ORIGINAL ARTICLE

The Impact of Teleradiology in Clinical Practice - A Malaysian Perspective

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Summary

Teleradiology is the most mature and rapidly evolving speciality in telemedicine. The use of teleradiology has grown tremendously during the past few years. This article describes the role of teleradiology in health care along with a brief history of its development in tandem with advances in telecommunications and computer technologies. Teleradiology standards, image acquisition, data compression, transmission and image interpretation are summarised. The impact of teleradiology in the practice of radiology, traces the evolution of the modality especially in the Malaysian perspective and its current and future role are discussed.

Key Words: Teleradiology, Telemedicine, Digital imaging

Introduction

Teleradiology refers to the use of computers and telecommunication networks to transmit diagnostic images acquired at one location to another for review and interpretation. This branch of radiology is the most mature and rapidly evolving speciality in telemedicine. The use of teleradiology has grown tremendously during the past few years. Many of the early problems with teleradiology are being resolved by the rapid advances in telecommunications and computer technologies, while changes in health care economics are driving the need to establish cost-effective and efficient communication links between rural and urban health care providers and tertiary care specialists. Effective arguments can be made both for and against the role of teleradiology in improving patient care[1-3]. This article discusses the impact of teleradiology in the practice of radiology, traces the evolution of the modality especially in the Malaysian context and its current and future role.

A Brief History of Teleradiology

Telemedicine systems were in the infancy stage during the 60's and 70's although the idea of using communications to distribute medical images was mooted prior to this[1]. The current interest in telemedicine has been fostered by several developments. The first has been the rapid advances in telecommunications technology and infrastructure as well as the evolution of powerful desktop computers. Increasing affluence and greater expectations of the public, as well as the need to provide quality care at a reasonable cost have been other major driving forces. The increasing role of private health care providers as important contributors in the overall health system is yet another factor. These organisations, being mainly profit driven, see teleradiology as a vehicle for maintaining quality while containing cost in a competitive marketplace. In the United States, there has been substantial investment by both the Federal Government as well as the military in teleradiology programmes. The technology has also been put to good use in correctional facilities to help reduce the increased expenditure in movement of the inmates, enforcement of special security measures and deployment of dedicated health care personnel.

Role of Teleradiology

There is still controversy raging as to the exact role of teleradiology which has its proponents as well as opponents; with emotions running high on both sides. Both these groups have a vested interest in the outcome. Most of these focus on the question of economics and market share. The practice of medicine is changing rapidly and radiologists are required to interpret images promptly as well as with high accuracy. The development of tertiary level private health care facilities threatens the existence of smaller, less efficient public and university departments. The pressure is on these institutions to improve both the efficiency and quality of care.

The ultimate role of teleradiology systems is to make a primary diagnosis from transmitted images i.e. allow the receiving radiologist or physician to make a diagnosis without having to review the original films. This would be advantageous for patients and practitioners in remote and inaccessible areas where consultant radiological expertise may be lacking. It would also allow the referring or consultant physician to review images at home. To achieve this level of primary diagnosis would however require the use of state-of-the-art systems. However a significant proportion of systems in current use do not meet this requirement of primary diagnosis of conventional x-ray based studies such as chest radiography. These lower end systems may be suitable for the lower resolution digital modalities like CT, MRI, ultrasound and nuclear medicine.

Teleradiology can be used to transmit images from the radiology department within a hospital environment, deployed as an intranet solution to clinics and wards. This would result in greater efficiency for both radiological and clinical practice. For institutions which have several facilities spread over a distance, teleradiology may be considered a viable cost-effective solution to provide daily or relief coverage when the resident radiologist is on leave. It is important that there be seamless integration of teleradiology with the radiological, hospital, clinical information systems as well as the patient records, to allow transfer of information across different medical enterprise networks. There are at least three ways whereby this integration can be carried out; one is by using "off the shelf" Web browsers such as Microsoft's Internet Explorer or Netscape's Navigator; the second is through the use of a global integrated system solution with a common interface and software applications built-in. The third solution is by deploying a complete enterprise-wide electronic medical record system.

