Consultation of Orthopaedics Cases Using Multimedia Messaging Services

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Abstract: *Background*: Frequently, radiological data is transferred verbally between the Emergency Department (ED) and orthopaedic registrar. Given the different language skills and medical experience of health staff, there is often a limit to the adequacy of the verbal description that could lead to suboptimal patient care. This study proposes that concurrent review of MMS teleradiology with traditional verbal reporting results in a significant therapeutic benefit.

Methods: Case notes of 40 patients who presented to ED were reviewed. Images were captured and sent to an Orthopaedic registrar along with a brief clinical synopsis. Information was collected on the diagnosis of the MMS radiograph, need for urgent admission and management plan outlined to ED.

Results: Correct diagnosis was made in 27 of 40 cases. Using the latest technology available, MMS teleradiology had 79% sensitivity, 83% specificity and an accuracy of 80%. 50% of paediatric fractures and 60% of undisplaced fractures were diagnosed successfully.

Conclusion: MMS teleradiology is not suitable by itself as a remote diagnostic tool. However, when combined with existing clinical practice, it is effective in screening patients, enhances confidence in decision making and communication between doctors.

Keywords: MMS teleradiology, teleradiology, remote consults, remote orthopaedic consults and image transfer.

Telemedicine has been studied in several medical and surgical settings with varied results. It enables capture of a clinical picture using the built in camera and relaying it to another mobile device. In recent times, there has been an increase in the number of options available for transmission of clinical information. The ease of MMS teleradiology makes it an appealing option, especially in the emergency department setting where a specialist opinion would be urgently required.

BACKGROUND

At Modbury Public Hospital, orthopaedic and trauma cases could present initially to the Emergency Department (ED). Cases meeting the diagnostic criteria are directly triaged to Orthopaedics. The remaining cases are acutely managed and followed up in the out patients department (OPD). When needed, the ED staff contact the remote orthopaedic support for advice. The remote support relies on the verbal description made by the emergency department staff. For successful assessment, they must be provided with an accurate clinical picture and interpretation of the radiograph by the doctor requesting the opinion. The accuracy of the clinical decision making depends on the ability of the ED staff to interpret and verbally communicate their findings to the orthopaedic surgeon. Implementing MMS teleradiology into standard clinical practice has the potential to improve this communication.

Theoretically, a comprehensive handover is sufficient to develop effective management plans but there is often a limit to the adequacy of the verbal description for a number of reasons including experience and language skills of the referring doctor. Ye at al., found an error rate of 35% and a clinically significant error rate of 39% in junior doctors [1]. Diagnosis rates have also varied with the type, site and quality of image along with the experience of the doctor interpreting them. Junior doctors have been found to successfully diagnose 32% of trauma X-Rays while the same X-Rays were diagnosed correctly by 80% of senior doctors [2]. Rate of misdiagnosis varied based on the site examined (Table **1**). MMS teleradiology allows greater utilization of the expertise of an orthopaedic surgeon in the diagnostic process and formulation of treatment.

Table 1. Accuracy of Detection of Radiographic Abnormalities by Junior Doctors [3]

Site	(%) Misdiagnosed
Spine	47
Shoulder	25
Pelvis	25
Knee	28
Ankle	59
Foot	40
Toes	18
Elbow	35
Wrist	27
Hand	41
Fingers	29
Long bones	13
Total	35

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Over the last few years, mobile phones have evolved from large and cumbersome devices to recently weighing only a few hundred grams. Camera phones became available around the turn of the century and since then, have improved in quality from 0.1 pixels to currently 5 megapixels. The greater the number of pixels in an image, the higher the resolution and better quality of the image. As the phones and cameras improved, so did their ability to process digital information. Newer phones can record digital images in a JPEG format. JPEG image compression is designed to accommodate limitations of the human eye by providing a small loss in colour rather than brightness. Along with the quality of camera, compression of the images, the bandwidth limit has increased from 30kbs to 500kbs after the introduction of 3G and 3G+.

MMS Teleradiology has been assessed in several fields as a diagnostic tool with a high degree of success. In the field of ENT, all cases examined in the emergency department were diagnosed accurately [4]. In plastic surgery, teleradiology has shown favourable results in remote diagnosis with 79% sensitivity and 71% specificity for skin defects [5], 76% sensitivity and 75% specificity in remote identification of bone exposure [5] and 90% diagnostic accuracy in correctly identifying digits with re-plantation potential [6]. Similar to ENT, all neurosurgery cases presenting through ED were accurately diagnosed using MMS teleradiology [7]. The high diagnostic rates in these cases were attributed to obvious radiological or visual diagnostic clues.

