Telemedicine in Australia

A discussion paper

Bernard L Crowe

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Executive summary

- The implementation of telemedicine systems in Australia is now feasible due to developments in communications and computer technology.
- Telemedicine involves the linking of doctors, nurses, patients and specialists using telecommunications with additional facilities such as slow scan television and voice conferences. Computer based systems can also provide access to diagnostic images and pathology reports as well as computer based information retrieval systems.
- The use of telemedicine systems would raise significant legal and security issues. There will be a need for community discussion of these matters before systems are introduced.
- Telemedicine has a potential to impact on both medical education and clinical support systems. However, before these developments can proceed there will be a need for agreement on standards to be adopted for the coding and dissemination of medical information. There are opportunities for developing Australian modules for medical education which could be distributed internationally.
- Aspects of telemedicine are already being implemented in Australia, including teleradiology systems and direct reporting of pathology results to general practitioners.
- New technologies are emerging in the use of telemedicine for home monitoring activities. Given the prevalence of conditions such as cardiac disease in the population, there is a need for further study of these developments.
- Interested parties, including Federal and State health authorities, RACGP and specialist colleges, university research departments, legal representatives and consumers, should confer to ensure that the benefits offered by telemedicine are co-ordinated in a manner which will be satisfactory to the Australian health system and to the community, possibly under the sponsorship of the Australian Medical Informatics Association (AMIA).
- A number of telemedicine pilot projects are currently proceeding in Australia and it would be desirable for the projects to be evaluated in a co-ordinated manner.
- While telemedicine appears promising, it should be subject to evaluation as regards costs and benefits before widespread introduction in Australia.

Introduction

The aim of this discussion paper is to examine developments in computer and communication technology and the application of these to the future practice of telemedicine in Australia.

The paper is designed to outline issues which require examination and to stimulate discussion, so that steps can be taken to avoid some of the potential problems posed by the introduction of new telemedicine technology in Australia.

The advent of powerful neural computer technology combined with artificial intelligence systems and high speed telecommunications provides the opportunity for the practice of medicine to change from isolated individual encounters into an integrated national and international medical system.

Telemedicine may be described as the linking of doctors, other health care workers, and patients through a communications network which provides facilities for consultation with specialists, access to diagnostic images and reports, and assists in diagnosis and medical education through computer based information retrieval systems. The computing and communication elements necessary for an integrated telemedicine-medicine system are currently available. The question remains as to how such elements can be integrated into the practice of medicine in Australia within existing doctor and patient relationships and a funding system which includes the fee-for-service remuneration system.

Historically, doctor - patient contact on a one-to-one basis was the pattern of medicine as `cottage' industry when practised in the nineteenth century. The relationship was subsequently modified by the introduction of the teaching hospital system and the development of specialised medicine, so that today a patient may be treated by a number of specialists, with a large number of diagnostic tests being performed by independent third parties. The patient may be subjected to brief surgical episodes in either large hospitals or day surgery clinics.

Frequently, no one medical practitioner is responsible for a patient. The management of medical records is performed by the passing of hand written notes from practitioner to practitioner. In addition, access to the vast amount of medical and pharmaceutical knowledge to assist in diagnosis and treatment is not always well coordinated.

The first major step in the introduction of telemedicine has been the use of computers and communications for on-line access to international medical data bases such as MEDLINE. However, at present their use in day-to-day medicine is the exception rather than the rule. Also, their use poses problems as to how such information systems are to be managed under present funding mechanisms and how they are to be integrated into general practice. An examination of Australian literature [1–7] shows that the issues associated with telemedicine are only just beginning to be discussed.
It is a truism that medical systems are complex and subject to change. A feature of change is that new medical technology is introduced at the centre and diffuses slowly to the periphery. Slow diffusion of technology is partly due to the basically conservative nature of the medical profession, accustomed to dealing cautiously with life-threatening illness. It is also partly due to the difficulty of continually re-educating a group of professionals with a long working life. Many doctors now in positions to make decisions about new technology were initially trained during the 1950s. Because of day-to-day work pressures they may be reluctant to invest the effort to acquire the new skills necessary to operate in a telemedicine environment.

As well, the practice of medicine operates through the existence of informal professional networks which, though effective, could be characterised as only partial sub-systems rather than total information systems. In other words, medical practitioners are skilled at obtaining the information which is needed to meet an immediate situation. However, the information gathering process may not be comprehensive, consisting of a combination of discussions with colleagues, semi-directed literature searching, information supplied by companies and attendance at conferences. Doctors are not specifically remunerated for such unstructured information gathering activities which may be extremely time consuming.

The aspect of telemedicine concerned with information gathering and analysis has great potential for improving the practice of medicine in the late 20th century. Other aspects, such as the retrieval and transmission of images and pathology data, are probably secondary to the potential for collating information and enabling discussions with colleagues in either local, national or international tele-consultation.

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Legal and security issues in telemedicine

There are a number of important legal issues in relation to the admissibility of evidence which could be raised about the introduction of telemedicine systems in Australia. Many of these legal issues are also related to the security of medical information, particularly in relation to access, privacy and confidentiality. Some are technical, in terms of computer security password protection. Other issues lie in the ethical domain, and include the ownership of medical information and patients' rights to control access to data concerning specific details of their medical conditions. While it is recognised that many such matters are already being discussed at various levels, the advent of telemedicine, with the storage of medical records on computers and the transmission of medical data across the public telephone network, will raise a further set of complex issues which need to be considered.

It is important that these issues be debated in advance of the day-to-day implementation of the technology. The debate should include groups composed of lawyers, physicians, ethicists, computer specialists, representatives of patients and medical administrators. There is a need for such broadly-based groupings to provide comprehensive guidelines to legislators.

Linkage of medical records

A major requirement of a telemedicine system is that data pertaining to an individual can be uniquely identified. This is the basis of computer processing, so that, for example, the records of `John Smith' are not confused with those of `John Smith, Jr'. Although this example may appear trivial, the history of computer systems associated with financial and social security systems is replete with cases of mistaken identity. A simple way to overcome the problem, as has been done in Sweden, is to allocate a unique identification number to each member of the population. However, such identification facilitates the exchange of information between data banks, with the possibility of information being put to a use for which it was not originally intended. Recent history in Australia shows that the concept of unique identification does not have widespread support. Failing the availability of such an approach, it would appear that telemedicine systems will have to rely on less secure methods of patient identification and record linkage, such as a combination of name, address and date of birth. As names and addresses change constantly, there will always be the possibility of incorrect linkages of medical data.

It could be argued that the security situation pertaining in a telemedicine system would be no worse than exists at present. However, society, in general, appears to be less tolerant of computer error than of human error. The historical transition of the practice of medicine from single doctor/patient encounters to modern specialist medicine, with many parties involved in patient treatment, has always had the inherent potential for misfiling of information.

These existing problems are likely to be complicated by the introduction of telemedicine systems. For example, there is a potential problem involving the automatic transmission of pathology results to the incorrect location. Society may have to decide if the perceived disadvantages of allocating a unique number to individuals are as serious as the potential problems likely to be caused by computer misclassification of medical data due to the absence of unique record linkage mechanisms. While allocation of identification numbers may not solve all potential problems involved in doctor/patient relationships, it has the potential to avoid the introduction of a new sub-set of errors caused by incorrect data linkages.

It should be recognised by telemedicine system designers that current legal trends appear to be against the use of data bases for record linkages. Decisions in Canada, for example, have resulted in medical data bases, which contain Social Security Numbers as identifiers, being declared a misuse of the original intention of the allocation of the number. This has resulted in considerable confusion, as data bases will now have to be re-constituted with other unique identification numbers. The outcome of the debate on similar issues in Australia relating to Medicare numbers will need to be closely monitored by administrators responsible for medical data bases, so that legal constraints can be taken into account when designing telemedicine systems.

Ownership of medical information

Attitudes to the ownership of medical data vary from country to country. This is an inherent problem for telemedicine systems which may be involved in international data communication for specialist consultations. By way of example, in Japan it is generally considered proper not to inform a patient of an unfavourable diagnosis, as this very information may make the patient's condition worse. Traditionally, the physician has been seen to be acting in the patient's best interests by withholding information.

In contrast, it is considered in Australia and America that the patient has a right to know relevant medical facts so as to make informed medical and social choices. Therefore, local laws and customs will have to be respected by the designers of telemedicine systems and this implies the need for lengthy discussions and regulation, preferably by legislation, on trans-border data transmissions.

This example is one of the many complications surrounding the issue of the ownership of medical information. In Australia there is a basic assumption that medical data are private and belong to the individual, on a basis of shared confidentiality with a doctor. However, such simple principles become less clear when the number of parties which may legally demand access to medical records is considered. A partial list would include:

- insurance companies in relation to medical conditions affecting life insurance;
- legal executors in relation to wills;
- parents in relation to the welfare of children;
- mental welfare authorities in relation to patients;
- police authorities in relation to forensic evidence;
- medical researchers in relation to notifiable diseases;
- workers' Compensation Boards in relation to claims;
- military authorities in relation to either benefits, or fitness for military service;
- social security agencies in relation to sickness benefits; and
- the Health Insurance Commission in relation to payments and services by providers.

This list is not exclusive, and demonstrates the many demands placed on access to medical records. Some arrangements are already covered by statute or precedent, such as the situation where a patient gives written consent for other parties (e.g. an insurance company) to have access to medical records. This in turn raises the further point as to whether the notes written in a doctor's file belong to the doctor or the patient. This issue is likely to become more contentious, if doctors' notes are to be recorded in computers in a standard format and transmitted from one doctor to another, for example when referring a patient to a specialist.

The rapid exchange of computerised records goes well beyond the simple concept of doctor/patient confidentiality and will require careful consideration if the rights of the individual are to be balanced with statutory requirements and legal entitlements to benefits.

Access to telemedicine information

Access to computerised information is generally controlled by password and encrypting systems. This approach, at varying levels of complexity, is taken to be the basis of computer security systems. However, the more secure the data, the more complex the access procedures. The requirement for security may be in conflict with a design goal of telemedicine systems, that of "user friendliness" or ease of access.

It is generally considered that one of the inhibiting factors in the adoption of computer systems by the medical profession is that the systems are too complex to use conveniently in a clinical environment. The imposition of multiple levels of security password systems is not likely to improve this perception. There has been a general trend in the design of telemedicine systems away from complexity and towards the use of simple graphical user interface devices (joy-stick, track-ball, mouse technology) to ensure that a physician merely has to "point and click" to gain immediate access to medical folders stored on computer. These systems work best in an institution or hospital department where access is not considered to be a major problem. This is an entirely different situation to the transmission of medical records over the public telephone network.

One might contrast the trend of simple access to medical information with developments in computer "hacking" (illegal entry) and the steps being taken to protect valuable information in computer systems. Invasive systems, which automatically dial sequences of telephone numbers and, upon locating a computer modem, attempt to enter the computer system by password decrypting, are in use by both professional and amateur computer hackers. Good computer security system design requires multiple levels of protection against unauthorised access. Therefore, users working from home or a remote office may first have to identify themselves to the central computer system before being permitted access to computer data by using another password. In simple terms, this implies two levels of security, at least, before work can commence.
As a further step, the remote user may have first to make contact with the central computer and then wait for the computer to call back to verify the user's identification through hardware encryption procedures. At the very least, users of a telemedicine system will be required to regularly change their password on a regular basis. This procedure may involve using an eight character alphabetic code in two, four character sets, none of which have been used in the previous twelve months. Such precautions are necessary due to the active though illegal exchange of passwords, either current or historical, by computer hackers. It may also be a security requirement that a user not allow another user to access data on their behalf. In clinical terms, this may prohibit a specialist requesting a technician to pre-fetch medical records prior to a tele-consultation and would greatly reduce the usefulness of a computer system.

The point of the security procedures is not to inhibit the development of telemedicine systems but to ensure that sound operating procedures are developed to protect medical data from unauthorised access. While it may also be necessary to develop legal safeguards and penalties for the illegal accessing of medical data, nevertheless the best protection lies in a clear understanding of the potential problems and acceptance by users of strictly enforced operating procedures. James et al [8] have noted the unique problems of clinical systems, with patients' data being continuously updated and with immediate access being required by the many professionals providing care. In view of these unique problems, a challenge facing designers of telemedicine systems will be to develop procedures which are in accord with traditional professional expectations while providing a satisfactory level of security of medical data. The task is not impossible, but will require a high level of co-operation between medical personnel, lawyers and system designers.

Computer records as evidence

A major advantage of telemedicine systems is the ability to rapidly update computer records concerning a patient. Good computer system design would provide an audit trail, so that the history of a patient could be reconstructed, if required at some later date. In this sense, the computer record is no different to a paper record, in that both may or may not be well maintained. Either type of record can be tampered with. Tampering might be accidental, for example by misfiling, or on purpose, for example to disguise the presence of a pre-existing medical condition.

However, the situation becomes more complex in a telemedicine environment, partly because of hardware aspects and partly because of the volume and speed of data processing. In hardware terms, loss of data by a "disk crash" is not unknown. Reconstruction of records is not always possible, for example, when back-up tapes contain corrupted data. Good system design should ensure that computer systems are fault-tolerant; however, it is recognised that distributed telemedicine systems using local area networks (LAN) or wide area networks (WAN) may not be as fail-safe as centralised large main-frame computer systems. The advantage of the distribution of computer power to remote users is offset by the disadvantage of possibly less secure systems.
The situation involving the loss of computer records is no different from the destruction of paper medical records, where copies have not been maintained at another site. Each institution or practice must have a policy on the protection of records. However, the concept of storing duplicate records for possible use as legal evidence has cost and benefit implications. Despite the cost expended in creating duplicate microform, or photocopying records in a paper system, there may be legal argument about the acceptability of copies as evidence. Cost considerations may dictate that computer-generated medical images be reduced in size by the use of data compression algorithms and stored on optical disc in compressed form. The image from the compressed record may show some variance from the original, and the admissibility of reconstructed records as evidence has yet to be decided.

As well, there are two main types of optical discs, permanent write once/read many times (WORM) optical discs and re-writable discs. WORM discs are expensive and can only be written once, whereas re-writable discs could be re-used, following a suitable storage period. However, re-writable optical discs, by their very nature, would be less likely to be accepted as a copy of an original image than would a permanent optical disc.

The matter of record storage is extremely complex and there are a number of issues to be considered. A cost benefit analysis might indicate that it would be less expensive for an institution to settle a potential court case due to lack of medical records as evidence, rather than to undertake the long term capital and re-current costs in maintaining duplicate medical records for reasons other than patient care. From the medico-legal view point, it may be that a specialist radiologist's report is sufficient and it should not be necessary to produce the original film as evidence. Each institution will need to design a policy in regard to the practices to be adopted for maintaining medical records in a telemedicine system, having regard to the needs of patients, legal requirements and costs.

Images and evidence

Computer-based digital imaging modalities have the ability to create a large number of static or cine images. A CT study may contain up to 60 images, an MRI study 100 images and digital vascular image modalities may produce images at the rate of 75 frames per second. Once created, these images can be post-processed and either enhanced or altered to provide further diagnostic information. Chest x-rays can be digitised and then processed by computer to improve image quality.