Certainly, teleradiology would allow consultation or second opinions of problematic cases with experts within a very short period of time with the option of even live conferencing. This is an area which has potential where expertise can be sought from not only within the group but globally where facilities for teleradiology exist.

A key application in the Malaysian perspective would be the promotion and dissemination of information for continuing medical education for the specialists as well as the general practitioners. The technology may also be used for distance learning programmes for post-graduate studies[4].

On the downside, concerns regarding the use of teleradiology may result in a decreased level of care for the patient since the reading of the studies are being done at remote sites and not at the site of image capture[2]. The radiologist will no longer be considered as part of the team with no actual interaction between the radiologist and attending physician. For institutions which are small and/or inefficient the expanded role of this technology may necessitate the need for re-engineering of the entire work processes.

Teleradiology Standards

In 1994, The American College of Radiology (ACR) drafted a set of standards for teleradiology[5]. This document outlines the requirements for image acquisition as well as display. The resolution of the monitors for the different types of radiological studies vary from a 2K x 2K x 12 bits for chest radiographs to 512 x 512 x 8 bits for Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and nuclear medicine. The document also specified the needs for accurate identification of studies carried out. The issue of patient confidentiality is also addressed. The display

monitors need to have sufficient luminance (50ft-lamberts or 538lumens/sq.meter), have options for adjusting image display levels, rotation, magnification, inverting the white-on-black to a black-on-white display as well as ability for image measurement. Though the ACR standard did not specify the levels of acceptable compression, the ability to use data compression should be available and the compression ratio should be displayed on the image. The ACR standards have gone even further in stating recommendations for licensure and credentialing. The issue of quality assurance is also covered.

In Malaysia, the Telemedicine Act 1997 has been formulated to "provide for the regulation and control of the practice of telemedicine: and for matters connected therewith." This Act has yet to be enforced. There has however been concern in some legal quarters that the act has been so loosely worded, that it might be less effective than desired[6]. The Act covers the requirements for medical practitioners to practice telemedicine (both local and foreign), the need for informed consent from the patient, need for confidentiality, as well as the institution of "minimum standards" and "quality assurance and quality control programmes" as are deemed necessary. There is no legal requirement for the local medical practitioners to have any certification for practice of telemedicine unlike foreign practitioners who are required to have licensure and certification from the Malaysian Medical Council to practice locally.

Image Acquisition, Data Compression, Transmission and Image Interpretation

The heart of teleradiology systems consists basically of acquisition methodologies for images in a digital form, transmitting the image (usually in a compressed form) over either a local or wide area network, and encompasses the technology to display the images at the remote site. A typical configuration for a teleradiology system is shown in Fig. 1.

Image acquisitions are usually carried out using either a high resolution film digitiser or scanner. The film is either scanned or captured using a charged coupled

