server–that compresses and transmits images
- Telecommunication network–this could be a Local Area Network (LAN) or a broadband internet connection
- Receiving station–that receives images transmitted from an images server and displays them on a coupled display station or serves archived images for multiple networked display stations (Figure 9).

Web-based teleradiology

The main advantage of web-based teleradiology is that dedicated image display software does not need to be installed on the reviewer's computer; instead images are displayed inside a standard web browser, e.g., Microsoft's Internet Explorer. Web-based teleradiology is increasingly being used by dedicated teleradiology service providers. These groups are not affiliated to one particular hospital but provide radiological reporting services for multiple institutions, often providing after hours-service to an institution from radiologists located in other times-zones. There are reports of external teleradiology service providers who are used to service hospitals in the United States (US) particularly for the review of emergency cases.[52]

CT scans are performed in the US and the images are then transmitted to a US-board-certified radiologist working in Bangalore, India for reporting. The resultant radiologist's report is transferred back to the referring doctor in the US. For CT head scans reported via this teleradiology service, the final radiologist's report was available in less than 40 minutes, which included an image transmission time of 6 min.[53]

Logistical factors

There are a number of important logistical factors to be considered when developing a telemedicine service. An overriding imperative is to focus on the clinical problem first with careful consideration given to the significant organisational changes which are associated with the introduction of a new method of service delivery. Expensive mistakes have been made. Even the most advanced equipment will lie idle if it cannot be integrated effectively and efficiently into the routine work flow of clinicians. In addition, for telemedicine to be effective it is important that all sites involved are adequately resourced in terms of staff, equipment, telecommunications, technical support and training.

For those contemplating the development of a telemedicine service the following principles described by Yellowlees[54] are useful:

Telemedicine applications and sites should be selected pragmatically, rather than philosophically

- In developing a telemedicine service, identify telemedicine champions who are keen and prepared to participate in the service.
- Give these clinicians all the support they require and consider gradual development of the service as the enthusiasm grows.
- Clinician drivers and telemedicine users must own the systems
- Acknowledge the importance of the clinical staff driving the telemedicine service and involve them in as much of the planning of the organisational aspects of the service as possible.
- Give clinicians ownership of the telemedicine service.

Telemedicine management and support should follow best-practice business principles

- Do not introduce another layer of management or a special project team to 'manage' the telemedicine service. These teams tend to lack clinical expertise and telemedicine experience and focus on policy before practice.
- Telemedicine services should be treated like all other health services and influenced by the normal management struc-

ture.

The technology should be as user-friendly as possible

- Ensure that the telemedicine equipment is easily accessible and clinician-friendly.
- If equipment is difficult to access or to operate, clinicians are less inclined to be involved.

Telemedicine users must be well trained and supported, both technically and professionally

- Training is very important. Routine training should be provided and adequate technical support should be available at all times to ensure that clinicians are able to deliver services without concerns for technical complications.
- Telemedicine applications should be evaluated and sustained in a clinically appropriate and user-friendly manner. Evaluation is very important for all telemedicine services to ensure that the effectiveness of the programme is being measured.
- Aspects should include feasibility, clinical effectiveness (diagnostic accuracy), user satisfaction, and cost-effectiveness.

Information about the development of telemedicine should be shared

- Despite the growing amount of literature on telemedicine, there remains a substantial amount of anecdotal evidence which lacks quantitative data.
- Regardless of whether results are positive or negative, they should be published for others to learn from these experiences.

Conclusions

Telemedicine offers great opportunity as an alternative method of health service delivery to rural areas. Although there are many examples of successful telemedicine applications in a wide range of clinical practice settings, more research is required to prove clinical and cost effectiveness. While considering a new telemedicine application, it is important to consider a range of logistical factors. A common and expensive mistake for telemedicine service developers is to focus entirely on the technology. It is essential that one considers the significant organisational changes that are required for telemedicine to be integrated as a mainstream health service. There should always be a clear reason for doing telemedicine, such as a proven clinical problem where online communication technologies may be helpful for the delivery of a health service. The telemedicine service should be subject to robust evaluation to determine the benefits over conventional services for the health service provider, the consumer and for society as a whole. It is recommended that new services be piloted on a small scale and gradually developed if proven beneficial. To conduct telemedicine successfully, it is important that all sites involved are well-resourced with the appropriate personnel, equipment, telecommunications, technical support and training.

Acknowledgments

The Centre for Online Health is one of the few research and teaching centres in the world, which focus on the evaluation of telehealth for the delivery of health services. For further information, visit our website: www.uq.edu.au/coh. We thank the Commonwealth Department of Health and Ageing (Medical Specialist Outreach and Assistance Programme), Queensland Health and the Royal Children's Hospital Foundation for funding and support.

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