Teleradiology at a children's hospital: a pilot study

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Summary

- A teleradiology pilot project was conducted by Royal Alexandra Hospital for Children, Camperdown, and Nepean Hospital, Sydney, a distance of 48 km.
- 575 paediatric X-rays at full resolution were transmitted over a three-month period.
- The results demonstrated that it was possible to transmit paediatric chest images of diagnostic quality in a reliable and secure manner. The images were transmitted in an average time of 3.2 minutes per image, which was considered to be an acceptable level of service.
- Costs were analysed in terms of transmission, equipment, maintenance and staff components. The results indicated that the cost per image transmitted would vary from $83.44 for 2,500 images per year to $34.00 for 10,000 images per year.
- Experience with the pilot study suggested that the introduction of secure high-quality paediatric telemedicine into the Australian health communications network is feasible. Adoption of such technology would have major implications for paediatric health care, including improvements in patient management due to a quicker diagnosis and earlier intervention, and savings through avoiding transfer of some emergency cases.

Introduction

Telemedicine, the provision of medical services through the use of a communications system, has the potential to provide both routine and specialist services to patients in rural and remote areas of Australia. This technology is seen as being of particular use in the management of paediatric patients. There is often a requirement for urgent treatment of accident and emergency cases, but specialist facilities are usually located in a central hospital in a capital city.

However, consideration of the introduction of telemedicine services for paediatric patients in remote areas needs to be examined in conjunction with an existing system for the provision of specialist medical services. The present system has developed in conjunction with professional bodies, health departments and the Medicare arrangements. Any proposed variation to existing arrangements needs to consider the interaction of new telemedicine services and existing specialist services.

There is also a need to examine the technical capabilities of telemedicine technology—including communications, hardware and software—to determine whether the technology can be used to assist in the provision of services in a timely and cost-effective manner. It is in this context that a pilot project in the provision of telemedicine services was undertaken by Royal Alexandra Hospital for Children (RAHC) in Sydney.

This report describes the pilot project, with particular reference to cost data, updating an earlier description of the study.[1]

At the time of the study, the RAHC was in the process of moving from Camperdown to a new hospital, located on the Westmead campus, and was implementing the concept of a filmless radiology department through the acquisition of a Picture Archiving and Communications System (PACS). This is a capital-intensive exercise and it is important that full use be made of the image database once it is established. Warburton has noted that a major advantage of PACS is its ability to provide teleradiology services to remote areas, with the central hospital PACS acting as a hub in two-way communication with remote country centres.[2]

As RAHC provides a State-wide paediatric service, often involving the transfer of patients and supporting relatives from remote hospitals to Sydney, a decision was made by the hospital to conduct a pilot teleradiology project to test the technical feasibility of providing remote paediatric diagnostic services. In 1992–93, the hospital received 32% of its admissions from rural New South Wales and interstate locations (5,738 patients). At least 10% of admissions to the Intensive Care Unit were non-metropolitan in origin. A sizeable proportion of patients at the hospital therefore come from areas outside metropolitan Sydney. Transfer and admission of these patients creates inconvenience to them and their families and additional costs for the health system. Availability of a rapid information link through teleradiology offered the potential to avoid transfer of a proportion

of patients from outside Sydney, with treatment being undertaken at hospitals closer to their homes.

The cost of equipment and support services, the reliability of communication services, and the quality of transmitted images were of major interest. Of equal concern were the organisational issues of how the provision of teleradiology services would fit in with the existing hospital systems for the management of patients, and what effect the introduction of the new technology would have on hospital staff who were using it.

The objectives of the teleradiology pilot project were

- to establish if communications systems would allow transmission of high-quality X-ray films in a secure and reliable manner;
- to establish if equipment was available to digitise and transmit high-quality X-ray films at a level suitable for subsequent diagnosis by a specialist at a central workstation; and
- to document the costs involved in the conduct of such an exercise.

A subsidiary objective was to provide both clinicians and management at RAHC with experience in the operation of a teleradiology system in order to assist in considering the introduction of similar systems to the new Children's Hospital at the Westmead campus. Also, the organisations assisting with the project—Telecom, Kodak and Network Designers—would gain valuable operational experience in the design, installation, operation and support of a teleradiology system.