As a large part of telemedicine is the capture, manipulation, transmission and interpretation of images, the question arises as to which image is original and which is a computer-created artefact. This question has a place in considerations of malpractice litigation which may involve an alleged failure to diagnose a particular condition. It may be claimed, for example, that professional negligence caused a cancer to be missed at a treatable stage, thus causing substantial injury to the patient. A diagnostician could protect against this eventuality by always erring on the positive side in making a diagnosis, but such action would be at the cost of increased patient anxiety, further tests, and increased medical costs. The difficult nature of the problem is noted by Potchen [9] who states that as many as 90 per cent of lung cancers can be seen on chest radiographs taken 12 months previously, once the diagnosis is established, thus providing possible grounds for litigation.

Again the question arises as to which images out of a set of images are to be treated as evidence. The process of diagnosis usually involves the selection of significant images from a series and discarding non-contributing image information. In addition, mathematical image processing may take place to emphasise specific diagnostic information. Legal problems may arise because the original data are often altered during the diagnostic evaluation process [10,11,12]. It is therefore a requirement of an image based system to allow retrospective determination of both image acquisition methodology and post-acquisition processing actions. All data relating to image processing should be provided with the diagnostician's final report and should become part of the patient's record, retrievable on demand to an authorised person at a computer terminal.

Due to storage considerations, not all images are retained permanently, so historical images may not be available in litigation proceedings, or the diagnostician may only store those images which support the final diagnosis. It is clear that a requirement of legal training in the future will be the inclusion of the ability to follow complex image based computer audit trails to determine if negligence has occurred. The situation will not be impossible to resolve, but will require a high degree of co-operation between specialist diagnosticians, computer system designers, lawyers, patients' rights groups and medical administrators to balance all factors so that the process of patient care is not unduly hampered by legal constraints relating to evidence. The possibility has to be considered that the existence of medical records on optical disc may result in an increase in litigation, once patients realise that such information is readily available.

Commentary

At first sight, the legal and security issues facing the implementation of telemedicine systems appear more daunting than the technical problems of data capture and transmission. In other computer areas, new technology has been used, often in a military or government research environment, and the legal and social issues have not emerged until some 10-20 years later. This has been the case, for example, with occupational health issues related to ergonomic aspects of computer terminal usage. Other computer systems, such as those in banking and social security payment areas, have had self-correcting features such as inquiry by customers about incorrect bank balances or complaints by a beneficiaries about social security cheques failing to appear on pension pay-day. The consumer is assumed to have a working knowledge of his or her file and the data held in the computer are not likely to lead to loss of life or iatrogenic related morbidity.

Computer-based medical information falls into a different category to other computer systems, party due to the potentially life-threatening aspects of incorrect diagnoses or the prescribing of incorrect drugs, and partly due to the community perception that an individual's medical status is a private matter. However, as discussed previously, there are many situations where medical data can be legally accessed to determine benefits or penalties to an individual. There are also examples of an individual's medical history being illegally obtained in order to discredit candidates for political office or for other reasons.

A number of social approaches might be considered to overcome some of these problems. For example, candidates for public office might wish to treat their medical histories as a matter of public record, as is now done with financial history. Medical data might be subdivided into categories with highly protected sensitive data at the centre, moving out to less sensitive data with lesser security features at the periphery. The legal right of individuals to query medical records held by government authorities which concern them could be improved, with a right to challenge any incorrect data. Social attitudes to illness might gradually be changed by education programs, so that in the longer term physical or mental handicaps may no longer be used for discrimination, either covert or overt, against an individual.

As noted by Regan [6], the absolute security of medical data is a myth. If highly protected military intelligence about national security issues can be obtained by computer espionage, then medical information can also be obtained. The best protection that an individual has to disclosure is that the medical record is accurate. Computer systems with public access and rights of correction go some way down this path of accurate records. However the greatest possibility of disclosure of information comes from inside the computer environment by authorised personnel, rather than from outside hackers working at random. In the final analysis, the best protection for the individual's right of privacy of medical data may be the enactment of stringent, legally enforceable penalties against individuals who abuse the rights provided to them by access to medical records in a telemedicine system.

In the interim, there appears to be a need for a national forum for doctors and lawyers to discuss the ground rules for evidence pertaining to medical data and medical images. At first glance, it is not unreasonable to request users of telemedicine systems to maintain a computer log of how data were obtained and processed and to maintain these records for a number of years. A system of accreditation could be considered, such that practitioners might be audited for system management on a random basis, along with the provision of supportive computer system education, if necessary. Given that it will always be difficult to detect fraud or abuse, a system should be designed which would encourage good practice in the use and maintenance of telemedicine systems.

Communications and telemedicine

The interest in telemedicine in Australia has been stimulated by developments in communication facilities offered by Telecom and by the second carrier, Optus. Australia has had advantages from a single supplier of facilities which has led to the integration of a national communications network.

This situation is in contrast to that in the USA, where changes occur so rapidly in the area of communication services that a user must contact local telephone utilities for details on options. For example, although a local telephone system may still use older analog switches, or has not yet implemented variable-rate data services, a permanent connection may be available for bridging into a nearby digital switching network and this possibility would need to be investigated when considering the establishment of a telemedicine system [13].

In Australia, the Telecom Integrated Services Digital Network (ISDN) provides a suitable communication link for the related aspects of telemedicine, video-conferencing and image transmission. It provides end to end digital connections operating at multiples of 64 Kbps. ISDN provides a flexible range of operating speeds so that the connection can be tailored to the requirements of a particular teleconsultation. For example, video-conferencing, using a Codec to convert the analog signal to digital, allows transmission of full motion colour video at speeds of 128 Kbps (2 x 64 Kbps) which may be adequate for many applications. Higher quality may be required for remote consultations and a speed of 384 Kbps (6 x 64 Kbps) can be used.

ISDN supports dial-up lines as well as dedicated links; this provides flexibility if, for example, only a few consultations are required each week. Dial-up connections also facilitate connection to other hospitals as they develop similar capabilities.

Costs—hardware and transmission

A video-conference link for telemedicine consultations would cost of the order of $140,000, incorporating cameras and monitors, Codecs and an echo canceller to compensate for the delays caused by the processing of the signal. The communications network, including network access controllers and ISDN Macrolink installation would cost approximately $30,000. There would also be a cost of up to $100,000 per year for rental and 10 hours per week usage (sites less than 745 Km apart). A teleradiology system would cost between $100,000 and $200,000 depending on image quality, storage and printing facilities. Thus the establishment of a full scale telemedicine system between two points might cost of the order of $300,000-400,000 with operating costs of up to $100,000 per year if a number of practitioners made use of the services for up to ten hours per week.

When considering these capital and operating costs, a balance could be made, given that the air ambulance transport of a patient may cost up to $4,000, plus accommodation for a supporting relative. A telemedicine system which reduced the number of unnecessary transfers by one or two a week could be amortised over a period of three or four years, while providing a service to patients and their families.

There is a need for an evaluation of these costs and benefits. Pilot projects, such as the NSW Wagga Base Hospital and the South Australian MFP project, could provide useful data in this area as full system evaluation is undertaken. The tasks of remote medical diagnosis, patient counselling and remote image interpretation all need to be subject to thorough evaluation to define the costs and benefits of each type of telemedicine application.

Communications within medical facilities

Significant changes in communications capabilities have occurred over the last few years. Performance has increased from 300 bps to the introduction of 2400 to 9600 bps modems on the public telephone system. ISDN now offers 64K bps and FASTPAC will range from 2–10 Mbps. Increases of this order of magnitude have implications for system design, making many new options possible. Apart from facilities in WAN there are also greatly increased facilities in LAN with Ethernet (10Mbps) FDDI (100Mbps) and proprietary systems such as Ultranet (1Gbps). With these capabilities it is possible to design high speed image transmission systems within large complex hospitals.

Developments in communications are of particular significance to diagnostic radiology, given the large amount of data contained in a radiology image, and the problems of transmitting such data in real time for a second opinion or to inform immediate clinical decisions.

The size of the problem to be addressed is shown by the fact that a CT study may contain 32 Megabytes (64 x 0.5 Megabyte images) which could be transferred from one location to another in 10–12 seconds using Gigabit transfer speeds [14]. Likewise an eight Megabyte computed radiology chest image could be transferred in under two seconds, achieving an effective rate of four Megabytes per second. At these transmission speeds, it is possible to implement image retrieval systems which match the functional requirements of diagnosticians and physicians. Provided that these systems are designed to provide sufficient image quality, then they offer the advantages of a number of users being able to view the same set of images at different locations within the hospital (tele-consultation). They also offer the advantage that the images are always available from optical or magnetic storage, rather than being "lost", either in the file room or in transit from one area to another.

Apart from LAN's within hospitals, the connection of systems between hospitals then becomes possible with WAN facilities such as 10 Mbps FASTPAC acting as the interconnection.

Table 1 shows the system design parameters that are now feasible for the transfer of diagnostic imaging studies between hospitals:

Table 1: *Transmission times for various imaging modalities*

Modality	M BYTES/ Image	No. of Images per exam	Transit Time(s)
• Magnetic Resonance (256 x 256 x 12 bits)	0.13	55	6
• Computed Tomography (512 x 512 x 12 bits)	0.50	30	12
• DSA (1024 x 1024 x 8 bits)	1.0	25	21
• Digitised Film (2048 x 2048 x 12 bits)	8.0	5	33
• Computed Radiography (2048 x 2048 x 12 bits)	8.0	4	26

Advances in communications now permit complex imaging studies, containing full image modality data (12 bits) to be transmitted from hospital to hospital with only a 30 second delay for the first transmission. The next study could be transmitted and available while the first study is being discussed. Such systems are capable of being implemented and could justify being described as full teleradiology systems. High speed transmission would eliminate the need for destructive image compression, thus avoiding one of the potential legal barriers to the acceptance of teleradiology systems for diagnostic purposes.

Telecommunications for film systems

At the same time as telecommunications developments in soft-copy or filmless systems have occurred, there have been significant advances by firms such as Du Pont and Kodak, in communications with film systems. These systems allow an image to be produced at one location by modalities such as MRI or CT and printed at other single or multiple locations on film.

For example, all trauma head scans could be printed in the emergency room as well as in the radiology file room in a hospital. Hard copy films of MRI scans can be printed automatically in remote sites such as clinics or operating rooms. Although expensive in terms of film costs, and relatively slow (30 seconds per film), these "print engine" systems give many of the advantages of picture archiving and communications systems (PACS) without the expense of viewing terminals and optical disc storage systems. Radiologists and physicians who prefer to work with film can continue to do so and films can continue to be filed in conventional film libraries, although these are not without retrieval problems.

Given that 100 viewing stations might cost of the order of $5M for a PACS costing $10M, the appeal of the "print engine" approach is strong and is made possible by modern communications technology and laser imaging printers. For a limited capital outlay on "print engine" technology (given that laser images are already in common use in hospitals) it is possible for institutions and radiologists to continue to work with film without any disruption to existing professional or administrative systems.

Telecommunications for rural practices

The use of the AUSTPAC service allows data communications to any part of Australia for the cost of a local call at 2400 bps via a modem. Users with a personal computer and modem can take advantage of commercial services which provide electronic mail (EMail), and bulletin boards. System software such as MEDCOMS, provided by a commercial organisation, Mednetwork, allows access to programs and data bases, and for sending bulk billing information directly to the Health Insurance Commission.

The Department of Community Medicine at Monash University has developed the PHOCUS (Primary Health Oriented Computer Users System) Project as a network to help general practitioners share in information and have access to teaching material and diagnostic support including drug prescribing and drug interaction information [15]. Services are accessed by "gateways" or pre-established communications channels to other providers such as MEDLINE.

Installation costs, including user registration, software and a modem, range between $780 to $1300, with monthly usage costs of up to $120 per month. Users need a personnel computer with hard disk and a colour display as a workstation. The commercial organisation charges $25 per month as a service fee for an account, but these charges can be shared by a number of users.

The provision of services such as MEDCOMS provide a low cost method of establishing a telecommunications network to act as a vehicle for the exchange of ideas and information. These services can be used as the basic building block of a telemedicine system. Other services including on-line pathology reports, teleradiology and slow scan television consultations can be added as necessary, thus providing the potential for the majority of general practitioners to have rapid specialist medical advice.

Commentary

The communications facilities necessary for full telemedicine systems are now in place. Conference telephone, facsimile, slow scan video, image transmission and image printing can be implemented using ISDN (64 Kbps) and FASTPAC (10 Mbps). Developments with fibre optics point to the future availability of digital "light pipe" networks working at 1.7 Gbps. The capability of these systems is defined by software performance, allowing the user to select a signalling rate for a particular diagnostic task. In these systems the user pays only for the data rate selected and the amount of time used [16]. Communications technology is now available to design systems to provide timely patient care. Capital investment in systems must be balanced with the potential benefits such as reduced operating costs and the provision of improved care. In the 1990's, there will be a need for evaluation, so that rigorous assessment can be performed on the costs and benefits of telemedicine systems as the technology becomes available.

Telemedicine—medical education and clinical support systems

In 1972 when commenting on medical information, Felson noted "Information is only as valuable as it is accessible and the more information you have the less accessible it is" [17]. The problems of keeping up to date with medical information faced by the medical profession twenty years ago is relatively insignificant compared to today's demands. Swett [18] working on medical decision making and information systems at Yale University School of Medicine, noted that new knowledge is created so rapidly in medicine that the entire body of medical knowledge doubles every five years.

Despite the increasing trend towards sub-specialisation, such that for example radiologists now specialise both by area of anatomy (brain) and by diagnostic modality (MRI), it is almost an impossible task to remain up to date with all developments in medicine. This in turn poses problems in two areas, basic medical education and re-certification of existing medical practitioners. A trend towards post graduate training for medical students is only part of the answer as, by extending the overall length of training, medical practitioners are likely to be out of date by the time they are ready to commence practising medicine.

An added difficulty in system design terms is that the teaching of medicine has a highly visual content, more so than a text-based discipline such as law. No medical lecturer is complete without a set of 35 mm slides, no matter how out of date. Advanced technology such as laser video-disc is useful to manage the vast amount of full colour anatomical detail for areas such as surgery, radiology or pathology.

The majority of medical education consists of practice in pattern recognition. As it turns out, this is a task that neural computers perform well and people perform less well with advancing age and decreasing visual acuity. It is of interest that computer technology has been applied rapidly and successfully in systems involving repetitive analysis, such as finger-print matching and identikit matching of photographic files, but has not been routinely applied in medicine.

Currently, there are opportunities for the application of computers and communications to the teaching and conduct of medicine. On-line computer access to structured medical information data bases and to image files are becoming essential for the practice of modern medicine. For example, a physician could consult a data base for the possible side effects of prescribing two drugs in combination or, on another occasion, could review a video-disc colour atlas of pediatric skin infections when examining a patient. Such systems are technically possible, and are being developed by centres such as the Department of Community Medicine at Monash University, but at the moment do not fit into the accepted methods of medical practice and funding mechanisms in Australia.

System design

In addition to well established medical text information retrieval systems such as MEDLINE, major developments are being made in America and Europe in the field of medical education with computer based teaching systems. These educational systems can be interconnected to large on-line data bases, and were discussed at the First Annual Computer Aided Instruction Festival at the George Washington Medical School in 1989 (19).

The training of medical students is changing from emphasis on memory to instruction in the effective use of resources for information and problem solving. A personal computer-based teaching file has been developed for areas such as anatomy or radiology which can utilise text retrieval systems, images on laser-disc video, or a text and image file on a CD-ROM, supported by interactive software and clinical records [20].