In orthopaedics, MMS teleradiology had a lower diagnostic capability. All existing studies have approached MMS teleradiology as a substitute for verbal reporting in remote diagnosis. Cheng *et al*. reviewed 100 sets of hip and pelvic X-Rays and found a false positive rate of 50% and a significant false negative rate. MMS images of radiographs had insufficient quality for diagnostic purposes. They used a Panasonic GD87 which has a 0.1 megapixels camera and a screen resolution of 132 x 176 pixels [9]. Chandhanayingyong *et al*. reviewed 59 patients to assess diagnostic accuracy of teleconsultation using MMS [9] and found a misdiagnosis rate of 40%, over diagnosis rate of 12%, under diagnosis of 27% and concluded that teleconsultation *via* MMS demonstrated good reliability but poor diagnostic accuracy using a camera phone with a 1.2MP camera and screen resolution of 176X208. In existing literature, the resolution of the images and the screen quality formed the bottleneck in using MMS of radiographs as a diagnostic tool [8].

The aim of this study is to benchmark the diagnostic capability of MMS teleradiology using the latest advances in telecommunications and determine whether information provided by viewing MMS of radiographs augmented the information gained through verbal handover between Emergency Department staff and a remote orthopaedic surgeon in orthopaedic cases that do not require urgent treatment.

METHODS

A list of patients who presented to the Modbury Public Hospital Emergency Department within a 2 year time frame, not satisfying the admission criteria and reviewed in the OPD was requested. This yielded 304 patients. One out of every five patients was selected to reduce seasonal and situational bias (61 patients left). Patients with missing X-Ray views, documentation and patients who failed to attend the OPD were excluded. 40 patients remained suitable for the study.

The cases that met the admission criteria for orthopaedics (Appendix 1) and cases sent directly to surgery were excluded due to the obvious clinical and radiological cues present. To properly assess the accuracy of MMS teleradiology; soft tissue injuries, non- displaced and minimally displaced fractures were included. MMS of radiographs were assessed by an orthopedic surgeon on a Sony Ericsson k850i. The use of the zoom function for closer inspection was permitted.

To establish patient management in the absence of MMS teleradiology, the case notes were reviewed to tabulate clinical synopses, radiographic evidence, diagnosis, management plan and outpatients follow-up (verbal handover data). This data is compared to the results of MMS radiology review. The orthopaedic surgeon was provided with MMS of the radiographs requested in ED along with the clinical synopsis of the patient. The brief clinical synopsis was created by recording the history of injury together with basic demographic data including age of each patient and data regarding important physical examination findings were noted. The orthopaedic surgeon reviewing the MMS along with the clinical synopsis tabulated the diagnosis of the radiograph, initial management, need for review (urgent or at outpatients), additional imaging and admission and diagnosis of the patient (MMS teleradiology data). The reviewer of the MMS radiographs was kept blinded to verbal handover data, official radiology reports and OPD notes to minimize bias. The data from both groups was compared to establish diagnostic capability of MMS teleradiology and its effect on patient management.

Diagnostic capability of MMS teleradiology is assessed through comparison diagnosis on MMS of radiology data with the established diagnosis. The gain in clinical data through integrating MMS teleradiology to existing clinical practice is assessed through comparison of 'verbal handover data' to 'MMS teleradiology data'. Conducting this study retrospectively would not alter the treatment of the patient and hence reduce bias.

The phone used in this study was a Sony Ericsson k850i and is a state of the art phone measuring 10.2 x 4.8 x 1.7 cm and weighing 118g (Fig. **1**). The screen has a resolution of 240x320. It is equipped with a 5MP camera, a picture resolution of 2592 x 1944 pixels and image is encoded as a JPEG. The software of the phone has very effective autofocus features and the camera interface that makes the operation of the camera and its features much more like that of a dedicated digital camera which means that the k850i takes high quality photographs comparable to digital cameras. The phone is housed in the ED next to the X-Ray viewing box. The image was captured with the X-Ray box on the overhead fluorescent lighting present. The MMS of the X-Ray was taken in the same film orientation as the radiograph and included all of the X-Ray excluding the patient details (displayed in the footer). The phone is used on

the Telstra network which sends the image re-sized to 500kbs.

Fig. (1). Sony Ericsson k850i used in the study.

RESULTS

Forty cases were studied to assess the function of MMS teleradiology as a tool to enhance communication between emergency and orthopaedics departments. To review MMS teleradiology, Sony Eriksson k850i mobile phone was used to capture and review MMS radiographs. The MMS images had a size of 500kbs with a resolution of 1944 x 2592 viewed on a screen with a resolution of 240 x 320. Ages ranged from 6 to 83. The mean age was 32. There were 10 paediatric cases in this series.

MMS of the radiograph had 100% accuracy in transmission of clinical data from the sender to the receiver. Out of the 40 patients, there were 30 fractures, 4 dislocations, 2 joint effusions and 4 patients with soft tissue injuries. All radiographs were deemed to be of acceptable quality. 23 of the 30 fractures and all 4 dislocations were successfully identified and diagnosed on MMS. None of the effusions were identified. Correct diagnosis was made in 27 of the 40 cases (67.5%) with a false positive rate of 20% and false negative rate of 26%. MMS teleradiology had a sensitivity of 79% and a specificity of 83% with an accuracy of 80%. All displaced and comminuted fractures, 60% of un-displaced fractures and 50% of paediatric X-Rays were successfully diagnosed (Table **2**).