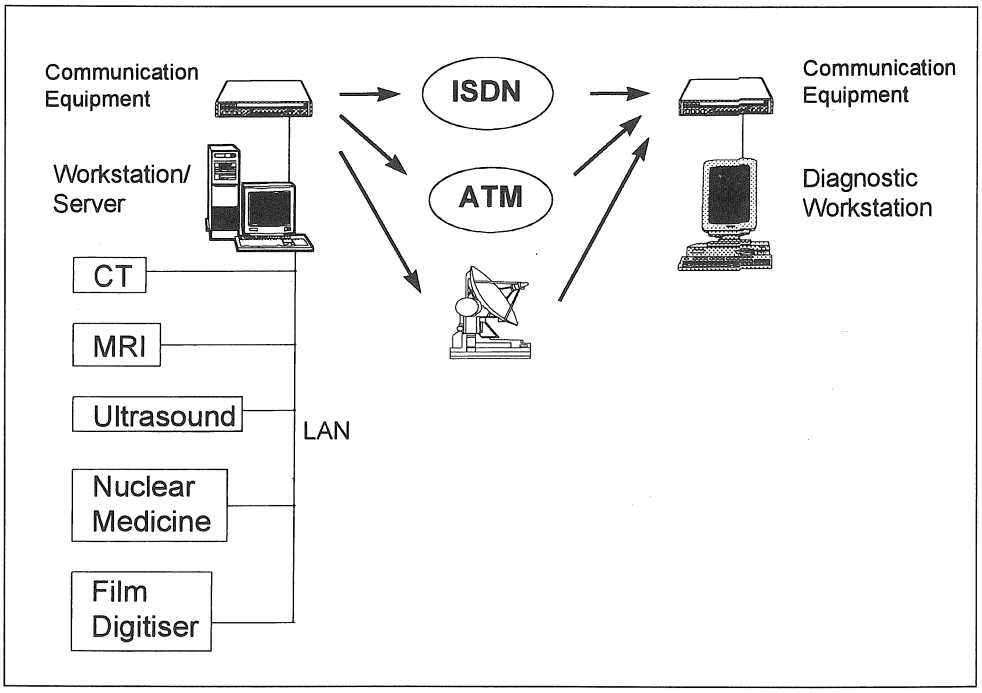

Fig. 1 A typical configuration for a teleradiology system. Image acquisition from various modalities, transmission via telecommunication networks and reviewing at remote site.

device (CCD) camera or a laser digitiser, which converts the image from an analog to a digital format. However with the increasing use of digital imaging systems both for conventional x-rays (using phosphor storage plates, selenium or silicon coated digital plates) and specialised studies (ultrasound, CT, MRI, angiography and even fluoroscopy) and the establishment of Digital Imaging and Communications in Medicine (DICOM 3.0) standards, this acquisition step is now not always necessary. The DICOM 3.0 standard was instituted by the American College of Radiology - National Electronics Manufactures Association (ACR-NEMA) to overcome the limitations of image information storage in proprietary format. The advantage of direct digital capture is that there is no degradation of the image with full windowing capability. Most teleradiology or PAC systems however, use video capture (frame grabbing) techniques as it is cheaper. Video capture converts the analog signal to digital with significant loss of information[1]. This results in loss of full windowing capability in addition to the need for more data transmission. The discussion of image acquisition would not be complete without considering the special problems associated with real-time studies e.g. ultrasonography, echocardiography and coronary and cardiac angiography. The extremely large data files which need both to be stored and transmitted cost-effectively had been a problem. This has been overcome to an extent by the use of data compression or by being more selective in the frames actually stored and transmitted.

The average data file size of various radiological studies is shown in Table I. The transmission times depend on not just the bandwidth of the network but also the compression ratios used. This is illustrated in Table ll. Images can be transmitted by means of common phone lines (twisted pairs of copper wire), digital phone lines (ISDN, switched 56, etc.), coaxial cable, fibre-optic cable, microwave, satellite and frame-relay or T-1 telecommunication links. Generally, there is a discrepancy between needs and availability of telecommunications services - areas which would benefit most from teleradiology are those with poor telecommunications infrastructure. The existing telecommunications infrastructure in Malaysia is adopting the ISDN but pushing for a Asynchronous Digital Subscriber Line (ADSL).

Data compression may either be lossless (reversible or no data is destroyed or lost) or lossy (irreversible) respectively. Even though it has been shown that the maximal compression for lossless data is in the range of 1.5:1 to 3.1[7], studies using receiver operating characteristic (ROC) curves[8,9] have shown compression ratios of at least 20:1 can be applied without compromising the diagnostic content. With the advent of newer compression algorithms e.g. wavelet, compression beyond 3:1 may be carried without loss of any data 10. As shown in Table II, a compression ratio of 20:1 would reduce the transmission time by 20 times.