As in any new area of technology a number of competing systems and standards have emerged. However, there are currently no compression or communications standards for still frame digitised video systems, so that potential users need to give careful consideration to the problem of selecting a suitable hardware supplier who will have the flexibility to adopt to such standards when they emerge. For example Toshiba includes a connector on their portable computer system board for an audio visual card. The card will allow users to view presentations containing full-motion video and computer graphics on the LCD screen as well as a large presentation screen.

The early use of laser-disc video provided an interactive video learning environment with television quality image display. A current teaching file in this format is distributed by the American College of Radiology. Another approach to building image files involves the use of a video camera and image capture and display board, with a video decoder communicating with a personal computer. Images are typically captured with eight bits of colour resolution or 256 shades of grey. Software such as Hypertext facilitates the interconnection of graphics, sounds and text for flexible multi-media computer programming. The use of CD-ROM drive allows access to 680 MBytes of data or the equivalent of 6800 100 KByte teaching images.

After studying a teaching file, it would be possible, using such technology, for a student to call up a patient's digitised film from a clinical data base PACS system. The PACS system might have a high resolution monitor (1024 x 1024 x 12 bits) allowing the student to view the clinical image in full detail with dynamic window and zoom capabilities and to interact with the teaching program on the personal computer [21].

Following on from the development of interactive computer based medical education systems are clinical data management systems for assisting in routine diagnoses and patient management. Expert systems, such as that developed by Greenes and others [22] at the Harvard Medical School, Computer-Aided Selection of Procedures and Evaluation of Results (CASPER), attempt to decide the suitable diagnostic workup strategy for clinical problems that involve diagnostic imaging procedures. These systems are designed to place the computer in the role of knowledge servant, whose job is to present clinicians with sufficient knowledge to enable more effective decision making. The role of the computer is to filter information, by evaluating the patient's clinical data, and to deliver carefully selected information to the clinician in a way that assists the understanding of the implications of the data.

Expert systems tend to use a critiquing approach, whereby the computer comments on a physician's stated diagnostic plan. The computer questions the physician, suggests alternatives, and explains its reasoning. The critiquing approach is suited to medicine where decisions often depend on subjective judgement.
Diagnosis has been greatly assisted by developments in imaging technology. However, this trend has increased the dimension of some problems faced by physicians as shown by the change in the diagnostic workload at a major radiology department in the USA [23]. The percentage of new technology procedures (MRI, CT, sonography, nuclear radiology and guided interventional procedures) has risen from five per cent in 1973 to a projected 27 per cent in 1993. In terms of total charges for diagnostic services, the new technology percentage has risen from 24 per cent in 1973 to a predicted 73 per cent ($US80M) in 1993. There is a need for computer based expert systems to assist with complex diagnostic workups [24].

Implications for Australian medical education

Telemedicine in Australia offers significant opportunities for medical education. For example it would be possible to develop educational software packages at one university and to transmit them, using ISDN facilities, to regional teaching centres. Alternatively, the packages could be distributed on CD-ROM discs for use at the regional centres, with updates and additional information transmitted by modem to the local sites. This approach is already being used with MEDLINE, which is available on a monthly issue CD-ROM. If required, the interrogation of the most up to date file can be performed on-line via dial-up modems to the MEDLINE centre at Bethesda, Maryland, USA.

In view of the global nature of medical information, it is likely that future developments in telemedicine will follow the MEDLINE model. Developers of medical curricula will have to make decisions as to whether to adopt American and European packages or to develop local programs on media such as laser video disc or CD ROM.

The high cost of producing multi-media software for medical instruction is likely to favour the adoption of overseas packages, although there will always be opportunities for niche marketing, such as the recent development of a specialised CD-ROM package for anatomy for a first year nurse education course, developed by Footscray Institute of Technology. An important point is that each teaching module involves many of hours of software programming (authoring) and the making of CD-ROM masters is expensive, so that numerous copies need to be sold to recoup development expenses. The Australian market is relatively limited in this regard with only 14 medical schools and a differing range of curricula, but the implications of overseas marketing should be examined with a view to international distribution of Australian products.

There are also decisions to be made about equipment and standards for computer-based educational material. For example, laser video discs have a number of standards (PAL, SECAM and NTSC), so there would be a need to acquire the more expensive dual standard players. Likewise, CD-ROM's are undergoing rapid change with both a 5.25 inch and 3.5 inch physical disc available. However, CD-ROM players are a relatively inexpensive addition to an existing personal computer system.

A preference for GUI and MacIntosh personal computers seems to be emerging amongst system designers, but IBM systems and Windows environment are very common. Although the majority of applications packages can be implemented, or emulated, on either platform, there will be a need for careful evaluation of hardware and software purchases. The danger lies in making an investment in an "intermediate" technology developed during the 1980's such as laser video-disc, when 2GB MOD's may soon be capable of providing image files at full 12 bit resolution. In Japan, the ISAC project includes standards for the format and display of images from 130 mm (5.25 inch) MOD and these standards may develop to become international ones, useful for computer based educational material..

As with all computer hardware decisions, there are no easy answers and the best that can be expected is that the equipment selected will have a future migration path available. However, the situation is more complicated in interactive medical education, as the original package designer must make a prior system decision as to what distribution media and format are to be used, and then follow this decision down an expensive and lengthy developmental path. For example, it would be difficult to imagine that the American College of Radiology teaching file would change from laser video-disc format given that a world wide network of users have presumably made the decision to purchase an NTSC standard player.

A different level of problem will be encountered in the use of expert systems for clinical diagnosis. In Australia it might be expected that these systems would first be used in a relatively few major teaching hospitals. In these cases, it may be preferable for the Australian hospital to link into an American site, rather than to undertake installation, maintenance and upgrading of a proprietary package on the hospital's own computer system (which may be different from the originator's computer system). Alternatively, given the existing interest in expert systems for clinical decision making in Australia, it may be preferable to sponsor the development of a local expert system.

Whilst these problems might appear daunting, they are only a degree of complexity greater than the problems already faced by the Australian health system in developing such projects as computerised administrative Hospital Information Systems [25]. On the positive side, the move by the International Organisation for Standardisation (ISO) to base its communication standards on a concept called the open systems interconnect model may serve to reduce the problems of standardisation in the longer term.

Future developments in medical education

At present, the systems mentioned in this section are in a development phase. However, the introduction of improved medical education curricula making use of computer-based information has the potential to improve all aspects of medicine from the teaching of surgery through to the provision of up-to-date pharmacological information, along with a re-structuring of the delivery of pathology services. In the future computer based CME has the potential to reduce present medical problems which are due to lack of current information at the time of consultation.

The nature of medical education is likely to change from "chalk and talk" lectures. Developments in this area are being undertaken by groups such as the Department of Community Medicine at Monash University. A likely new learning situation is one where students work on personal computer based problem oriented modules, plus clinical work in hospitals. The computer based modules will use multi media with text, sound and images giving interactive instructions, such as moving a pointer over an image of the chest to produce typical heart sounds that can be heard through a stethoscope. The teaching modules could be self-paced and progress remotely monitored by the student being connecting to a supervisor by a modem. There will no longer be a need for all students to be in the same lecture theatre at the same time, so that medical education could be dispersed across cities, states and countries. However, clinical teaching would need to take place in a hospital or a community health setting. The problem of computer hardware standards will remain, with students requiring a standard personal computer with CD-ROM and laser video disc capabilities.

Given the complexity of modern medicine, the practice of specialist medicine in teaching hospitals can benefit from support by expert systems, providing information and guidance and supporting human memory with structured advice. Expert systems range from the Stanford University MYCIN system which was designed to help a physician diagnose and treat infectious blood diseases, to ATTENDING which critiques plans for anesthetic management. Trainee surgeons could be assisted by computer design programs to ensure optimum fit of bone grafts. Radiotherapy planning could be improved and performed interactively with a computer system to provide optimal beam location and dose effect parameters. An image directed robotic system to support the surgical task of total hip replacement (ORTHODOC) has been developed as a pre-surgical planning system for use in medical education.

With expert systems available, clinical support systems and medical education start to merge. The existence of a hospital wide PACS would result in both clinicians and students having on-line access to image teaching files and to patients' images on high resolution monitors [26]. Such extended applications would tend to spread the high capital costs of PACS over many users and, at the same time, provide a wider range of up to date images than could be provided on CD-ROM. For example, a series of films on a chest disease, such as asbestosis, can be digitised and stored on optical disc in the PACS system, without the need for mastering and distributing a CD-ROM. Access could be made available to the PACS system via a teleradiology link to any desired location, including, for example, student's homes, given implementation of a security system to prevent unauthorised access.

Such distributed clinical support systems have the potential to address one of the most serious problems in the practice of medicine, the need for continuing education. The American Medical Association has conducted a trial study linking practising physicians by modems to self-paced examination modules. Experiments of this kind will continue in an effort to ensure that doctors remain up to date. These on-line educational activities will support existing efforts in Continuing Medical Education (CME), including attendance at conferences and seminars. Publishers are assisting by producing anatomy atlases in both hard copy and optical disk, so that reference images can be accessed interactively by physicians.

Developments in telemedicine are as important to CME in general practice as they are to specialists in teaching hospitals. Dr L. Weed [27,28], the developer of the Problem-Knowledge Coupling approach has been of this view for many years and has designed a number of computer based systems to support GP's in diagnosis and record keeping. The development of Read codes in UK allows doctors to code diagnoses numerically so as to allow structured interrogation of medical records. In Japan the ISAC Project will permit a patient's medical, radiological and pathological data to be continuously stored on a 130 mm MOD. Thus the treating doctor will have full access to a patient's medical history at each consultation regardless of the geographical location of the patient.

Other health care personnel, such as pharmacists, also need access to a wide range of prescribing data to keep up to date with developments and this is being provided by computer systems. The need for interactions between the prescribing doctor and pharmacist, could be met by an interactive terminal system so they each could be made aware of recent developments in the use of drugs.

Expert systems have been developed for analysis of pathology slides. Following slide preparation, systems under development such as NEOPATH, automatically screen out slides showing normal pathology and refer the balance for human interpretation. Pathology slides can be digitised and transmitted by tele-pathology systems to a central location for interpretation. Such a system is under development in South Australia as part of the Multi Function Polis (MFP) Project.

There is also a capability for telecommunication systems to report the results of tests back to general practitioners and to automatically update the patients records with the pathology results. In the case of a patient being hospitalised, expert systems can review the results of pathology testing and advise as to other tests which may be required. Full access to a patient's previous test results has potential to reduce the number of unnecessary tests.

Overall, CME can be seen as playing its part in linking the diverse aspects of patient care, covering specialists, general practitioners, nurses, pharmacists and diagnosticians including radiologists and pathologists. The vehicle for this integration could be the use of telemedicine systems linking all parties together with patient records based on standard formats and standard codes.

Commentary

The use of telecommunications and computers in medical education, clinical support, general practice and continuing medical education is likely to play a major role in the future structure of the practice of medicine. While much of the technology will be imported to Australia from America, Europe and Japan, there are nevertheless unique local opportunities for system design and development. The meshing together of educational, clinical, budgeting and administrative support computer systems is a task which needs to be undertaken at a local level. The initiative to develop a Health Communications Network in Australia could assist materially by providing an infrastructure which would allow such development to occur.

The role of evaluation is important in order to ensure that cost-effective systems are developed and implemented in a uniform manner. Because of the broad geographical areas in Australia, there is an obvious requirement for national distributed telemedicine services. Common standards have a large part to play in ensuring that development effort is not duplicated or that non-standard systems do not emerge which would inhibit the flow of patient information both nationally and internationally.

At the same time, telemedicine systems must be developed in concordance with ISO open system standards to ensure that products developed in Australia can be marketed to the wider global medical community, as for example in developing distance learning packages for other medical institutions in South East Asia.

Telemedicine in general practice

The aim of this section is to review developments in telecommunication technologies and to consider the factors which may lead to the adoption or non-adoption of such technology in general practice. Although the majority of the issues are related to the Australian health care environment, similar developments which are occurring in Europe, America and Japan will also be discussed as the possibility of adopting international standards for the exchange of medical data needs to be considered, given, amongst other reasons, the high mobility of the Australian population and the need for comparative statistics and research on medical matters.

The introduction to the Western Canada Conference on Telecommunications for Health Care in 1990 (WESCANEX 1990) noted that the timely availability of medical diagnosis via telecommunication could reduce morbidity, mortality and the costs of transportation of patients to advanced health care facilities. As more and more technological limitations were overcome, telemedicine would rapidly become a viable means for health care in various situations, particularly for people living in remote areas, and for populations in developing countries [29].

Given the rate of developments in telecommunications facilities since 1990, it is understandable that consideration has been given to their application in primary health care, as this area is potentially a major user of services. The basic assumption is that the quality and continuity of care given by primary care physicians could be improved by use of a computerised population and patient database and recording system together with a computer knowledge base and literature retrieval software.

The technology could be useful, in the first instance, for overcoming the perceived isolation of rural doctors. As noted in Appendix B, applications which have been implemented in the USA include tele-consultations with specialists, access to data bases such as drug interactions information, on-line retrieval of pathology and diagnostic results, as well as continuing medical education activities [30]. There are a number of organisations in Australia actively investigating these applications, including the RACGP. the Department of Health Housing and Community Services, Monash University Department of Medical Information, Mednetwork, a subsidiary of the Australian Medical Association, the Standards Association of Australia, and the AMIA.

The principal aim of the use of telemedicine in general practice should be to enhance patient care while making better use of resources. Due to the complexity of the arrangements in Australia for the provision of health care, there are three major groups involved in decision making, often with differing aims and objectives. The first group involves patients and general practitioners, the second includes state and federal health authorities involved in administration and payment activities, and the third is comprised of research bodies with interests in aggregated health data and epidemiology. While the three groups have a great deal in common, it is understandable that conflicts can arise over issues such as level of care versus cost of care, or the privacy of medical information versus the need for institutional access to information for planning and research purposes.

Technology developments

A practical telemedicine application for general practice is the development of a service to provide clinical information which constantly needs to be updated. A service has been developed by the RACGP Family Medicine Program called CHECKUPDATE which was designed to provide new and significant information concerning diagnosis or management of a condition. The system can be accessed by a general practitioner from anywhere in Australia, using either a personal computer, suitable software and a modem, or a dedicated videotext terminal to Telecom's videotext service DISCOVERY. The service covers many areas including antibiotic use, travel immunisation details, and hypertension. The concept underlying the service is that expert researchers in a topic prepare a clinical abstract which is then edited by an experienced general practitioner and set into a format which will be useful to a busy general practitioner.

The advantage of such a structured approach to rapidly changing clinical data is that it provides a filter over a large amount of medical information. Alternative information technologies, such as MEDLINE using a CD-ROM or on-line access via DIALOGUE, are relatively expensive, require a degree of searching skill and tend to provide a large amount of information. Access to MEDLINE is useful for researchers, but is of less use to the majority of general practitioners. The difference between a structured service designed for general practitioners, such as CHECKUPDATE, and a general library information system such as MEDLINE, emphasises the need for information technology to be useful in assisting a general practitioner to perform routine tasks more efficiently if it is to be adopted. The extended use of a system like CHECKUPDATE assumes that there is a computer literate population with access to computing facilities. This is not generally the case, as yet, in Australia.

The area of prescribing of drugs by general practitioners is a potential application of telemedicine technology. An issues paper by the National Health Strategy [31] estimated that at least 170,000 people in Australia are exposed to significant risk of experiencing an adverse drug reaction, but that there are no formal processes for drug use review jointly by doctors and pharmacists. Use of a personal computer based telemedicine system would allow a general practitioner to maintain a patient's record, complete with diagnosis and history of drugs prescribed, and to transmit information to pharmacies and link into a national drug contraindications system. In the UK such systems are used to produce and print a prescription, showing other drugs which the patient is taking. A drug information database, PHILEX, is used to provide product information, standard dosages and warning messages, if appropriate.