Organisational issues

It was recognised that existing courier services provided an effective service to many centres and that the major benefit of teleradiology was likely to be in an emergency situation. In order to provide an effective routine teleradiology service, there would be a need for 24-hour on-call access to a radiology registrar at RAHC and for on-call access to paediatric specialists in intensive care. The establishment of such organisational arrangements for the pilot project was not envisaged. It was decided that existing procedures for the clinical management of patients would continue, with the focus of the study being on technical performance, cost and ease of use of the teleradiology system.

One of the main reasons for the decision not to impact on existing diagnostic services was the complexity of the current service delivery arrangements. There have been historical difficulties associated with attracting specialists, both radiologists and paediatricians, to work in country areas and there is a perception that the provision of teleradiology services has the potential to alter the existing balance between country and city hospitals.

Apart from professional and economic aspects, there are also considerations of legal responsibility, authenticity of images and patient privacy, which have not yet been resolved in the Australian health care setting.[3] In the selection of a remote site to cooperate in the conduct of the pilot project, it was necessary to

strike a balance between the need of paediatricians at smaller centres to have prompt access to specialist advice, and the need to establish the technical feasibility of teleradiology without affecting existing arrangements.

It was agreed that the usual approach to the clinical management of patients would continue and that, after diagnosis had been completed, the X-ray images would be digitised and transmitted to RAHC for technical evaluation as to quality of image. After a suitable period, the same radiologist at RAHC would obtain access to the original films at the remote hospital and report on these. Subsequently, a Receiver Operating Characteristic (ROC) study would be performed to compare the effectiveness of the two systems.

Technical issues

While it was recognised that it is possible to use existing dial-up Telecom services (19.2 Kbps) to transmit compressed images in under two minutes, it was considered that full-resolution chest X-rays should be transmitted in uncompressed format using Telecom's ISDN service, Microlink, at the rate of 128 Kbps. This would require a transmission time of up to 10 minutes for a 35 x 43 cm chest X-ray.

This approach was arrived at after discussions with Telecom, having regard to cost, availability and reliability of communications services throughout the State. High-speed data services such as FASTPAC (2 Mbps) could have been used to transmit uncompressed chest X-ray images in under one minute, but it was recognised that these services were not universally available and were relatively expensive for low-volume applications. The transmission time would be only one element of the overall procedure. A more critical technical parameter was image quality, leading to the decision to use Microlink to transmit full-resolution, uncompressed, digitised chest X-rays.

Details of the pilot study

A decision was made to proceed with a trial of the use of teleradiology between RAHC and Nepean Hospital. All paediatric studies conducted at Nepean during the period July–September 1993 would be transmitted to RAHC in order to allow an overview of a range of paediatric X-ray examinations, and thus test the technical capabilities of the teleradiology system. A subset of paediatric X-ray images with known pathology, selected from the RAHC film library, would also be transmitted from Nepean Hospital in order to ensure that cases of sufficient complexity were included in the study.

Equipment installation

Assistance was provided by Telecom for communications and by Kodak (Australasia) Pty Ltd for X-ray film digitising and image viewing equipment. Kodak also arranged for assistance from Network Designers to supply ISIS Access Server Kits to connect the Kodak equipment to the ISDN facilities provided by Telecom.

The teleradiology equipment provided by Kodak included a film digitiser and quality control workstations at Nepean Hospital and a two-monitor workstation at RAHC. In order to connect the viewing workstations to the ISDN service, it was necessary to aggregate two 64 Kbps lines using a Network Designers ISIS Access Server Kit and a 386 personal computer at each site.

System operation

From the outset it was decided that images should be sent at full resolution without the use of compression techniques, in order to ensure that the image used for diagnosis at RAHC was as close as possible to the original X-ray film. A 35 x 43 cm film, digitised at 2K x 2.5K resolution with 12 bits (4096 levels) of Grey Scale resolution, would comprise some 10 MB of data. At a transmission rate of 128 Kbps, this would take approximately 10.4 minutes. As it turned out, the majority of X-ray examinations were of paediatric chests and used small films, resulting in approximately 3.2 MB per image, which were transmitted at an average time of 3.26 minutes.

It was considered that a delay of 3–5 minutes in the transmission of an image would be acceptable in an operational teleradiology system, as Nepean Hospital could contact RAHC in an emergency and advise that an image was about to be transmitted. It would then be possible for a paediatric specialist at RAHC to be contacted in order to be on hand by the time the image, supported by case notes sent by fax, was transmitted for diagnosis at the RAHC workstation. A diagnosis could be performed and a report made by telephone to Nepean Hospital, to be confirmed by a later written report. The ISDN service was considered to be

suitable, therefore, for operational requirements, having transmission speeds of under 5 minutes per uncompressed image.

