

Teleradiology: 21st century communication in surgery

Teleradiology was first introduced to provide a solution in emergency situations where a timely report of diagnostic imaging was required for the emergency management of certain conditions. This article provides an overview of teleradiology including its potential value and drawbacks.

The introduction of picture archiving and communication systems (PACS) has revolutionized medical radiology. The ability to quickly access images has helped clinicians to make decisions more efficiently, regardless of the time of day. In practice basic information regarding the care of patients presenting with surgical emergencies can easily be relayed by the accident and emergency doctors to the most senior person on call via the phone. However, in more complicated cases, there is the problem of image interpretation and reporting whereby a quick decision to intervene is based on images being reported by a specialist (Ahmed et al, 2006). Although most surgical trainees are confident in interpreting overt changes in images, most subtle and critical changes require a radiologist for more solid decision making. In addition it is a legal requirement that decisions are based on reports by specialist radiologists. As a rule in most departments, radiologists are non-resident and in some cases may cover more than one hospital at the same time. The concept of teleradiology was introduced to overcome this issue. This enables images taken in the radiology department to be transferred to a consultant radiologist elsewhere for reporting and allows accurate and solid decision making.

Early steps

There have been several attempts over the past decades to develop systems to allow health-care providers to get instant consultation in emergency situations from expertise at a distant location. Early in the 1970s Bird from Massachusetts General Hospital was the first to describe a closed-circuit interactive television system between Logan Airport in Boston and the hospital to provide teleconsultation to travellers (Bird, 1972). Around the same time in Walter Reed General Hospital, Washington, a similar closed-circuit television connected the radiology department to the emergency room to provide instant images for clinicians to aid management. However, this system failed to establish itself as a standard of care as a result of poor image quality and high cost of system installations (Thrall and Boland, 2002). Interest in teleradiology was revived in the 1980s following the development of computers. The method of teleradiology has changed from real time image transmission via television to 'store and forward' method whereby images were

stored in a digital form in preparation for future transmission. Further progress in this field has been achieved with advances in telecommunication, the introduction of the internet and the development of relatively low-cost super-fast computers which allow transmission of large digital data files such as computed tomography scans and magnetic resonance images (Thrall, 2005).

The American College of Radiologists has defined teleradiology as the 'electronic transmission of radiological images from one location to another for the purposes of interpretation and/or consultation' (Frey and Spicer, 1999). Advances in diagnostic imaging and the widespread use of complex imaging techniques such as computed tomography scans have increased the multidisciplinary approach whereby a radiologist and a physician make vital decisions jointly, especially when it comes to performing emergency operations after hours. Larson and co-workers carried out a survey among radiologists in the United States in 1999 and found out that 75% of radiologists used teleradiology to provide preliminary reports, the majority of which (95%) related to computed tomography scans (Larson et al, 2005). The widespread use of teleradiology in the United States resulted in the introduction of the term 'telehawk' to describe the radiologists who provide an after-hours service (Boland, 2008).

In a study of the role of teleradiology in decision making in urology, Lee and co-workers (1999) looked into the quality of decision making by examining digitized images stored on a computer and conventional radiographic images and concluded that the former can provide a suitable means of decision making. In daily practice radiology images were sent between dedicated computers installed in the radiology department and the homes of consultant radiologists. However, this was not successful in urological emergencies as radiologists were seldom involved in the final clinical decision especially

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when it comes to deciding between conservative treatment and intervention. In addition the installation of dedicated computers for urology consultants and specialist registrars was not cost-effective, especially as specialist registrars might only work in a particular department for a brief period as a part of a training rotation. In addition, with a desktop computer, it is only possible to receive images in an office setting. This may be impractical in the on-call setting, as the specialist registrar or the urologist may be attending an emergency elsewhere (Lee et al, 1990).

Mobile phone technology

More recently mobile phone digital photography came to play a role in diagnostic image transfer (Tang et al, 2004; Baumgart, 2005), with the advantage of being lightweight and more convenient to transport. There are various methods for data transmission onto a remote portable device. Infrared data access and Bluetooth are used for short distance transmission although Bluetooth is faster. Wireless local area network is used within office settings with a speed of transmission that can be as high as local area network. This requires the use of routers to allow wireless transmission. Code division multiple access, on the other hand, is a channel access method which allows several transmitters to send information simultaneously over a single communication channel. Code division multiple access uses spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code) to allow multiple users to be multiplexed over the same physical channel. This is currently the most widely used mode of data transmission in mobile phones (Lee et al, 2008).