As the patient is the link between the general practitioner and the pharmacist, there is the possibility of a patient holding a portable medical record which could be updated by the general practitioner and then presented to a pharmacist prior to prescribing a drug. A pilot system at Exeter, UK, uses a smart card containing medical information which is held by the patient [32,33]. The pharmacist views selected areas of the medical record, marks the card with the items dispensed, and produces a label with appropriate instructions and warnings. The demand for a similar system is increasing in Australia. The Health Issues Centre are concerned about matters such as patients being responsible for their own health care, the use of portable medical records to help cut back on inappropriate drugs, and over-prescribing of drugs. Standards Australia has recently issued a draft Australian Standard for comment on Patient Held Medical Record Cards which calls for debate on the issue [34].

International developments

A computing solution to such problems as the reporting of adverse drug reactions involves the wider issues of a computer-based patient record (CPR) including unique patient identification and standard coding procedures for clinical data. In considering these issues, discussions about telemedicine technology move from hardware to software and standards matters. World-wide, a number of parties are involved in standards, and bodies such as the RACGP, which has produced a statement of requirements for computerised medical records systems [35], is a necessary stakeholder. In Japan the ISAC Project is examining standard formats for medical record storage and display based around the 130 mm MOD as a portable personal medical record [36]. In USA, the Institute of Medicine has established a Computer-based Patient Record Institute (CPRI) with the objective of moving towards computerisation [37,38]. As regards medical terminology, the RCGP has endorsed the Read Clinical Classification (RCC) codes system for use in UK, which would enable a standard method of recording medical information [39]. Local decisions on standards and formats for medical records will need to have regard to decisions being taken by major overseas organisations, if the goal of international exchange of medical information is to be achieved.

The decision in the USA to fund a national institute to establish routine use of a Computer-based Patient Record system in all health care settings is particularly significant. The activity of this Institute can be expected to have a major influence on the availability of medical record hardware and software systems in Australia. Overseas developments have implications for the exchange of medical information on the international level and the Standards Association of Australia has formed a Health Informatics committee (IT/14) which is examining overseas developments in telecommunications with a view to providing guidelines for the developers of Australian systems.

Local developments

The recent NCEPH discussion paper on health information issues in general practice in Australia (40) considered that progress could be made in computer records over the next five years, given suitable incentives to the general practitioner to keep high quality health care records in electronic form. The RACGP has a continuing interest in testing computer systems in general practice and has been involved in the Computer Assisted Practice Project (CAPP). Similarly, the Department of Community Medicine at Monash University has established the Primary Health Orientated Computer Users' System (PHOCUS) as a computer based telecommunications network for general practice. As the importance of the area of telemedicine in general practice increases, there will be a need for close co-operation between the major interested parties in Australia, including a need for evaluation of pilot projects.

The adoption of computer based patient record systems by general practitioners in Australia faces a number of inhibiting factors. While such systems would facilitate services in areas such as vaccination and immunisation and would assist in the monitoring of chronic diseases, there are high costs connected with the creation and maintenance of medical records in electronic form. Although many general practices use computer based accounting and billing systems which have proven advantages in terms of financial control and the ability to undertake systematic audits in terms of quality and type of consultations being performed each month, there has not yet been a major trend towards the use of computers for patient management.

Future developments in the use of computers depend partly on the attitudes adopted to electronic data interchange (EDI). Any anticipated administrative advantages of automatic claims processing could be reduced by the disadvantages of managing a claims processing system in which some general practices submit electronic claims and others continue with paper systems. It will be necessary for discussions about the implementation of electronic data interchange as a method of payment for billing to involve general practitioners, as developments in EDI would highlight the need for medical practices to adopt computer systems for financial accounting.

The recent initiative by the Department of Health Housing and Community Services to establish a national Health Communications Network has potential to develop communication standards in relation to the security and confidentiality for exchange of medical information. There is, however, the need to recognise that consideration of the needs of general practitioners in delivering primary health care should outweigh factors related to administrative efficiency in the implementation of telecommunications systems.

In this respect, it is of interest to note that an administrative factor was a reason for the introduction of computer based claims submission systems by pharmacists. The difficulties associated with a central claims processing system, including the volumes of data to be entered into the computer and the repetitive nature of the centralised data processing task, was one of the factors which led to a decentralised approach being adopted.

While it is recognised that the centralised nature of the Australian system of medical reimbursement will be a factor when issues of greater administrative efficiency, standardisation of data collection and exchange of medical data with other government authorities are discussed, such considerations should not outweigh the requirements of general practitioners in performing their primary function, patient care. The RACGP has proposed that, following an initial survey in 1988, there should be regular surveys of general practitioners to determine attitudes to the use of medical computer systems for full medical record storage, and this recommendation has been implemented.

The Department of Health Housing and Community Services' program for examining the structure of general practitioner services has noted the need to develop and trial initiatives in information management (41). An important reason for the implementation of telecommunication systems in general practice is the potential for the exchange of clinical and treatment data with hospitals to ensure continuity of care. There is a need for an accurate hospital discharge summary so that general practitioners are aware of patients' diagnoses, treatment, pathology results, and any medication prescribed while in hospital. The integration of health care information by telemedicine technology for a mobile population, who may choose to visit more than one general practice, is desirable if primary care, hospital visits, and continuing care and medication are to be co-ordinated.

Commentary

Telemedicine systems and improved communications would be in the patient's interests if they were used appropriately. However, the adoption of uniform medical records and a unique patient identification system would need to precede the implementation of a co-ordinated medical data system, and this raises the issue of privacy of medical records.

As noted in the previous section on legal and privacy issues in telemedicine, there are no absolute guarantees about security of medical data in a computerised system. If a system were to be developed which used portable electronic medical records, then there would be a requirement for a system to replace the record if lost or destroyed; this in turn assumes the ability to locate a patient's complete medical data in order to recreate the portable electronic record (42,43). While the availability of a secure Health Communications Network and stringent administrative and physical security systems would provide a high level of protection of medical data, nevertheless it needs to be recognised that centralised systems provide the opportunity for illegal access to information. The draft Australian Standard on Patient Held Medical Record Cards addresses this issue, recognising the need for a three part approach to security.

On balance it appears that there is a need for increased public debate over the issue of a computer-based patient record. Improved patient care needs to be balanced with clinical practice and data security issues. The question of costs and benefits also needs to be examined as the capital and operating costs of telecommunications systems are high and the benefits are often of an indirect nature (44). Clearly there is a need for continuing discussions and evaluation of pilot projects before major decisions are made which would affect the conduct of general practice in Australia.

Telemedicine—diagnostic imaging

There are two major reasons why the application of telemedicine to diagnostic imaging has attraction in Australia. Firstly the factor of distance often necessitates urgent consultation between staff at country hospitals and major teaching hospitals. Secondly, congestion in the major capital cities makes attractive the tele-transfer of diagnostic information between city hospitals to avoid the delays of urban traffic. Image transmission would assist specialists working in public hospitals and private rooms who require access to patients information at a number of locations. In addition, teleradiology would be of assistance when there is a need for consultation prior to deciding on the transfer of a patient from one medical facility to another. A complicating factor is that the Australian population is highly mobile so that there is always the possibility of a medical emergency occurring to individuals away from their usual residence and medical records.

Developments in teleradiology have occurred rapidly over the past three to five years, partly due to the increase in the use of digital imaging modalities including CT and MRI. As noted in the previous section on communications (Table 1), an imaging study can now be transmitted in 30 seconds using FASTPAC facilities, thus allowing teleradiology consultations to take place in real time. Alternatively, images can be captured one at a time by CCD camera and transmitted over the public telephone network at approximately two minutes per image.

The nature of the telemedicine application will determine the cost, speed and image quality. In a review of teleradiology systems, Batnizky et al (16), noted that there are two basic types of teleradiology systems, either fully diagnostic for radiology reporting or lesser quality for medical decision making. As prices of systems vary from $20,000 to $200,000 there is a need for careful specification of requirements. Attention seems to be turning to the lower cost tele-imaging systems (45,46). Examples of these are described in Appendix A. A typical application is the transmission of several CT images from a remote hospital to a neurosurgeon at a specialist referral hospital (1). These systems operate under manual control and are capable of operating in an adequate time frame to allow decision making on the need for the transfer of a patient.

In the past, discussion of teleradiology has tended to be centred on the image quality necessary for diagnostic function. The demands placed on these systems—transmission of high resolution digital images in real time—have been such that the communications, storage retrieval and display specifications have resulted in systems which can only be considered by large teaching hospitals or, in one particular case, the US Defence Forces (the MDIS project). However, developments in ISDN communications and personal computers have resulted in a range of low cost tele-imaging systems becoming available. Appendix A contains a description of the use of some of these systems in private radiology practice in Australia.

Commentary

Given the range of teleradiology systems now available from both international diagnostic modality suppliers and from specialist companies in Australia, it is likely that these systems will come into common use. As one of the major benefits of teleradiology is the ability to exchange images, there is a particular need for open system standards in the area.

Experienced observers, Dwyer et al (47), have commented that the selection of efficient and cost-effective systems for teleradiology is presently more an art than a science, adding that no models exist by which radiologists can apply the experience of others to design and implementation of a teleradiology system. Rather than each hospital or radiology practice experimenting with systems, there is a case for a co-ordinated research centre which could evaluate systems and provide advice on standards to be adopted.

The concept of an image network has attraction, so that an image could be transmitted to an appropriate specialist for advice, similar to the present facsimile system. The problem of image standardisation is being addressed in a co-ordinated manner in Japan with the ISAC Project. A similar project investigating standards for the recording, storage and transmission of images could be considered for Australia.

Telemedicine—pathology

The development of a fully digital pathology laboratory, supporting an international network of pathology diagnostic services, has been under active discussion over the last five years. A paper on Telepathology—System design and Specifications—was delivered by Weinstein and others from the University of Arizona in 1987 (48). A high resolution telepathology system was installed at Emory University Hospital, Atlanta in 1990 and has been in use for pathology consultation between two hospitals (49).

The types of developments in personal computers, data transmission and data storage which have stimulated investigation by radiologists into PACS, have also raised interest amongst other diagnosticians, including pathologists. The potential advantages of on-line diagnostic services including the provision of specialist services to remote areas, access to computer image banks for confirming diagnosis and assisting in education, and the ability to store and retrieve large numbers of images have attractions for pathologists as well as radiologists. However, with telepathology there are additional factors such as the need to review pathology images in colour and the immense amount of data (over 1GB) contained in a histopathology study. These factors present technical and cost barriers to the adoption of telepathology systems.

The major concept in telepathology is dynamic video imaging—the imaging of histopathology slides by panoramic scanning in real time (50). A pathologist at one location is able to move a glass specimen slide mounted on a motorised microscope stage of a robotic microscope at another location, and at the same time, see the image of the moving slide on a video monitor. Advances in video microscopy, computer sciences and robotic light microscopy are such that telepathology services can now be implemented over broad band telecommunication networks. These services can be either within institutions using fibre optics, or between institutions using the high band widths now available in the public telephone system.

In addition to the transmission of images, two pathologists are able to communicate verbally, while the primary pathologist uses the "transmit" workstation and the consultant pathologist uses the "receive" station to review a case. Clinical documents can also be exchanged. An important aspect of a telepathology workstation is a matrix panel, with controls for microscope function, magnification and illumination. The keypad also includes robotic microscope stage controls for directional movements (x and y coordinates), speed, and focus (z-coordinate). It is necessary for a virtually flicker-free image to be produced on the video monitor, as a pathologist's tolerance is low for blurring of images during the scanning process. Thus, as well as adequate resolution, telepathology systems must provide colour fidelity, image stability and reduced motion blur during the movement of glass histopathology slides on the microscope stage. These specifications call for the transmission of large amounts of data at high speeds.

An alternative to dynamic telepathology is static video imaging, using an image board to acquire and store a single video frame into a frame buffer of a digital image processing computer. Images can be transmitted to a remote workstation, either one at a time or in batch mode, for later viewing by the consultant. Images at 512 x 512 x 256 grey levels (0.8 megabytes) can be transmitted in 3–5 seconds without the use of compression algorithms. Higher resolution images, in 1024 x 1024 format with 4096 grey levels, would involve 4.7 megabytes per image. Image compression at 2:1 or higher may be used to satisfy the requirements for many pathology applications, although such approaches to compression will require continuing evaluation for accuracy of diagnosis.

The usefulness of static imaging depends on the proper microscopic fields being digitised at the transmission site. This in turn depends on the ability of the technician or pathologist responsible for the initial evaluation of the slide. Disadvantages of static video imaging include the relatively small number of images that can be examined per case and the inability of the consulting pathologist to examine microscope slides by panoramic scanning in real time. Nevertheless static imaging could be used in many instances and could be a useful solution where tele-consultation is desirable within group practices.

Telepathology systems in operation

A telepathology system providing a remote frozen section service in Norway from Kirkenes Hospital to Tromso University Hospital (400 km apart) was described by Nordrum et al (51). Both live (dynamic) and static images were sent over a two way video and telephone network with 2 Mbps capacity. Live images were compressed before transmission to reduce the volume of image information using a video codec. Still images, with 576 x 720 resolution, did not require filtering but involved 3.5 seconds per image transmission time. In the Norwegian project, a combination of dynamic images were used, with static images available for greater detail after preliminary examination. Live images, giving full motion display in real time at reduced 256 x 286 resolution were used for overview interpretation and the examination of uncomplicated structures. Still images were used for interpretation of details. Average examination time was 15 minutes per case.

An important feature of telepathology systems is robotic control of the microscope by remote control. This was performed from the keyboard of a personal computer at Tromso University Hospital. The motorised functions of the microscope, including five objective lenses, stage movement in 0.25 µm steps and focus, were connected to a computer which was activated from the Tromso workstation via the telenetwork. The results from use of the telepathology system were reported as clinically satisfactory.

A fully dynamic telepathology system between two hospitals 6.4 km apart (Emory University Hospital and Grady Memorial Hospital, Atlanta) has been installed (52). The system makes use of a broad band tele-communications channel, a private point to point 12 mHz microwave system, sending 30 images per second in full colour at high resolution. The system (CORABI DX 1000) incorporates high definition television (1050 scan lines) providing a resolution of approximately 700 test lines.

The system is bi-directional, so that pathologists at either hospital can transmit and receive slide specimen images. The system is capable of sending high resolution images of moving tissue sections without loss of detail. The elimination of motion artefacts, such as blurring, is considered essential for the critical steps of determining specimen orientation on the slide and for general interpretation of histological detail.

Although resolution is comparable between the two systems described, the Atlanta system operates at 30 images a second compared with a still image transmission time of 3.5 seconds in the Norwegian system. The variation in speed is due to broad band width (12 mHz) versus 0.1 mHz and has a direct effect on costs. Sending live images in Norway at 0.1 mHz involved image compression and lower resolution, with consequent image degradation when a tissue section was moving on the microscope stage. Static image viewing of a few selected fields is less satisfactory than being able to view thousands of fields dynamically. In live transmission, the pathologist can move the stage about in order to orient the specimen, select diagnostic fields, fine focus the microscope and optimise the visualisation of details. Thus, if sufficient band width is available, it is not necessary to revert to the transmission of static images to obtain high quality resolution.