Privacy impact statement

A number of steps were taken to ensure the privacy of patient records during transmission, as follows:

- Only authorised staff at the Nepean Hospital Radiology Department had access to X-ray films.
- Each case was allocated a coded record number before transmission, with the master list retained at Nepean Hospital.
- A removable patch was placed over identifying data on the X-ray film before digitisation.
- A password protection system was implemented at each end to ensure that only authorised persons either transmitted images or had access to them at RAHC.
- A second password was installed between each Access Server to ensure that only authorised persons could contact the workstations at RAHC. This feature was implemented to prevent random access to the RAHC workstation by unauthorised users or random hackers.
- The workstations were located in a secure area within the Radiology Department of each hospital.
- Images were stored on magnetic disk in a coded format and were destroyed after being reported upon.
- Reports on the images were recorded on coding sheets under the coded record number, and the reports held in a secure area.

These procedures were approved by the Ethics Committee of the Australian Institute of Health and Welfare and by the appropriate administrative area at each hospital.

Establishment of the teleradiology service

The pilot project involved the establishment of tele-linkages in parallel within RAHC itself (in the Radiology Department and the Neonatal Intensive Care Unit) and at Nepean Hospital. The distance between the hospitals is 48 km. X-ray images obtained at Nepean required digitisation at the remote site using a Kodak film scanner. All diagnostic images were viewed at RAHC upon their transmission on a Kodak PDS workstation. Transmission of additional patient information, such as clinical history and examination details, pathology results, blood tests and ECGs, was by fax or telephone.

Results from the pilot study

A total of 575 paediatric X-ray images were transmitted from Nepean Hospital to RAHC during the three-month period. The quality of the images was examined by an experienced paediatric radiologist and was considered to be suitable for diagnostic purposes. A report was made on each image and these reports will be compared with the actual reports made on the original X-ray films at a later date.

Cost analysis

Transmission and facility costs

Actual transmission costs were modest. The average time for the transmission of a paediatric X-ray image (average size 3.2 MB) was 3.26 minutes, at a transmission cost of $0.65 per image. There were overheads associated with maintenance calls by technicians during service and maintenance of the teleradiology facility, which amounted to $0.23 per image. Other overheads, of $0.04 per image, resulted from unsuccessful attempts at image transmissions (e.g. because of a disk at RAHC being full). The average transmission cost per image was therefore $0.92.

In addition to image transmission costs, there were installation and rental costs associated with the Telecom Microlink service, involving an installation charge of $360 per end and an annual access charge of $912, or a total of $5,280 over five years (undiscounted). Assuming an annual image transmission volume of 2,500 images per year, this would result in an installation and rental cost of $0.42 per image over a five-year period. This figure would decrease if transmission volumes were to increase in a fully functioning teleradiology system. The cost of other communications such as telephone and fax has not been included in the analysis, on the assumption that these facilities would be only a small part of the normal communications between two hospitals.

Based on these results from the three-month trial, the transmission costs for an annual volume of 2,500 images of 3.2 MB uncompressed paediatric images, using Telecom Microlink 128 Kbps service over a distance of 48 km, were estimated as $1.34 per image.

Equipment costs

The cost of the teleradiology equipment used in the trial, and listed in Table 1, was approximately $520,000, including capital equipment, minor fittings and local wiring of electrical services. On the basis of straight line depreciation over five years, there would be a capital cost of $104,000 per year. A 24-hour on-call maintenance contract would involve 15% of capital costs or $78,000 per year, resulting in a depreciated capital and maintenance cost of $182,000 per year. At an annual volume of 2,500 transmitted images per year, the average equipment and

maintenance cost per image would be $72.80. However, a more realistic annual volume for an established teleradiology service between the two centres would be 5,000 images, as both hospitals emerged from a learning environment. At that rate of use, equipment and maintenance cost per image would be $36.40.

A full-scale teleradiology service would serve more than one hospital and there would be economies of scale in that the equipment at RAHC would be connected to a number of users. For example, extending the teleradiology service to another remote site would reduce equipment and maintenance costs to approximately $30 per image, at an annual volume of 10,000 images (Table 2).

Staff costs

The experience during the trial was that there was a considerable amount of radiographer time involved at Nepean Hospital in managing the system. Radiographers were involved in selecting X-ray films, allocating unique master codes and attaching labels to films to protect patient privacy, operating the film digitiser (including the preparation of bar-code labels) and performing quality control on digitised images. They maintained contact with RAHC and operated the image transmission system, including fault finding and retransmission of images as required. Similarly, there was a need for radiographer participation at RAHC to ensure that successful image transmission had occurred, to assist in resolution of system problems and to record and code transmitted images.