The advent of personal digital assistants (PDAs) has further pushed mobile technology forward. Similar to conventional computers, the core of the PDA is built around a microprocessor that operates at 60–200 MHz. The display is an energy-efficient, liquid crystal display similar to those used on notebook computers. Improvements in display design with thin film transistor technology now permit a backlit colour display ranging from 160x160 pixel to 640x480 pixel resolution and 16-bit colour. In most instances, the display doubles as an input device by using integrated touch-screen technology, thus eliminating the need for a conventional keyboard. PDAs store all essential data in lightweight and inexpensive memory chips.

A detailed Medline search revealed a number of studies which tested the value of teleradiology across a wide range of surgical specialties. The first use of a mobile telephone with an integrated camera to convert hard-copy radiographs to digital images was reported in 2003 by Yamada and co-workers (2003). Assessing the accuracy of diagnosis of intracranial pathology from emergency computed tomography scans and magnetic resonance images, the team concluded that the mobile phone system was very useful to correctly diagnose early intra-

cranial haemorrhages and aneurysms up to 2 mm. Subsequently, Wallace et al (2004) discussed the possibility of integrating PACS with general packet radio services (GPRS)-compliant mobile telephones allowing digital image transmission using multimedia messaging service (MMS) technology for mobile telementoring, specifically for trauma and orthopaedic cases.

The system of image transfer using mobile phones has been tested in a tertiary otolaryngology centre by Eze and co-workers (2005) and was found to be a reliable method for teleconsultation, comparable with X-ray box examination of images. Kim et al (2005) examined an instant image transfer system based on a PDA phone with a built-in camera. They captured images displayed on a PACS monitor and transmitted them from an emergency centre to a remote physician via a wireless high-bandwidth network. They concluded that for satisfactory remote consultation a minimum size of 640x480 pixels was required for computed tomography and magnetic resonance images and 1024x768 pixels for angiography images, with higher resolution imaging requiring longer transmission time.

Johnston and co-workers (2005) evaluated the feasibility and diagnostic accuracy of a simple method of wireless transmission of digital images (computed tomography scans) to a hand-held PDA in emergency urology patients. A diagnostic interpretation was recorded for the presence or absence of an upper tract stone, stone location, estimated size and upper tract obstruction in ten patients with renal colic, and radiological staging for one patient with a renal injury. They concluded that wireless teleradiology to PDA units provided image quality sufficient for diagnostic interpretation.

Anticipated improvements in wireless transmission and PDA screen image resolution will enhance the speed, quality and quantity of images transmitted. Image transmission using email was tested by Yaghmai and co-workers (2004) who described using email to transmit a complete set of cranial computed tomography images to a commercially available wireless PDA for remote consultation. A complete set of images from the head computed tomography of a trauma patient with subdural haematoma (19 images) was captured from a PACS system and transmitted wirelessly as an e-mail attachment after being compressed, with the entire procedure (including image capture, transmission and review) taking approximately 11.5 minutes. They concluded that, using this technique, the wireless PDA may be a robust medium for facilitating care of brain trauma patients by allowing rapid access to trauma radiologists or neurosurgeons.

Piek and co-workers (2006) from Germany used mobile phones with built-in cameras for image transfer for patients with various neurosurgical emergencies and concluded that the mobile phones are reliable in quickly transferring images between the resident on call and the most senior team member and enabled immediate decisions in all emergency situations.

Lee and co-workers (2008) studied the time required for images to be transferred from a centralized server containing patients' details and a remote PDA carried by the treating physician. They calculated that it took 90 seconds to transmit thirty images with 832 x 488 pixels resolution, 24-bit depth and 0.37 Mb size. This provided treating surgeons with instant access to images in emergency settings. Granot et al (2008) studied the use of mobile phones as a mode of transmitting raw images taken at the remote patient site (data acquisition device) to a central processing site and subsequent transfer of processed images into the patient site. In their experiment they uploaded images taken at the data acquisition device into the mobile phone or PDA. These images were subsequently transferred (via email or multimedia file MMS), processed in a central unit, and then the processed images were transferred via mobile phone to the peripheral unit. This has proved to be of particular value in remote health centres that lack complex diagnostic imaging facilities. Lim and co-workers (2007) from Australia developed a mobile phone-based medical report delivery system from a medical imaging department whereby a text summary of the medical report along with a screen capture of the image was sent via the mobile phone to the treating physician for instant decision making.