It remains a matter for evaluation as to whether the capital and operating costs of dynamic telepathology will be balanced by the assumed benefits of access to remote areas and facilitation of teleconsultations between pathologists.

Apart from the use of telepathology systems for either dynamic or static consultations, there remains the problem of the storage and retrieval of pathology specimens, for consultation, teaching or medicolegal purposes. Weinstein (50) estimated the total number of microscopic fields required to digitise and store an entire case electronically (eg. images of all histopathology slides). The following table was produced for a case involving atypical epithelial cells:

Table 2: *Example of Storage Requirements for Pathology Diagnosis*

Type Section	Number Sections	Aggregate Surface Area (cm^2)*	Number Images
Frozen	5	6.63	602
Permanent	4	5.93	539
Totals	9	12.56	1,141

* Number of images, using a 10x objective lens.

Thus the storage requirements of the single frozen section case would use over a gigabyte of storage, assuming 0.8 megabytes per image without compression. Such storage requirements mean that on-line telepathology systems are not at present a realistic proposition given the current cost of storage media.

Although terabyte storage systems using optical tape are in use, it appears that there will need to be significant increases in storage capacity and associated reductions in storage costs before dynamic telepathology systems can be implemented. Alternatively, there may be a need for receiver operator curve (ROC) studies to determine acceptable levels of data compression, which would significantly decrease storage requirements. The evaluation of the MFP prototype telepathology systems in South Australia will examine if storage and resolution problems can be overcome so that cost effective systems can be developed for both consulting and educational purposes.

Automation of pathology

A number of overseas firms are developing automated cytology systems, based on research over the past twenty years which has identified the key morphologic features of abnormal cells (53). One approach is the use of neural computing to perform analysis. After training on "normal" smears, a neural computer has the potential to recognise abnormal cells that differ from the normal reference. Given the high number of "true" normals in a population with a low occurrence of disease, this approach has the potential to reduce false negative findings.

An alternative approach is a major change in the slide preparation technique to avoid the problems that occur with a conventional smear. By producing a cell monolayer for video digitisation, the analysis task is simplified for later computer processing and production of a cytologic status report (54). The report can be reviewed on a computer workstation, allowing a cytologist to examine nominated abnormal cells for final analysis and reporting. As the cytology image has been digitised, it can be transmitted to a senior colleague for a second opinion, either within the laboratory or over the public telephone network to another institution.

Reporting and storage of pathology results

Apart from the extensive use made by large institutions of pathology reports, results are returned to general practitioners for information and for subsequent incorporation into a patient's record. In view of the volume of pathology tests performed annually there is an opportunity for the use of tele-reporting. There are a number of levels of tele-reporting of results ranging from fax, computer print-out of results in a doctor's office, transmission of results to a computer file on the doctor's computer system for subsequent updating of the patient's record, automatic updating of the patient's record or automatic patient notification of normal results.

Some of the above approaches have been implemented and are designed to ensure the efficient processing of pathology results. A standardised method of recording of laboratory results, as has been established in the USA since 1988, assists in the collation of the pathology results with existing clinical data. As general practitioners are concerned about correctly applying pathology results so as to reduce or eliminate any further unnecessary tests, efficient computer storage of test results has the potential to ensure that patient records are not "lost" or temporarily unavailable. Pathology results when stored on computer could be accessed by approved para-medical staff and reported to patients, if appropriate.

Telepathology systems in medical education

A significant component of professional time is involved in student teaching and in training of staff. It has been suggested that pathology information should be recognised as a distinct discipline [55]. The nature of medical science involves complex assessment of visual information in areas such as anatomical pathology, microbiology, cytology and hematology.

A feature of a telepathology system is the ability to store images on optical and video media for later review. Suitable cases can be selected to form specific teaching files which can then be stored on laser video discs as teaching material or transmitted by modem to a student's personal computer. It is possible to use a telepathology image data base to continuously update teaching files for students. The rapid transmission of data has potential advantages over other methods of distribution of complex, full colour, medical images. A supporting computer system would also allow for teacher/student interaction and for the recording and marking of test performance. On line teaching systems would allow structured access to increasingly complex teaching modules or could be used to provide subsidiary image teaching files for review purposes.

When taking into consideration aspects of student teaching, staff training and continuing professional medical education, the potential educational benefits of a telepathology system require evaluation. Once the capital costs of implementing a telepathology system have been undertaken, the system then has potential for use in distance learning activities at both national and international levels.

Commentary

Developments in telepathology are of interest to Australia. However, in practical terms, the existing coverage of pathology services is such that few if any communities are without access to diagnostic services. The major use of telepathology as described in the literature would appear to relate to consultation on histopathology between two hospitals. While there is a need in Australia for consultation and second opinions, such activity would only represent a very small fraction of the bulk of pathology services. As well, the relatively high capital and operating costs of telepathology would need to be evaluated to determine the costs and benefits in terms of patient management and patient outcomes.

However, the use of telepathology for assisting in education is a development which should be evaluated, as should the possibility of the use of telecommunications for the reporting of pathology results.

Telemedicine—home monitoring

An alternative to institution based health care for many patients is home based care. In retrospect, the twentieth century may have witnessed the rise and fall of the great hospitals as it gradually became apparent that large institutions were an inefficient way of delivering health care for all but acute surgical conditions. Large outlays on capital, maintenance and staffing of hospitals greatly reduce the resources for the management of an increasingly elderly population with mainly chronic conditions.

While in the past it may have been acceptable to care for geriatric patients in either nursing homes or on a long term stay basis in public hospitals, this is no longer deemed to be acceptable. There is a world wide trend towards reducing numbers of non-acute hospital beds and the length of hospital stay of acute patients. There has been a corresponding increase in the use of day surgery centres, and other alternatives including hospice care, nursing homes and maintaining ambulatory patients at home with community support services.

Just as improvements in computers and communications technology raise the possibility of the decentralised office, with individuals working from home, so developments in telemedicine raise the possibility of monitoring patients at home. An analysis of institutional usage would demonstrate that many patients are in hospital for tests, monitoring, observation or recovery. Given the high overhead costs of running hospitals (the "hotel" component), there is an opportunity to consider the costs and benefits of providing monitoring services by an alternative such as telemedicine.

The growth of telemonitoring services is shown by an estimate that remote patient monitoring over the telephone in pregnancy and heart disease accounts for an expenditure of $200–$300M per year in the USA and is increasing rapidly [56]. A study by Arthur D Little, Inc. [30] indicated that cost reductions of the order of US $15 billion per year at 1990 prices could be achievable in the USA by the use of telecommunications to support home health services, as compared to institutional care.

A review in 1988 by the Dutch Steering Committee on Future Health Scenarios [57] concluded that systems which work to provide appropriate technology to people in their home seemed to be good for all parties—patients, those who pay for health care, and government. However the report noted that the evidence as to whether home care does or does not save money was not very extensive. It also noted that home health care may result in better care by servicing needs that would otherwise not be met, but at extra cost as existing levels of usage of physician and hospital services would continue.

Of course, there are other factors to be considered apart from costs, including patient safety, professional responsibilities, reliability of technology and patient acceptance of non-traditional modes of diagnosis and management. Legal issues and security of medical data are involved, as well as alternative reimbursement methods for telemedicine services. Under present financial arrangements in Australia, State and Federal Governments share the hospital costs of public patients and health insurance organisations and individuals share the hospital costs of private patients. It is not immediately apparent how these complex financial arrangements would apply to remote telemedicine services delivered by third parties.

While in the first instance, patients may be prepared to pay for the convenience of telemonitoring services at home, in the longer term there would need to be an adjustment of existing financial arrangements to support the use of complex technology over lengthy periods of time for an elderly, and often indigent, patient population. As well as elderly patients, there will be other groups, such as infants and young children, who may benefit from telemedicine monitoring. Thus there is a need to examine a range of the possible uses of telemonitoring and how they might complement existing health services.

Telemonitoring of cardiac patients

Following developments in the use of implantable cardiac pacemakers it was a logical step for monitoring devices to be developed to transmit cardiac patterns by the public telephone system to a physician's office. Indeed, such an application was one of the first uses of telemetry modems in Australia and the transmission of ECG data by telephone has been occurring routinely since that time. Ambulatory monitoring of cardiac patients (Holter monitoring) over a period of 24 hours is performed for patients with a range of symptoms including intermittent arrythmias and palpitations. HIC data show there were 43,000 uses of the relevant MBS item in 1990–91. However, because of the irregular nature of the symptoms, a single 24 hour monitoring often does not show a series of cardiac events which could lead to a definitive diagnosis.

More recently "event monitoring" systems have been developed which can be activated by the patient at the time of symptoms occurring. Equipment such as PACERVIEW (Micromedical Industries, Inc.) will record cardiac data for two series of observations for 60 seconds before and after the event thus providing four minutes of data. The data are recorded in analog form and transmitted by telephone to a physician for analysis. "Event monitoring" could provide diagnostic data and reduce the usage of public hospital facilities where patients present for monitoring of signs of cardiac arrythmias and palpitations.

Given the rapid rate of development in cardiac event monitoring using microprocessor-based technology, it is likely that features such as looping memory will improve the detection capabilities of the devices. Also, the development of expert systems will allow for developments in automated diagnosis of patient data. Applications such as remote pacemaker analysis and the monitoring of compliance with medication have been developed. An advantage of computer based expert systems is that they allow the comprehensive analysis of the patient's current recordings. Analysis of previous history, unique to the patient, can detect changes and monitor the effect of cardiac medication.

The range of patients being considered for tele-monitoring includes post-infarct patients, those with symptoms of angina, those on long term medication and pre and post cardiac surgery patients. Although ambulatory monitoring technology in the past had limited success in providing useful diagnostic data to physicians, the newer technologies of event monitoring and computer analysis of data have the potential to improve the diagnosis and management of cardiac patients [58].

The potential for cardiac monitoring in Australia is demonstrated by the existing usage of ECG and exercise ECG tests at approximately 1.2M services per year. Although the mortality from cardiovascular disease has decreased since the mid 1960's, there remains a large patient population who have either survived heart attacks or suffer from angina or who require monitoring following cardiac surgery. The size of this population has been estimated at approximately 200,000 patients in Australia and there is an on-going discussion as to how this population should best be monitored to ensure optimal care at reasonable cost to the health care system [59]. As part of this debate it is necessary to define which sub-group of cardiac patients are most likely to benefit from telemonitoring. Capone et al [60] reported on the use of trans-telephonic monitoring in USA to provide surveillance and emergency intervention in a group of patients who had experienced acute myocardial infarction. The report concluded that telemonitoring could detect complex arrhythmias of prognostic significance, improve quality of life and reduce cardiac mortality.

A preliminary cost analysis of cardiac monitoring for Australia has been performed by Rockliffe [61], based on estimates of DRG coded separations from hospitals for pacemaker procedures (4,300 patients) and cardiac arrhythmia (21,990 patients). Noting that pacemaker monitoring is normally continued over a period of several years, it was estimated that average hospital stays might be reduced from five to 1.5 days at an annual saving of $2.6M. This estimate was based on the assumption that all pacemaker patients are suitable for telemonitoring. In the case of cardiac arrhythmia patients, it was assumed that some 20 per cent might be suitable for telemonitoring (4400 patients) giving estimated savings of $2.6M. While such savings in hospital usage are potentially significant, they must be balanced against the estimated cost of $350 per month per patient proposed for an arrhythmia event monitoring service.

There is a need to replicate overseas studies in the Australian health care environment to determine the effect of cardiac telemonitoring on selected patients. A study would provide useful guidelines for such matters as :

- assessment of telemonitoring technology systems
- comparison with existing procedures (eg. Holter monitoring)
- compatibility with Australian telecommunications system
- ethical and legal responsibilities of the providers of telemonitoring services
- selection of categories of patients most likely to benefit from telemonitoring
- assessment of costs and benefits of telemonitoring.

Telemonitoring for pregnancy

Telemonitoring devices have been developed for monitoring uterine activity at home. As the prevention of premature births is a major problem in obstetrics, the management of at risk groups—patients with hypertension and diabetes—has potential to improve outcomes and reduce the costs associated with premature births. Telemonitoring can be used from week 24 to week 36 by the patient attaching an external recording device over the uterus twice a day for one or two hours and the recording being transmitted by telephone to a central station. There is contact between the patient and a nurse to provide advice about when to go to hospital. The monitoring device is based on the concept that a patient will have an increase in uterine contractions before the onset of preterm labour, but that this increase is not normally recognised by the patient.

During 1991 the FDA approved the use of a home uterine activity monitor, developed by Tokos Medical Group, for the early detection of preterm labour in women who had had a previous preterm delivery. Debate about the clinical value of such devices has occurred [62] with claims that the efficacy of the system has not been proved and that the detection of symptoms does not equate with the prevention of an unfavourable outcome. Concern was also expressed about cost (US$5000 per patient) and that the limited approval by the FDA for a device for a specific set of conditions may lead to widespread marketing of the device for other conditions.

The manufacturer has replied that the controls imposed by the FDA, plus other controls by physicians, would ensure that the device would only be used by patients at highest risk. The point was also made that a device cannot prevent preterm birth, but that the early detection of preterm labour affords the opportunity for intervention. This would include the provision of tocolytic therapy and the potential prolongation of pregnancy [63].

The debate over the use of home monitoring of uterine activity is an example of the problems likely to be faced in Australia by developments in telemonitoring technology. While the technical operation of the device is not in question, there will be debate about effects on clinical outcomes and the cost of new technology [64,65,66]. The need for evaluation by methods such as randomised clinical trials is evident, before resources are directed from existing needs to new technology. The debate over the use of fetal heart rate monitoring [7,67] is indicative of the need for evaluation when this type of technology is proposed to be linked by telephone to a patient at home.

Other telemonitoring applications

Given the medical concerns with conditions such as sleep apnea and the difficulties of monitoring and diagnosing the condition, the development of telemonitoring devices has potential to improve performance in the area. Monitors can record ECG and respiration plus oxygen saturation and pulse rate using a pulse oximeter. Alarms can be activated in cases of apnea, low breath rate, and low or high heart rates. Data collected can be transferred by modem to a centre for analysis at a cost of approximately $300 per month.

Commentators such as Kilpatrick et al (29) have noted that the use of home monitors for the detection and prevention of Sudden Infant Death Syndrome (SIDS) in infants has experienced limited success and substantial controversy about the incidence of false positive alarms during apneic episodes. The development of newer microprocessor based systems, allowing for the storage and retrieval of data preceding an alarm was described, which allowed the data to be retrieved and analysed at a physicians office by use of telecommunications. The physician could also change alarm parameter settings remotely and such flexibility was designed to reduce the number of false alarms.

Another example of telemonitoring is the development of Home Assisted Nursing Care systems. These "robots" can dispense medication, monitor vital signs and provide automatic transtelephonic reporting to a monitoring centre. The implications of this technology for existing patterns of nursing care have been discussed by Bryant (68). Issues such as access to technology, relationships between the nurse and the patient, time involved in analysis of telemonitored data, and quality assurance were raised. An important concern was seen as the co-ordination of care, given that there may be a simultaneous combination of hospital care, general practitioner care, and care by an independent service providing telemonitoring. There would be a need for definition of medical responsibility so that there is a clear path to be followed from the recording of a telemonitored event to the notification of appropriate medical authorities (hospital specialist or general practitioner) and initiation of subsequent action.