While there will often be a higher level of staff involvement in a trial project as compared to an operational situation, it was considered that an allowance of 0.3 FTE of a radiographer's time should be made for managing the remote end of the transmission system and up to 0.2 FTE at the receiving end. This would amount to 0.5 FTE of a radiographer's time and, with salary and overheads, is estimated at $15,000 per year or $6 per image, allowing for 2,500 images per year. With greater familiarity with the teleradiology system, radiography staff might be able to manage an increased volume of images more efficiently and, at a throughput of 5,000 images per year, the staff component may decrease to approximately $3 per image.

Estimated total costs per image for a teleradiology system might, therefore, vary between $80.14 and $34, depending on the level of use (Table 2).

Table 1: *Costs of a teleradiology service, based on equipment used in pilot project*

Item	Total cost	Annual cost[(a)]
Nepean Hospital		
Kodak Film Digitiser (FD-1)	$240,878	
Quality Control Workstation (Kodak PDS-2)	$94,667	
RAHC		
Image Reporting Workstation (Kodak PDS-1)	$165,333	
Network Designers Access Server Kits (2)	$11,860	
Personal Computers (2)	$6,000	
Installation	$1,300	
Total equipment cost	**$520,038**	**$104,000**
Maintenance (15% of list price)		$78,000
Total cost		**$182,000**

(a) Depreciation over 5 years.

Table 2: *Estimated costs per image of a teleradiology service*

	Trial	Routine operation	Additional site
Images per year	2,500	5,000	10,000
Transmission cost per image	$1.34	$1.13	$1.00
Equipment cost per image	$72.80 ($18.00)	$36.40 ($9.00)	$30.00 ($5.25)
Staff cost per image	$6.00	$3.00	$3.00
Total cost per image	**$80.14** **($25.34)**	**$40.53** **($13.13)**	**$34.00** **($9.25)**

Note: Figures in brackets represent costs based on more recently available systems.

User requirements

Following a review of the use of the teleradiology system at Nepean Hospital, a number of points emerged relating to user requirements for efficient systems operation. These point to the need for suppliers to understand, service and maintain relatively sophisticated equipment, often installed in remote locations, and to provide adequate training and support to first-time users. Brief details are given here; a fuller description has been published elsewhere.[1]

Screen messages

A major point made by users was that their first point of contact with the teleradiology system is the messages displayed on the computer screen of the image workstation (Personal Display Station). If these messages are not clear, then the user is left with a feeling of frustration and a disinclination to use the system.

There are good reasons from the suppliers' point of view as to why the messages might be generic in nature, relating to the complex nature of transmission and communications systems.

While it is usually possible to isolate subsequently any faults in the ISDN service, the automatic location of other faults in real time presents difficulties. Therefore, when a teleradiology system is not operational for any reason, a generic message is usually displayed and it is only by experience, in cooperation with the supplier, that the user will learn what series of actions to take to resolve the problem.

Site-to-site communications

Other problems were encountered related to site-to-site communications. For example, on some occasions, the receiving end was not switched on or images could not be sent because there was not enough hard disk space at the receiving site. Clearly, a message indicating the amount of free disk space on the receiving end would be helpful, as the size of the disk is limited to 1.3 GB which provides space for approximately 200–300 images at any one time.

While the disk capacity can always be increased (up to 5 GB, if required), in routine teleradiology operations there will be competition for disk space and a message on the amount of free space available should be displayed at the sending station.

Support and maintenance

A factor which emerged from the trial is the need for a structured support system to provide assistance to the user of the teleradiology system on a 24-hour, 7 day a week basis. One of its principal uses will be in emergency situations, where X-rays are transmitted to a specialist at a central hospital for advice on how to manage a critically ill patient. In this situation, any operational problems encountered with the teleradiology system must be resolved quickly or it will be bypassed and the patient transported from the base hospital to the specialist centre.

For the trial, Kodak had designed and implemented a structured support system to satisfy this eventuality. Both the Nepean and Camperdown sites were connected to the Kodak System Response Centre in Coburg, Victoria, which provided a 24-hour service to resolve problems. As discussions by telephone might be necessary, the system also had a dial-in facility so that the Kodak Centre could connect to the teleradiology system and run diagnostic tests. Once the particular problem was identified, one of three trained field engineers could be called to the particular site (e.g. Nepean), if necessary.