More recently Modi et al (2010) from Alberta, Canada examined the use of the Apple iPhone for the diagnosis of acute spinal injuries. They concluded that iPhone-based teleradiology provides a rapid, secure and accurate method for visualization of medical images with a sensitivity of up to 80%. It is worth mentioning that Apple iTunes has incorporated radiology applications into its store of apps. These will provide platforms for web-based PACS as well as teleradiology (Shih et al, 2010).

Legal implications

Teleradiology has been the focus of health-care decision-makers in recent years as a result of its role in advancing the quality of health care. In the United States a Bill was introduced into the Senate to enact the Telehealth Improvement and Modernisation Act of 2002. This act was introduced to revise telehealth payments and improvement of telehealth services. It also resulted in the introduction of a licensing system for radiologists providing interstate teleradiology services to ensure adequate protection for both patients and the reporting radiologists (White, 2002).

Essentially teleradiology involves three main concepts (telediagnosis, teleconsultation and telemanagement). Telediagnosis is made within a few hours of the production and transmission of images to a remote site. Teleconsultation occurs within half an hour of receiving the images and the patient may still be waiting at the examination site, primary care or GP clinic. Telemanagement occurs in real time and the radiologist manages the patient as if the patient was on site for the

examination, so that an immediate diagnosis is required. Therefore, one may also need to consider the individual duties that fall under the term of teleradiology in order to be able to understand the legal responsibility and liability of the treating physician (Huang, 1996).

Security of transmission remains the issue of highest importance, as patient confidentiality and data protection have to be maintained. Clinicians who wish to use MMS via their mobile phones to transfer clinical images of patients should ensure that they comply with the data protection laws of their country of practice, as highlighted in the Royal College of Radiologists (2010) guidelines on standards for the provision of teleradiology.

Teleradiology: a promise or a threat?

Teleradiology as a concept seems a promising solution for the radiologist overwhelmed with the case burden and the on-call surgeon who needs a quick radiology report to manage an emergency case. In essence it provides some relief for consultant radiologists after hours and at weekends, and offers subspecialty interpretation and radiological support for remote hospitals. However, this comes at a cost to radiologists and radiology departments as a result of fierce competition from private companies providing teleradiology services. Levin and Rao (2011) from Thomas Jefferson Hospital in Philadelphia published a review of the potential threats of teleradiology to radiologists and radiology as a specialty. The key issues that they discussed were as follows:

1. Loss of the concept of radiological consultation: as a general role, radiologists not only provide reporting for images but they evaluate requests for appropriateness, oversee the examination and provide further advice for the treating physicians. These are lacking with teleradiology
2. Reduced fees of consultant radiologists: this will be the ultimate result of competition with private teleradiology companies. In extreme cases hospitals may not hire new consultants or may even be encouraged to dispose of some of their own radiologists
3. Bad image quality and suboptimal reporting: in order for radiologists to optimally provide patient care, they should have access to patients' clinical details, laboratory tests, previous images and contact with the treating physicians. In addition they should have prior knowledge of the protocols in radiology department that govern individual diagnostic imaging. Lack of this essential information will ultimately result in poor consultation standards.

Conclusions

Teleradiology is establishing itself as a standard in providing patient care, especially in the emergency setting. It provides rapid access to radiological imaging (by the treating surgeon) along with reports by consultant radiologists to aid decision making in the emergency setting. This method has proved successful in a wide range of

surgical specialties and its role is growing further with advances in mobile phone and image archiving technologies. There are still issues of patient confidentiality and licensing that still need to be carefully addressed by the health departments and these limit the widespread implementation of this system. In addition the new teleradiology culture is recognized as a potential threat to radiologists and radiology departments as a result of the competition to provide radiology services. However, it is the authors' firm belief that because of clinical governance issues and working in a successful multidisciplinary setting, with a number of radiologists, a team approach could overcome these perceived threats. **BJHM**

Conflict of interest: none.

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KEY POINTS

- Teleradiology is an effective method for urgent reporting of medical imaging in emergency situations.
- This also helps with remote hospitals which lack specialist diagnostic radiological services.
- The advancement in smart phones and personal digital assistant technologies have further helped to popularize this method.
- Despite its initial appeal, teleradiology is not free of risks and drawbacks.