Commentary

There are a number of efficacy, administrative and cost benefit issues that need to be considered, along with issues of patient acceptance, before advanced telemonitoring systems can be used routinely in the Australian health care system. The aim of improving patient care should be paramount, remembering that computers and telecommunications cannot replace doctors and other health care professionals. The realisation of such potential benefits depends on education of the patient population in self-help along with adequate back-up and patient monitoring services to ensure that the devices are being used appropriately.

For these reasons there is a need for a comprehensive evaluation of telemonitoring systems including both the tangible aspects and the social interaction aspects. Despite the predicted advantages of the telemedicine in home monitoring, it appears that current developments both in technology and support infrastructure, have been relatively small in terms of patient impact. While the development of specific applications such as cardiac monitoring has been achieved, an integrated system of total home monitoring has not yet been developed. It appears that institutional care will continue to be the standard in the near future until significant breakthroughs occur in the provision of an administrative framework for the delivery of high technology telemedicine services to the home.

Evaluation of telemedicine

The need for evaluation arises from the perception that the introduction of telemedicine systems in Australia is likely to involve capital expenditure and the utilisation of scarce medical resources. The history of the use of computers in Australia, with many suppliers competing in a small market, does not provide any confidence that the introduction of telemedicine will be managed well unless clear evaluation strategies are developed and the results of such evaluation acted upon in a logical manner by a co-ordinating body.

Developments outlined in the paper show promise but few have been rigorously evaluated in the context of routine health care. Also costs and rates of technological change are both high. Reviewing recent history involving the introduction of computer systems, it appears that, although there would have been significant advantages, in terms of administrative efficiencies, if all government departments—Federal, State and local—had acquired computers to a single standard—with benefits of standardisation, data exchange, personnel training and system maintenance—this did not occur. Pressures applied at all levels for a "fair share" of the market by major international vendors ensured that a wide variety of incompatible systems were purchased.

In addition there was pressure for purchase of locally designed and manufactured systems, so the situation emerged of overseas suppliers from USA, Europe, and Japan, plus local suppliers, competing vigorously in a small market. After 25 years of purchasing uncoordinated computer systems, the Federal government has adopted a standard communication protocol (GOSIP) for all electronic communications, so that, in the future, non-standard systems should at least be able to exchange data. It is to be hoped that the consideration of new telemedicine systems will be based upon an "open systems" approach, so that standard systems will allow for the integration of medical information using a common health care network.

The thrust for the development of "open systems" connectively has come mainly from Europe, reflecting progress towards the creation of an European Common Market. With a combined population of over 600 million, Europe has sufficient purchasing power to require that all computer systems be compatible so that purchasers are not locked into proprietary, and exclusive, standards of one particular supplier. The European standards body CEN has led the way in open systems, thus putting pressure on American standard bodies such as ANSI and ACER-NEMA, which have been traditionally influenced by equipment manufacturers, while Japan has largely taken a separate direction

The need for evaluation of telemedicine systems arises because Australia, with only a small local industry, is a minor player in the field of computers and medical informatics. Health administrators and system designers will watch with interest the outcome of such projects as the AIM Project of the Commission of the European Community, funded at the level of $100M per year, the CPR Project in the USA, funded at $50M per year, and the ISAC Project, sponsored by the thirty major companies in Japan, knowing that they are likely to be purchasing the systems developed by these projects at some time in the future.

Rather than re-inventing the wheel, decision makers in Australia need to monitor overseas developments and produce Australian standards which will allow the best use to be made of both the hardware and software which emerges. The body responsible for standards, Standards Australia has issued, through Committee IT/14 (Health Informatics), preliminary discussion documents. As a starting point, these documents should be examined to see how they might be applied to local pilot projects in telemedicine. Subsequently, there will be a need to evaluate the likely costs and benefits of such systems, before substantial commitments are made to the purchase and implementation of telemedicine systems in Australia.

Evaluation methodology

A considerable amount of evaluation work has already been performed in areas such as teleradiology, but there has been little agreement on the adoption of a standard methodology, so that results have been inconclusive. The costs of PACS system has been identified in the region of $10–15M per system whereas the benefits have been less clear (69). In this situation, decision makers have been reluctant to invest large capital outlays in teleradiology systems when there are more pressing demands for capital funding in the health services. Thus there is a need for a methodologically sound evaluation of a PACS and teleradiology to be performed in Australia.

When considering an evaluation methodology for telemedicine, the normal principles of efficacy, effectiveness and efficiency should be applied, as to other initiatives in the health field (70). As regards efficacy, there is enough preliminary evidence to suggest that, under ideal conditions, telemedicine may do more good than harm to patients by, for example, eliminating unnecessary patient transfers. Hendee et al (71) reported on a successful application of telemedicine during the aftermath of the Armenian earthquake in 1988. Crawthorn et al (72) provided a preliminary assessment of the use of teleradiology during Operation Desert Storm between Saudi Arabia and an army medical centre in San Antonio USA for clinical assistance to patients. Wong et al (73) have now implemented a fully operational, fault-tolerant PACS system at UCLA.

In terms of evaluation study design, there are opportunities in Australia for controlled studies by observing the outcomes of patients with telemedicine services compared to those in another region without such services.

A difficulty with hardware based technology is that it is not possible to blind the observer to the presence of the telemedicine technology. Some bias may be introduced into the study, as the persons most likely to be involved in the conduct of the study are those with an interest in seeing that the technology is implemented. Also, the enthusiasm of the manufacturers of telemedicine systems has to be taken into account, particularly in situations where the equipment is on loan, or on trial, or being evaluated for a specific period, subject to purchase and possibly wider dissemination. In these situations, the definition of providers must also include the telecommunications supplier, Telecom or Optus, who may have a particular interest in seeing that new technology, or services such as ISDN or FASTPAC, are adopted and used extensively.

Discounts on telecommunication services may have particular importance in determining overall system costs. Developmental technology, including modems, may be provided at a discounted rate, as there is great flexibility in charging policies for telecommunication services, so that the likely final cost of equipment needs to be evaluated.

There is a need to measure all relevant outcomes, particularly those relating to quality of life and patient values. For example, the wish of a patient to receive treatment in close proximity to relatives and family support may necessitate a patient transfer which could have been avoided by the use of telemedicine systems. In this case the potential usefulness of the technology would be outweighed by consideration of patient satisfaction.

Evaluation of effectiveness, the utilisation of a technology in a real life or community setting, is a particular problem for telemedicine applications in home monitoring. Effectiveness studies need to have regard to the wider population in which the technology is likely to be used and factors such as the likely diagnostic accuracy, the understanding of the use of the technology by health professionals and the proper training of patients in the use of the equipment.

Early literature reports of efficacy of a technology on selected patients cannot be equated with effectiveness in the wider community. Thus the results obtained from equipment such as cardiac event monitors on patients in a hospital setting, with good training and supervision in the operation of the equipment, cannot be assumed to apply to the total cardiac population without further evaluation and the conduct of community based evaluation studies.

Evaluation of efficiency, the relationship between cost and benefits, presents the most difficulty if for no other reason than the high capital costs of telemedicine systems and the intangible nature of many of the assumed benefits, including improved patient care, reduction of rural isolation and improved levels of medical education. The conduct of cost-effectiveness evaluation studies of telemedicine systems is indicated, as it is unlikely that it will be possible to convert benefits into the appropriate monetary units necessary for detailed cost-benefit studies.

Evaluation strategy

Given the high cost, the high rate of change in technology, and lack of agreement about benefits, there is a need for very specific studies of the costs and benefits of telemedicine systems, preferably conducted in a controlled environment. A number of approaches might be considered involving either the establishment of a centre for telemedicine evaluation or the evaluation of selected projects. Given the scarcity of evaluation resources, there would seem to be an argument for a co-ordinated approach, so that effort is not duplicated and findings are pooled.

As discussed earlier in this paper, a number of pilot telemedicine projects have already emerged in Australia, and these might become reference centres for evaluation. A suggested approach might involve co-ordination of the evaluation results from the following projects:

PACS :	Introduction of proposed telemedicine and PACS at the Children's Hospital, Westmead, including development of appropriate methodology for estimation of costs and benefits to enable comparison with similar projects in overseas institutions.
Telemedicine :	The Wagga project for neurosurgical consultation with St. Vincent's Hospital, Sydney.
Telepathology :	The MFP project for the transmission of pathology results between Whyalla and Adelaide.
Communications :	The Australian Computing and Computation Institute (ACCI) project in Melbourne for the transmission and processing of medical images using high speed 10 Mbps facilities in conjunction with St. Vincent's Hospital and Monash Medical Centre.
	The Austin Hospital, Melbourne, project for the evaluation of image transmission.
Education :	The Department of Community Medicine, Monash University project on the development of computer-based medical teaching modules for distribution to other medical facilities.
General Practice :	The Computer Assisted Practice Project (CAPP), in conjunction with the RACGP and the Department of Health Housing and Community Services, evaluating the use of computerised medical records in general practice.
Teleradiology :	The Royal Melbourne Hospital project for the transmission and reporting of MRI images.

These studies provide a nucleus of pilot projects whose activities could be co-ordinated in conjunction with the development of standards for health informatics by Standards Australia. Such activities could form part of the "Field Studies" module in the Research Partnership proposed by the NCEPH [40] and could be co-ordinated by the proposed Health Communications Network Agency.

Funding for telemedicine evaluation projects might also be sought from existing granting agencies or there may be a case for establishing a targeted research program, with support from both government and industry. Looking to the future, there will be a need for co-ordination between professional bodies, government, industry and research institutions if national policies on computer-based patient records, portable medical records and standard coding systems for medical data are to be developed. Therefore it may be desirable to anticipate these future needs by involving AMIA in the co-ordination of the evaluation of field studies. Such a mechanism would ensure that the results of evaluation of pilot projects flowed through to interested parties and formed a basis for decision making on the wider health policy issues involved in telemedicine systems.

As well, there is a need to involve representatives of patients and legal bodies in evaluation studies so that decisions on telemedicine are not made in isolation from the perceived health needs of the population and the existing legal system.

The need to involve patients and institutions was emphasised by the findings of the US Institute of Medicine Committee on Improving the Patient Record [37]. The report concluded that the primary barriers to realising complete Computer-Based Record Systems were not technical, but were behavioural or organisational in nature. Apart from technical problems such as the need for voice input for clinical data, the major problems were seen as lack of appropriate confidentiality or security measures, inadequate health data-exchange standards, and the problem of liability for system defects in the case where a physician relies on computer output without further checking.

It is considered that the pooling of the evaluation results of pilot telemedicine systems would provide an opportunity to examine behavioural and organisational issues in the framework of the Australian health care system prior to full-scale introduction. Recognising that many of the system and hardware solutions to telemedicine will be developed overseas, it is considered desirable to evaluate these products and systems in the local environment. The unique Australian features of Federal/State sharing of health responsibilities, universal health insurance, fee-for-service medicine and a mixture of private insurance and public hospital systems, means that no other country has an identical health system to Australia. Therefore it will be necessary to test overseas solutions in a local environment to ensure that proposed solutions to telemedicine meet the needs of the Australian community.

The conduct of an evaluation program, co-ordinated by a body such as the Health Communications Network Agency, would ensure that developments in telemedicine are implemented in a cost-effective manner to the overall benefit of the Australian health system. As a first step a list of pilot projects in telemedicine should be drawn up and the projects examined as to suitable for funding in terms of their likely effect on patient management and patient outcomes. Any further steps would have to have regard to initiatives by other organisations such at DITAC and State health authorities. However, it should be possible to ensure that existing projects are evaluated in a standard manner so as to provide clear guidelines for the future development of telemedicine systems in Australia.

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Appendix A

Teleradiology applications in Australia

New South Wales—children's hospital telemedicine and PACS projects

A proposal has been made to install a PACS system in the new Children's Hospital at Westmead, Sydney, which is a 350 bed fully equipped hospital with 50 intensive care beds, theatres and emergency care. Radiological services will include ultrasound, nuclear medicine, CT and MRI involving a total of twenty rooms. The PACS will be serviced by a comprehensive data base of images and reports with integration through a fibre optic backbone to a Clinical Information System and a Hospital Information System. The Imaging Department will have 11 plain X-ray rooms apart from 9 special service rooms, and in view of the wish to have a digitally based imaging system, computed radiography systems have been designed as an integral part of the operation of the hospital for both static and mobile x-ray procedures. A teleradiology system will link the hospital with other centres to provide pediatric diagnostic services both nationally and internationally

An overview document calling for expression of interest in the PACS project was issued in July 1992. Selected groups of suppliers will be asked to tender for the complete system during 1993/1994 with a view to the system commencing operation in 1995/1996. A pilot telemedicine project will be conducted during 1993, linking the Children's Hospital with three remote sites, to provide preliminary data on costs and performance.

An evaluation strategy has been proposed which involves collection of data on the operating of the imaging department at the existing Children's Hospital before it is moved to the new `filmless' site at Westmead in 1995/1996. It is proposed to collect a wide range of cost and perfomance data during 1993/1994 to enable comparative statements about cost efficiency to be made once the filmless imaging department becomes operational. It is anticipated that the conduct of comprehensive evaluation of the PACS project and the telemedicine project at the new Children's Hospital would provide guidelines for other hospitals considering similar systems in Australia.

New South Wales—Wagga Wagga project—teleradiology for neurosurgical consultation (Dr GD Richardson)

The Wagga Wagga Base Hospital, some 500 kilometers from Sydney, is a pilot site for the NSW Department of Health Hospital Information System. The city has had a CT unit located in a private practice since 1983 and has participated in the activities of the State Trauma Committee since 1987. Regional Rural Critical Care Groups have been formed to improve communications between District Hospitals and Base Hospitals in the management of severely traumatised patients. The possibility of utilising teleradiology for transmission of CT images to assist in head injury management was discussed and implemented during 1991. The aim of the project is to link the surgeons and anesthetists at Wagga Wagga Base Hospital and the Neurosurgical Unit and Intensive Care specialists at St Vincent's Hospital, Sydney.

Administrative arrangements

A protocol was developed covering the administrative aspects of trauma management. This ranges from initial contact by an outlying doctor or ambulance, to the admission of the patient in the Accident and Emergency Department of the Base Hospital, to the transfer of the patient to the private CT and the discussion of the case with specialists at St Vincent's Hospital. There were 45 cases during 1990, with motor vehicle accidents being the predominant cause of injury. There is a significant saving in transport costs if the patients can be managed locally.

St Vincent's Hospital operates a 24 hour Accident and Emergency X-ray department. The hospital is informed of all ventilated closed head injuries and all emergency craniotomies performed at Wagga Wagga. The cases are referred either pre-operatively for advice, or the following day for stable cases.

Teleradiology equipment

The teleradiology system used is one developed by a local Australian company, Image Med. The system consists of a high quality digital video camera which photographs the image to be transmitted. This approach to image capture is known as "Camera on a Stick" as compared to techniques which use either a video scan (frame grab) or direct digital capture from the original imaging modality such as a CT unit.

The advantage of the Image Med system is that it can photograph any existing film under manual control, whether CT, X-ray, ultrasound, or an angiogram for example. The image is compressed using a proprietary image compression algorithm in the computer (2:1) and prepared for transmission via a modem to St Vincent's Hospital. A range of between 1 and 14 images are transmitted with an average of six per patient. The transmission time per image averages 100 seconds, giving ten minutes for six images. The system provides for storage of images on 100 MByte hard disc with grey scale manipulation by software at the receiving end.