Table I
Comparative image file sizes of radiological studies (1)

Modality	Image matrix	Images/study	File size (Mbytes)
Digitised mammograms	4096 x 5120 x 12	4	160.0
Digitised radiographs	2048 x 2048 x 12	4	32.0
Digital fluoroscopy	1024 x 1024 x 8	18	18.0
CT	512 x 512 x 12	30	15.0
MR imaging	256 x 256 x 12	50	6.3
Ultrasound	256 x 256 x 8	24	1.5
Nuclear medicine	128 x 128 x 8	24	0.4

Table II
Effect of compression ratios and available bandwidth on the transmission times (minutes) with approximate 70% efficiency (1)

Compression ratio	Phone 28.8 kb/s	Switched 56 kb/s	T-1 (ATM) 1.544 Mb/s	DS-3 44.736 Mb/s
1:1	56.6	29.1	1.0	0.04
2:1	28.3	14.6	0.5	0.02
10:1	5.7	2.9	0.1	0.004
20:1	2.8	1.5	0.05	0.002
30:1	1.9	1.0	0.03	0.001
60:1	0.9	0.5	0.02	0.0006

The Current and Future Role of Teleradiology in Malaysia

In the Malaysian perspective, telemedicine is designated as one of the seven thrust areas in the development and flowering of the Multimedia Super Corridor (MSC) project[11]. Teleradiology forms an integral part of the Telemedicine concept. There have been several pilot projects undertaken not only to exploit available technology but also to leverage the strengths of existing local systems and manpower resources. A substantial number of these have been supported by the efforts of Telekom Malaysia.

The University of Malaya Medical Centre (UMMC) at Kuala Lumpur has been involved in evaluating a teleradiology system to transmit the CT images of trauma patients to the neurosurgeons at the Hospital Kuala Lumpur (HKL). This programme was borne out of a real need - the UMMC at the present time has no resident neurosurgeon; although the geographical separation between HKL and UMMC is not great, actual travelling time may be in the order of an hour given the traffic in the city. The project was started in November 1997 and has undergone extensive evaluation since then. A total of 22 patients were evaluated using the system during the first 3 months. The system is server-based using a web browser (Netscape) with the appropriate plug-ins available[12]. Even though used for teleradiology at the moment this system can be easily configured into a Picture Archiving and Communication System (PACS) system which would allow acquisition, viewing, printing, transmitting and sharing medical data on desktop computers. This could be done at a fraction of the cost of similar Unix-based workstation configuration, with no necessity of any interfaces between connecting centres. The image quality is acceptable although transmission times to image download is dependent on transfer rate. On a dial-up connection the time may be long depending on the image size, quality and compression ratio used. Radiologists or physicians at home can also access the images if they have the necessary authorisation. Though there have been minor technical problems encountered we believe that this will prove to be a viable option in the management of patient services especially for secondary image viewing. Another ongoing pilot project to transmit MR images is underway.

A local project between Universiti Sains Malaysia (USM) and Universiti Teknologi Malaysia (UTM) has developed a teleradiology software operating under a Windows 95 environment. It has been reported that image compression of 25% to 75% was achieved without loss of information. Transmission of data is done using an Integrated Services Digital Network (ISDN). This has been shown to be satisfactory during preliminary trials both in terms of the cost and speed of transmission[13] though use in clinical cases has yet to be demonstrated.

There are other similar teleradiology systems being evaluated by the Ministry of Health and one being studied as a pilot study in Sarawak, based on the Windows NT operating system. This has been supported by a grant from the Dutch Government. The other project being considered is to connect some of the hospitals with HKL for the neurosurgical support.

It cannot however be argued that teleradiology allows the rapid transmission of digital images without loss of content or resolution[14]. Teleradiology will become cheaper, faster and the interface will become more intuitive. Malaysia must exploit the full potential of teleradiology. Though there is uncertainty we cannot stand on the sidelines otherwise we may be overwhelmed by the more advanced countries who are out to export their medical technology. More and more hospitals are embracing this new technology with not just the university or government hospitals involved but being lead by the private medical centres. However caution needs to be exercised in acquiring this technology since there is a danger that some of the systems being offered may be inappropriate. Proper health technology assessment in the local context needs to carried out. In addition we feel that Malaysia should also be actively involved in the development of teleradiology systems with local flavour in support of the MSC project. We believe that teleradiology would be able to provide a rapid, accurate and cost-effective system for clinical care as well as continuing medical education.

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