As well as computer and engineering support, training in operation of the teleradiology system was provided by an experienced Kodak account manager who was assisted by account representatives, one at Nepean Hospital and another at RAHC. These people were responsible for day-to-day contact with each hospital to conduct initial training, to resolve minor problems as they arose and to provide a higher level of ongoing training as users became more familiar with the operation of the system.

A troublesome problem that can occur with teleradiology systems is the introduction of scanning artefacts on the image during the process of film digitising. If, for example, the artefact takes the form of a straight line, it may be misread as a fracture in a bony surface when, in fact, a fracture is not present. Image artefacts may be introduced at any part of the complex links throughout the image scanning and transmission system, but the most likely cause is in the film digitiser itself. In the trial, artefacts were detected on images on two separate occasions and were resolved, one by power supply voltage adjustments to the Kodak Film Digitiser (FD-1) and the other by physical cleaning of the optical scan path.

The Telecom ISDN service encountered no transmission problems during the period of the trial. The Microlink service operating at 128 Kbps was shown to be suitably reliable for the transmission of images.

Establishment of organisational procedures

Apart from equipment reliability and support and the performance of the ISDN communications service, the major requirement for a successful teleradiology service is the establishment of a working protocol between the remote site and the central hospital. This involves not only training personnel in the use of the system but also setting up hospital arrangements so that appropriate specialist staff can be contacted in an emergency.

While there are many points that might be made about the coordination of complex medical services, the point that stands out from the trial is the need for cooperation and good working relationships between the sites to ensure that the relatively minor but frustrating problems that arise from time to time are resolved quickly in a mutually supportive manner.

Discussion

Experience with the pilot study suggests that the introduction of secure high-quality paediatric telemedicine into the Australian health communications network is feasible and also realistic in terms of cost. Adoption of such technology would have major implications for paediatric health care in Australia, including:

- An improvement in paediatric patient management and the potential for better patient outcomes, due to quicker diagnosis and earlier intervention as a result of the timely enlistment of specialist paediatric expertise. In a number of cases, this intervention would occur at the sending hospital, thus avoiding the estimated $7,000 of a costly patient transfer.
- When transmission resulted in a diagnosis where patient transfer was necessary, the receiving hospital might be better prepared to quickly manage the patient.
- A new choice in the way that paediatric specialist expertise was provided to non-metropolitan hospitals. This might help to ease the problems caused by the difficulty of attracting specialists to the more isolated country areas. At the same time, it would support those specialists and general practitioners who are in such areas and finding it increasingly difficult to acquire and maintain current paediatric clinical knowledge.

The pilot project estimated the cost of providing a fully functioning teleradiology service capable of transmitting paediatric chest X-rays in uncompressed form at high resolution.

Apart from providing a specialist paediatric service to a remote location, one of the aims of an operational teleradiology service is to avoid the unnecessary transfer of paediatric patients, and supporting parents or relatives, to a central hospital. When emergency air services are used, the overall cost of a transfer is estimated to be of the order of $7,000–$10,000. Some 20 transfers per year, a not-unreasonable expectation, would need to be avoided for a financial break-even situation to occur.

In addition, it would be important to consider the value of the intangible benefits of providing a 24-hour specialist paediatric diagnostic service to a remote hospital. Such a study might cover issues including physician and nurse reassurance, improved quality of care, and the potential to improve patient management and outcomes through the use of teleradiology systems. The pilot project was concerned only with issues of technical performance, reliability, cost and security. There remains the need for a further detailed study to attempt to document these perceived intangible benefits.

Since the selection of equipment for the pilot project was made, cheaper systems and equipment have become available. A recent system of comparable quality would have an estimated capital cost of $150,000; if depreciated over five years at $30,000 per year and with 10% maintenance costs per year ($15,000), this type of system would give an average annual operating cost of $45,000. As equipment

costs represent a large part of the overall costs of a teleradiology system, the use of a lower cost system would have a significant effect on decreasing the overall costs of image transmission. The figures in Table 2 for more recently available systems indicate that the total cost per image would be reduced to the order of under $10 per image for a volume of 10,000 images a year.

This brief pilot study has given encouraging indications of the potential for teleradiology to improve the standard of paediatric services. Further, more detailed appraisal would be desirable, following establishment of routine teleradiology links, to further define the impact of the technology on costs, patient management and operational procedures at the hospitals.

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