The hospital at Wagga acts as a sending and receiving station with a receiving station at St Vincent's Hosspital. Telephone contact is made prior to transmission to ensure that the receiving station is switched on, and, at the same time, an official consultation request form is sent to St Vincent's Hospital by facsimilie. Experience has shown telecom usage of approximately 25 minutes per patient for image transmission and consultation, costing $15 per case.

Image med system—Wagga/St Vincent's hospital, Sydney

• Costs:	Send/Receive Station	$24,000
	Receive Station	$17,000
	Maintenance Costs	7 per cent per annum
	Phone line—Installation	$240
	Rental	$240 per annum

- Usage: Over six months, 18 teleradiology cases were transmitted to St Vincent's Hospital for consultation.

System operation

As only selected images are transmitted, and image quality depends on camera focus and contrast, there is a need for good communication between the referring doctor and the consulting neurosurgeon to provide relevant clinical information and to decide which images should be transmitted. The system has flexibility in that the surgeon in Wagga can ask for an urgent opinion from the neurosurgeon at St. Vincent's Hospital. Alternatively, an opinion can be obtained the following day, having transmitted the images during the evening at cheaper telecommunication rates. The consultant's opinion can be verbal in urgent cases or by facsimilie. In most instances, the report has been obtained from the neurosurgeon within 24 hours. As no hard copies of images (films) are available at the "receive" station, the neurosurgeon must report from the images on a computer screen. However, there have been no difficulties experienced with the quality of the image for neurosurgical reporting. Other applications, apart from routine CT brain images, have been the transmission of carotid and cerebral angiograms, a cystogram and CT image for an extensive bladder tumour, as well as chest X-rays.

Summary

The aim of the Wagga project is to assist the rural surgeon to provide optimal management using the advice of a remote neurosurgical consultant. Outcomes have been reassurance to the surgeon in Wagga and comfort to patients' relatives, knowing that consultation with a neurosurgeon has occurred. Future expansion of the teleradiology system to District Hospitals and to the Children's Hospital in Sydney is seen as desirable.

Victoria—Royal Melbourne hospital—low-cost teleradiology system for neurosurgical practice (Dr PJ Dohrmann)

The aim of the system is to make radiographic images available to the treating neurosurgeon from the earliest possible moment, thus making possible the implementation of critical decisions for patients before they arrive in a surgical department. Routine clinical communications from hospital to office or home can therefore be enhanced.

Teleradiology equipment

Image Capture—Film, radiographic viewing box, Panasonic High Resolution Camera Model WV–1850 fitted with 16mm lens, to provide video signal.

Hardware

IBM AT Personal Computer, digitising card, Video Graphics Array monitor, software and storage on hard disc in graphic format.

Transmission

Image Compression on archiving software and transmission by Net Comm 1234 Modem (2400 bits per second) at two minutes per image. An average of 5 images results in transmission time of approximately ten minutes.

Receive station

IBM AT or XT compatible personal computer, or Apple, Commodore or Amiga) with modem and software to view images.

System costs

Send/Receive Station	$6,000
Receive Station	$3,000

System operation

If early and accurate data are available to the treating neurosurgeon, it enables advice on patient transfer, and preparation for the mode of transfer, and treatment to be commenced before transfer. The system as described has been used in a busy neurosurgical department where many CT scans and angiograms are performed out of hours. Previously the decision to operate was based on a telephone description of the radiological findings by a trainee or registrar. In peripheral hospitals, house staff often have little experience in assessing acute neurosurgical emergencies.

The system has been used for urgent cases and for routine matters. Postoperative and elective patients have benefitted from enhanced communications between hospital staff and neurosurgical consultants.

Outcomes

Improved care from better out-of-hours decisions. Savings following fewer unnecessary or inappropriate transfers from remote sites. Fewer staff recalls to interpret CT scans.

Summary

There is a great deal of interest in low cost, personal computer based image transmission systems for use by neurosurgeons. These systems are typically "pre-view" systems, rather than radiologist "diagnostic" systems, but offer features of convenience, speed, and ease of use.

Victoria—Austin hospital

Objectives

- To network the Austin Hospital and the University of Melbourne departments (Heidelberg campus) with University of Melbourne (Parkville Campus) the Australian Academic Research Network (AARNet).
- To implement digital image and image report (PET, MRI, SPECT, CT, X-ray) distribution to image display workstations throughout the Heidelberg campus for clinical reference.
- To establish wide area image distribution to other hospitals and medical institutes.
- To further develop and include hospital patient information access (both locally and remotely) through the network using existing networked workstations.
- To implement and undertake a detailed cost benefit analysis of a pilot PACS, initially dedicated from hospital medical imaging departments to the Intensive Care Unit (ICU).

Partners

Austin Hospital

Centres for Positron Emission Tomography and Health Informatics.
Departments of Nuclear Medicine, Radiology and Information Systems.
Intensive and Coronary Care Units.

University of Melbourne

Information Technology Services (for networking/image distribution expertise).
Faculty of Medicine.

Australian and Overseas Telecommunications Corporation (AOTC)

Health Care Division.
Network Products Division (for FASTPAC services).

Progress to date

- An optic fibre and ethernet network has been installed and commissioned at the Heidelberg campus (August 1992).
- The Heidelberg/Parkville FASTPAC link supplied by AOTC (32 MBit/sec) has been installed and commissioned (August 92).
- A digital image and image report distribution has been established within the hospital (Oct. 92) using Wide Area Information Server (WAIS) software and X-windows based image viewing and manipulation software.
- A wide area image distribution including patient confidentiality has been demonstrated using WAIS software into remote institutions. (Sept. 92).
- Electronic mail access to AARNet has been implemented throughout the Heidelberg campus (progressively from Aug 92).

Future developments and requirements

- A networking administrator, and a programmer are required for management and development of the network, particularly to implement patient confidentiality and security features.
- An image server, film digitizer and a number of display workstations are required to implement the pilot PACS within ICU.
- An ethernet interface is required for the hospital mainframe computer to enable network access to patient records.
- Funding is required to support the AARNet link and to expand this link to include the Repatriation Hospital.
- To receive and provide expert reports of radiological images transmitted from the Albury Hospital.

Queensland—North West telemedicine project (Dr DS Watson)

In 1986 the Queensland Department of Health established Q-Network to enable a test of satellite communications. The North West Telecommunications project, linking the Royal Brisbane Hospital, the Royal Flying Doctor Service at Mt Isa and remote communities around the south of the Gulf of Carpentaria, was designed to explore ways and means of enhancing health care for people in remote areas.

Telemedicine system

The project used four two-way earth stations. Small business switching systems (SBX) at the remote stations allowed up to six users to share the single satellite channel. The hub of the telemedicine network was Mount Isa base hospital with a star configuration to five remote sites and links to a Base Hospital (Cairns) a Regional Hospital (Townsville) and a teaching hospital (Royal Brisbane Hospital). All sites were supplied with conference-style telephone, facsimile equipment and freeze-frame video transceivers. Dedicated telemedicine studios were established at Mount Isa Base Hospital and the Royal Brisbane Hospital. Six slow scan transceivers were also part of the network.

Operating procedures

Recording forms were developed for evaluation of each telemedicine consultation. For each consultation, the appropriate hospital records were searched later to obtain a separation diagnosis, coded to the International Classification of Health Problems in Primary Care (ICHPPC-2). Performance during the trial was compared with activity data for the nine months preceding the trial. From June 1986 there was a rapid decline in the use of radio for consultation purposes. Staff members at isolated hospitals used Q-network to contact other hospitals directly. The facsimile transceiver was used extensively, both for consultation and to transmit administrative material to the Health Department in Brisbane. The slow scan transceiver was used for sending patients' x-ray films and ultrasound images and during for example, September-October 1987 was used on 35 occasions. The slow scan transceiver was also used for family support purposes, so that parents at remote sites could see and communicate with children in Royal Brisbane Hospital.

Costing

Installation costs were approximately $75,000 per remote earth station with a lease figure of around $15,000 per annum per community. This represented the Health share of the satellite transponder lease of $2.6 million per annum for all Queensland government departments. Some 300 health consultations per year were estimated to cost of the order of $438 each.

Outcomes

During the operation of Q-network over 12 months, there was a reduction of 19 per cent in both emergency flights and patients (from 215 flights to evacuate 263 patients to 174 flights for 212 patients). The consultation process using Q-network was seen as more satisfactory and the confidence in the diagnosis was improved in most cases.

An editorial by Lazarus and Leeder (1989) was cautious about accepting the benefits of the pilot project without further detailed assessment, noting that the effect of telemedicine on health outcomes in Australia remains to be measured.

South Australia—Multi Function Polis (MFP)

Telemedicine project

A significant aspect of the MFP project is the proposed use of computers and communications to improve the delivery of health services. The MFP concept of telemedicine ranges from the use of telecommunications for remote consultations to the provision of a specialised teaching network to facilitate distance learning, as well as providing international on-line consultations in specialist areas of medicine such as cranio-facial surgery.

Telemedicine facilities

A pilot study of the MFP telemedicine project will involve the transmission of pathology information from a hospital in Whyalla to the Royal Adelaide Hospital. The system involves an CCD camera focused on an eyepiece of a microscope containing a pathology slide. The full colour information (4096 colours) can be captured in digital form and stored in a 486 (Extended ISA) computer with a 32/64 Megabits/second transfer bus. The pathology information will be stored on a 300 MByte disc at the sending station for transmission at 9,600 bps to a similar computer at Royal Adelaide Hospital for display on a 1600 x 1280 line monitor with 4096 (12 bit) full colour display. The system will be capable of using ISDN facilities, when applicable, at transmission speeds of 64 Kbps. An optical disc storage system using rewritable 130 mm (5.25 inch) discs with up to one GB jukebox capacity will be available at the receiving end for the long-term storage of pathology information.

A complete tele-consultation service is envisaged with a digitiser to transmit high quality x-ray films, as well as colour images, voice and slow speed scan television, plus fascimile facilities for transmission of diagnosis.

Outcomes

The proposed telemedicine system has the potential to avoid unnecessary transfer of patients from remote areas and will be subjected to a full-scale evaluation study. The provision of a full range of on-site specialist diagnosis could make the transport of patients to teaching hospitals unnecessary.

Cost

The tele-pathology system provided by Binary Image Inc, is expected to cost approximately $100,000, with extended features to be considered at a later date.

Victoria—St Vincent's Hospital, Melbourne—Tele-Medical Imaging Systems—Enhancement of MRI and CT images. (Dr K Morris)

The installation of an MRI unit in St Vincent's Hospital, Melbourne provided the capability to produce excellent MRI images on film for diagnosis. However many hospitals do not have a high speed workstation to allow the further processing of the image data for such activities as image processing and 3D interpretation. A project has been initiated by the Australian Computation and Computing Institute (ACCI) in Melbourne for the transmission and interpretation of MRI images in real time to the ACCI super-computer, using the Mayo Foundation "Analyze" software. Image processing tasks represent a challenge as an MRI study consists of some 30–60 images containing up to 30 Megabytes of data. With improved communication facilities, such as the FASTPAC 10 Megabit system, it should be possible to transmit, process and return images from ACCI to St. Vincent's Hospital in approximately 4 seconds. Applications for the MRI data include sharpening blurred images, volume rendering (30 reconstructions), image editing, tracing of blood vessels and presentation of oblique sections mathematically produced from source data. Such activities would be either time consuming or expensive as a stand-alone work-station but, because of the availability of communications and computing power at ACCI, can be performed quickly in a reliable and cost-effective manner.

As well as making possible the post-processing of images, the availability of super computing facilities makes possible other activities such as dynamic radiotherapy planning. Digital information, based on multiple views of the patient's tumour, can be transmitted via gigabit networks for processing in real time. The computer can then analyse the radiotherapy plan, simulate the effect and return radiation dosage and effect data to the treating docotor. This process can be repeated until a satisfactory therapy plan is developed. Such developments open up new possibilities for the improved treatment of patients and will be further developed at ACCI.

Private practice teleradiology systems

Apart from public hospital systems, there has been considerable interest amongst private radiologists in the transmission of CT and Ultrasound images during the past two years in Australia. As the majority of radiology practices cover large areas and involve a number of partners, there is a need for transmission and interpretation of images, either for routine reporting, consultation with colleagues or emergency after hours reporting of patients' images. These developments follow similar activities in USA where teleradiology is an established technology and where reimbursement fee structures allow for over-reading of teleradiology images.

Commercial teleradiology systems tend to be classified into three types, low resolution (video camera), medium resolution (512 lines) and high resolution (1024 lines and above) digital systems. The first two systems are generally used for pre-viewing of images, whereas the high resolution system may be used for diagnostic purposes. Price varies with the quality of the system, the transmission protocol, the degree of automation and the image storage and hard-copy reproduction facilities. The systems fall in the price ranges of $10–15K, $40K plus and over $200K, depending on the facilities required.

The lower cost video camera systems, involve a considerable amount of human interaction. A film is produced, placed over a light box, and a selection made of which frames are required for video camera capture. The images are transmitted via a modem using 2400–9600 bps dial-up lines at approximately two minutes per image. The systems are not designed to transmit a full CT study of 20–30 images, only selected images for temporary storage on magnetic disc at the receiving station. Images can be compressed to reduce transmission time, so that, for example, five images might be transmitted in under ten minutes.

The medium range teleradiology systems are designed to capture video monitor images with a video capture board using eight bits (versus the 10 or 12 bits stored in the imaging computer of the acquisition equipment itself). These images may be of diagnostic quality for CT, MRI, nuclear medicine and ultrasound and may be subject to non-destructive image compression prior to transmission, usually at 9600 bps. Some systems have the ability to operate in unattended mode, so that a series of images can be stored at the receiving station, awaiting interpretation. Alternatively a seven kg "display-only" monitor can be carried from place to place for remote viewing of images.

The more complex full diagnostic teleradiology systems offer direct digital capture of original data from the CT or MRI unit. They can also support a full 12 bit laser scanner for digitising chest x-rays or mammograms. Because of the amount of data involved (up to 8 Megabytes) compression and high speed data transmission is involved, using ISDN facilities at 64Kbps. These systems may be supported by optical disc systems for image storage, either as a single drive or a juke box, and if necessary, a laser imager for reproducing images on film.

In practice, there are a range of systems for a range of applications. At one end, it may only be necessary to send one low resolution image to a neurosurgeon for a professional opinion so that transmission time, storage, and image quality are not of paramount importance. Alternatively, it may be necessary to establish a full-scale radiology interpretation service involving large numbers of complex images requiring high speed transmission, high quality images and viewing screens, and extensive storage and reproduction facilities. The majority of vendors are prepared to offer alternatives, up to major Picture Archive and Communications Systems (PACS) depending on the applications and the future growth path of the practice or institution.

Examples of private practice teleradiology systems include:

Vic : A video camera based teleradiology system has been installed between Royal Melbourne and Epworth Hospitals, with links to Preston and Community Hospital and Western General Hospital. (Far Away Image Systems).

A system linking Box Hill and Dandenong hospitals (Image Data Corporation Multiview) has been installed with links to a portable viewing station which is taken home by an on-call radiologist. Images from the hospital's CT unit are captured by an external scan rate converter and stored on the Multiview hard disk for transmission to another workstation or to the protable unit. CT images can also be transmitted between the two hospitals.

SA : Perret, Harrison and Partners have recently installed a Binary Image Pty Ltd Digital Micro PACS system linking the Port Pirie Regional Hospital and the radiology practice at Memorial Hospital Adelaide. The system is capable of scanning radiology films such as fractures or chest images and transmitting them via ISDN links at 128Kbs to Memorial Hospital for reporting. The system is primarily designed to provide an after hours reporting service to

Port Pirie to cover accidents and road trauma, but the system is also used during normal working hours. It is proposed to have direct digital input of ultrasound and CT images. Images are presently sent in 3–4 seconds to Adelaide and reports are made to the referring doctor by either telephone or facsimile. The system is similar to the Binary Image Pty Ltd Micro PACS system installed between Whyalla and Royal Adelaide Hospital and the possibility of joining the systems in a network has been discussed.

NSW: A teleradiology system has been installed between Goulburn Base Hospital and John James Hospital in Canberra. Direct digital images are captured from the Goulburn CT (GE Sytec 2000) and transmitted by modem for storage on a hard disk on the receive station (IBM PC) at John James Hospital. Transmission takes approximately 60 seconds per image with an average of 6–10 images per case. The images are reviewed by the on-call radiologist in Canberra and a report made by telephone

Appendix B

Overseas telemedicine pilot projects

(Extract from Arthur D Little, Inc. Report 'Telecommunications—Can It Help Solve America's Health Care Problems?' July 1992, Reference 91810–98)

The following pilot project reviews expand the description of selected trails mentioned in the text. This appendix, however, is not meant to be an exhaustive list of the ongoing pilot applications.

Video Conferencing

Kyoto Prefectural Unviersity of Medicine

Kyoto Prefectural University of Medicine is the only site in the world that has used high definition television (HDTV) in providing medical care. This Tokyo teaching hospital is using ISDN to receive high resolution images of frozen pathology sections on an HDTV monitor. The pathologists at the University then can analyze the frozen sections by remotely controlling the automated microscope at the rural hospital.

Texas telemedicine

The Texas Telemedicine Project in Austin, Texas, offers interactive video consultation to primary care physicians in rural hosptials. The demonstration was funded by philanthropic foundations and vendors. A 65-mile network of T1 circuits between facilities in Austin and Giddings, Texas, was created to alleviate the shortage of specialists due to hospital closures in rural areas. More than 1,700 patients in rural Giddings have consulted with Austin-based specialists via this link. This system also features a patient education component in rural areas.

This trial has attracted nationwide attention as a vehicle for improving access to specialized medical care, mental health, and dialysis services, and increasing patient satisfaction in rural areas. It is providing at least 14 per cent savings over traditional care delivery due to a decrease in patient transfer costs and provider travel.[1]

The Medical College of Georgia

The Medical College of Georgia and BellSouth are using broad band telecommunications technology to enable specialists at the teaching hospital in Augusta, Georgia, to examine patients 130 miles away. Through sophisticated biomedical telemetry devices (e.g. electronic stethoscope, digitized X-rays, microscopy, and EKG) and interactive video equipment, practitioners at Medical College of Georgia have actually heard heartbeats, studied X-rays and laboratory results, and peered down the throats of 41 patients at Dodge County Hospital in rural Eastman, Georgia. The specialist has two monitors, one to interact with the patient and rural physician; the other to view images (e.g., video, EKG) and close-ups from cameras attached to biomedical devices. Only five required transfer to the Medical College whereas, in the past, all would have been transferred. The rural hospital and community have been the biggest winners. For example, the network keeps money within the community by allowing this rural hospital to maintain full occupany. Rural physicians at Dodge County Hospital also report that they have learned how to treat cases from the sub-specialist.

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1 Preston, Jane M.D., Brown, Frank W.M.D., and Hartley, Bette, M.L.S., 'Using Telemedicine to Improve Health Care in Distant Areas '*Hospital and Community Psychiatry*, January 1992. Vol. 43, No. 1, pp25-32.

Home Health

MEDphone Corporation

Among these devices is the remote defibrillator, `MDphone' introduced by MEDphone Corproation (Paramus, New Jersey). At least ten hospitals, including Jewish Hospital in St. Louis, Medical Center of Delaware in Wilmington, and Sacred Heart Hospital of Pensacola in Florida, and some Fortune 500 companies, are using the MDphone device. The device allows hospitals to diagnose and resuscitate a homebound patient who has suffered a cardiac arrest. This transtelephonic defibrillator device consists of a patient 'briefcase' and hospital base unit. When the patient feels that he or she is suffering a heart attack, someone with the victim must open the briefcase, which is connected to a telephone, and place electrode pads on the patient's chest. An EKG immediately is sent to the hospital, and an interactive speaker phone is activiated. If the hospital base station determines that the patient indeed has suffered a cardiac arrest, the device triggers the patient unit over the telephone line to deliver an electric shock impulse to revive the heart. Already, six lives have been saved. A cellular model is in testing at Medical Center of Delaware.

Harvard Community Health Plan

InterPractice Systems a joint venture of HCHP in Boston, Massachusetts, and Electronic Data Systems in Dallas Texas-is placing hundreds of these terminals in HCHP subscriber homes in Burlington, Massachusetts. The selected homes were 'heavy users of health care,' such as the elderly, pregnant women, and families with young children.

The system allows patients to call a toll-free number to guide them through the following steps to receive their care:

- Download patient record from the hospital to their home terminal;
- Pose a series of questions about their symptoms using artificial intelligence (e.g., high temperature, chest pain);
- Depending on the answers, triage the patient to the appropriate next step (e.g., self care, call to practitioner or appointment with practitioner);
- If self care is chosen, provide further information on the ailment to assist the patient in the selected treatment (e.g. dressing a wound).

The system performs a triage function that recommends actions, rather than diagnoses.

Surprisingly, preliminary results indicate a negative correlation between system usage and the patient's education level. The trial has increased patient satisfaction and is expected to reduce unnecessary telephone calls and visits by the 'worried well'.

Hosptials and Physicians

The Children's Hospital

The Children's Hospital (Boston, Massachusetts) created a text-based electronic medical record (EMR). NYNEX is working with the hospital to supplement the EMR with voice annotation and images. A pilot is planned that will allow a pediatrician to make a conference call to a colleague using image and text, as well as voice. The two physicians, located in different parts of the hospital, will be able to review the same information, manipulate the image, and interactively discuss a case while pointing to specific co-ordinates on the medical image. These electronic pointers are displayed on the monitors at both locations. The physicians can access a remote textual or image-based database. This system also will include electronic mail so that, for example, the physician can send a patient's record and radiographs to a specialist for consultation the next day.

Massachusetts General Hospital

Massachusetts General Hospital (MGH) is using a NYNEX fiber optic network to enable the transfer of high resolution medical images and records quickly among its main hospital, an imaging centre in Charlestown, and a film library in Somerville, Massachusetts. The network also is used to receive images from Harvard Community Health Plan's Burlington clinic for interpretation at the main hospital of MGH. The hospital employs 59 people solely for image retrieval and transport.

The system will include multi-media mail so that for example, a physician can send a patient's record and radiographs to a specialist for consultation the next day.

Glossary of acronyms and abbreviations

AARW	Australian Academic Research Network
AC	Alternating Current
ACCME	Accreditation Council for Continuing Medical Education
ACCI	Australian Computing and Communications Institute
ACM	Association for Computing Machinery
ACR	American College of Radiology
ACR/NEMA	ACR/National Equipment Manufactures Association
A/D	Analogue to Digital Conversion
A & E	Accident and Emergency
ADL	Automated Disc Library (Jukebox)
ADT	Admission, Discharge and Transfer Information in HIS
AI	Artificial Intelligence
AIM	Advanced Information in Medicine Project
AHA	American Hospital Association
AIHW	Australian Institute of Health and Welfare
AJR	American Journal of Roentgenology
AM	Acquisition Module
AMA	Australian Medical Association
AMIA	Australian Medical Informatics Association
ANSI	American National Standards Institute
AOTC	Australian and Overseas Telecommunications Corporation
ASCII	American Standard Code for Information Interchange
ASTM	American Society for Testing and Materials
ATM	Asynchronous Transfer Mode
B	Bytes (8 bit data element)
BIR	British Institute of Radiology
Bit	Binary digit (0 or 1)
B-ISDN	Broadband-Integrated Service Digital Network
bps	bits per second
Byte	eight bits representing a character
CADMIN	Cost Analysis Model for Digital Imaging Networks
CAI	Computer Aided Instruction
CAR	Computed Assisted Radiology

CAPP	Computer Assisted Practice Project
C C D	Charge-coupled device
CCITT	International Consultative Committee on Telephony and Telegraphy
C C U	Cardiac Care Unit
CD-ROM	Compact Disc—Read Only Memory
C E N	Comite European de Normalisation
C H C S	Composite Health Care System (DOD Standard)
C M E	Continuing Medical Education
C O N	Certificate of Need
CPR	Computer-based Patient Record
CPRI	Computer-based Patient Record Institute
CPU	Central Processing Unit
CR	Computed Radiography
CRT	Cathode Ray Tube
CT	Computed Tomography
CUA	Common User Access (Standards)

DA	Digital Angiography
D/A	Digital to Analogue Conversion
D-ATR	Digital-Audio Tape Recorder
DDA	Direct Digital Acquisition
DDIP	Digital Diagnostic Imaging Project
DDR	Digital Data Recorder
DF	Digital Fluoroscopy
DHHCS	Department of Health Housing and Community Services
DITAC	Department of Industry Trade and Commerce
DINS	Digital Imaging Network System
DMM	Data Management Module
DOD	Department of Defence (USA)
DR	Digital Radiography
DRILL	Digital Radiology Image Learning Library
DRG	Diagnosis Related Group
DSA	Digital Subtraction Angiography
D-VTR	Digital-Video Tape Recorder
DV	Digitised Video
DVA	Digital Videl Adapter
DW	Diagnostic Workstation

EDI	Electronic Data Interchange
ECG	Electrocardiogram
EEG	Electroencephalogram
ER	Emergency Room
ETHERNET	10 Megabits per second network
ET Net	Educational Technology Network (national Library of Medicine, Bethesda, MD, USA)
FCR	Fuji Computed Radiography
FD	Film Digitiser
FDA	Food and Drug Administration, USA
FDDI	Fibre optic Distributed Data Interface Network (100Mbps)
FIPS	Federal Information Processing Standard, USA
FN	False Negative (Rate)
FP	False Positive (Rate)
FROC	Free-Response Receiver Operating Characteristic Methodology
FTE	Full Time Equivalent Staff
GB	Gigabyte (10^9 8-bit bytes)
Gbps	Giga bits per second
GI	Gastro Intestinal
GUI	Graphical User Interface
HCN	Health Communications Network
HIC	Health Insurance Commission
HIPACS	Hospital Integrated Picture Archiving and Communication System
HIS	Hospital Information System
HL7	Health Level 7 (Application Level Standard for Data Formats)
HPPI	High Performance Parallel Interface (800 to 1600bps/Network)
IAPR	International Association for Pattern Recognition
IC	Integrated Circuit
ICD9-CM	International Classification of Diseases, Revision 9-Clinical Modification
ICN	Intensive Care Nursery
ICU	Intensive Care Unit
ID	Integrated Diagnostics
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers

IES	Illumination Engineering Society
II	Image Intensifier
IMACS	Image Management and Communication System
IMIA	International Medical Informatics Association
IMS	Image Management System
I/O	Imput/Output
IP	Image Place
ISAC	Image Save and Carry Project
ISDN	Integrated Service Digital Network
ISO	International Organisation for Standardisation
IT	Information Technology
IVD	Interactive Video Disc
IVP	Intra Venous Pyelogram
JAMIT	Japanese Association of Medical Imaging Technology
JDI	Journal of Digital Imaging
J-PACS	Japanese Society of PACS
JRS	Japanese Radiology Society
K	Thousand (10^3)
KB	Kilobyte (10^3 8 bit bytes)
Kbps	Kilo bits per second
KIDS	Kyoto University Hospital Image Database and Communication System
kVA	Kilovolt Amperes
LAN	Local Area Network
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LFD	Laser Film Digitiser
LLP	Lower Level Protocol (error correction and detection)
LP	Laser Printer
lp/mm	line/s pairs per millimeter
LTA	Long Term Archive
M B	Megabyte (10^6 8 bit bytes)
MBS	Medicare Benefits Schedule

Mbps	Mega (10^6) bits per second
MCA	Monoclonal Antibody
MDIS	Medical Diagnostic Imaging Support System
MEDIX	Medical Data Interchange (IEEE Working Group using ISO/OSI Standard)
M F P	Multi Function Polis Project
M H	Megahertz
MIPS	Medical Image Processing System
MIPS Standard-87	Japan Data Interchange Standard
M O D	Magneto Optical Disc
M P U	Micro Processing Unit
M R	Magnetic Resonance
MRA	Magnetic Resonance Angiography
MRI	Magnetic Resonance Spectroscopy
MRS	Magnetic Resonance Spectroscopy
ms	millisecond (10^{-3})
MTBF	Mean Time Between Failure
MTF	Modulation Transfer Function
NCEPH	National Centre for Epidemiology and Population Health
NEMA	National Equipment Manufacturers Association
NICU	Neonatal Intensive Care Unit
NIH	National Institutes of Health (USA)
NM	Nuclear Medicine
NMRI	Nuclear Magnetic Resonance Imaging
OCR	Optical Character Reader
ODL	Optical Disc Library
OR	Operating Room
OSI	Open System Interconnection (standard of ISO)
OSI/TP4	OSI Transport Protocol
PA	Posterior-Anterior (Chest X-ray)
PACS	Picture Archiving and Communications System
PC	Personal Computer
PCR	Philips Computed Radiography
PDM	Physicians Display Monitor

PET	Positron Emission Tomography
PHOCUS	Primary Health Oriented Computer User's System
PICU	Pediatric Intensive Care Unit

RACGP	Royal Australian College of General Practitioners
RACE	Research on Advanced Communication Technology in Europe
RAM	Random Access Memory
RCC	Read Clinical Classification Codes
RCGP	Royal College of General Practitioners
RCR	Royal College of Radiology
R&D	Research and Development
RIFF	Raster Image File Format (expanded TIFF format)
RIM	Radiology Information Management (System)
RIP	Raster Image Processor
RIS	Radiology Information System
RISC	Radiology Information System Consortium, USA
ROC	Receiver Operating Characteristic
ROI	Region of Interest
ROM	Read Only memory
RSNA	Radiological Society of North America
RTP	Real Time Processor
RVS	Results Viewing Station

SCID	Soft Copy Image Display
SCSI	Standard Computer System Interface
SMPTE	Society of Motion Picture and Television Engineers
SNM	Society of Nuclear Medicine
SPECT	Single Positron Emission Computed Tomography
SPIE	Society for Photo-optical Instrumentation Engineers
STS	Short Term Storage

T-1	Telephone 1.544 megabit per second dedicated data transfer link
TB	Terabyte (10^{12} 8 bit bytes)
TCP/IP	Transmission Control Protocol/Internet Protocol
TIFF	Tag Image File Format (graphics file format)
TN	True Negative (Rate)
TP	True Positive (Rate)

UCLA	University of California, Los Angeles
UL	Underwriters Laboratories
UPS	Uninterruptible Power Supply
US	Ultrasound
USA	United States of America
VF	Video Fluoroscopy
VRS	Voice-Recognition Systems
VTR	Video Tape Recorder
WAIS	Wide Area Information Server
WAN	Wide Area Network
WHO	World Health Organisation
WORM	Write once read many times (Optical Disc)
X-RAY	Ionising Radiation
XTP	Express Transfer protocol