Out of the successfully identified radiographs, additions to the management plans were observed in 9 cases. Three additional cases were identified where admission under the orthopaedic department was necessary. The three patients were followed up in the outpatients department where one underwent surgery and two were treated conservatively with surgery as an option. In 18 of the 40 cases, the surgeon found that MMS of radiographs accompanying the clinical picture provided additional details that would have contributed to the diagnosis and overall management. In five cases, the need for additional views and/or radiographs to assist with diagnosis and management was identified.

Table 2. Radiographs of Fractures and their Diagnosis Rates

Radiograph of Fractures	Diagnosis Rate (%)
Displaced fractures	100%
Un-displaced fractures	60%
Comminuted fractures	100%
Paediatric fractures	50%

DISCUSSION

In this study, the radiographs of 40 patients presenting to the ED not meeting the admission criteria were reviewed for MMS teleradiology using a phone with a 5MP camera, MMS resolution of 2592 x 1944 and a network capable of transmitting MMS at 500kbs. Correct diagnosis was made in 27 of 40 cases. Using the latest technology available, MMS teleradiology had 79% sensitivity, 83% specificity and an accuracy of 80%. Despite the significant improvement in diagnostic capability compared to previous studies, it was limited in diagnosing paediatric and un- displaced fractures accurately.

To minimise the cases with obvious radiological and diagnostic clues, cases that satisfy the admission criteria to the department of Orthoapedics and Trauma were excluded. Using the latest in telecommunications, MMS teleradiology has a diagnosis rate of 67.5% with an accuracy of 80%. Previous studies have found the low resolution of the MMS image to be the bottleneck in achieving adequate diagnostic accuracy. As expected, diagnosis rates have improved significantly with greater resolution of the MMS images (Table **3**).

Table 3. Diagnostic Accuracy with Phones of Different Resolutions

Resolution of MMS	Diagnostic Accuracy of Orthopaedic Cases
This study - 2592 x 1944	80%
480 x 640 [10]	60%
176 x 208 [9]	40%

As per the guidelines of American College of Radiology, for teleradiology, a minimum resolution 2000 × 2000 pixels is required for the diagnosis of subtle skeletal disorders such as fractures with only disruption of trabecular pattern [8]. This requirement encompasses all radiology from X-Rays to mammograms. Some radiological mediums do not require the same resolution as others to achieve diagnostic quality. Even though a resolution similar to this was achieved in this study, the diagnostic accuracy of 80% is unacceptable in clinical practice. The lower than expected accuracy was due

to the loss of quality from photographing the radiograph rather than scanning which would preserve more of the detail. X-Rays have been found to require the least resolution before loss of detail was noted [11]. Due to this lower required resolution, X-Rays would have a greater confidence of diagnosis than other imaging with MMS teleradiology.

Higher diagnostic capability compared to previous orthopaedic studies is also attributed to better compression of images. Unlike the older phones used in previous studies, this phone processes images similar to a digital camera to maximise the quality of the images. All images in the phone were compressed as a JPEG image. Compression enables more data to be stored in a given space. JPEG image compression is designed to accommodate limitations of the human eye. Small colour changes are perceived less accurately by humans than small changes in brightness. JPEG compression provides both lossless compressions. The compression algorithm has three steps: transformation, quantization, and encoding. The quantization step is the only one in which information is lost. The image is divided into 8X8 pixel blocks and each block is transformed separately using the discrete cosine transform (DCT) algorithm. At low-ratio JPEG compression is "visually lossless", mainly removing high-frequency noise [12]. When interpreting radiographs, such compressions are preferred as it removes the "salt-and-pepper" noise [13]. In paediatric and un-displaced fracture, subtle interference pattern on the films interfered with the diagnostic cues of the radiographs. Higher compression ratios are responsible for producing this artefact [14].

Despite the less than ideal diagnostic accuracy, MMS teleradiology as it stands today, has the potential to improve patient care. Minimal data exists on integration of MMS teleradiology into hospital practice and its impact on patient care. By concurrently reviewing MMS of the radiograph with the clinical synopsis of the patient, additional detail was gained in 18 of the 40 cases. Additions to the management plan were observed in 9 patients. Differences were noted in the method of splinting, choice of bracing and the weight bearing status of the patient. Three cases were identified where surgical management would have been more appropriate. The enhanced communication would improve patient care in emergency department and screening for patients requiring admission and surgical treatment.

Several forms of teleradiology have been assessed. One such option studied is installation of computer network systems at consultants'/registrars' houses. This would send high quality images directly to the treating surgeon. The image quality was high enough for diagnosis and the image transmission time was found to be approximately 20 seconds. The drawbacks for this is the cost of installation, training, technical support and lack of portability of the workstation [15]. According to a report by Grey *et al.* setup of a data station including communication system, personal computer, software and other equipment costs approximately $US20,000 [16]. This is a similar system to the one used in inter- hospital transfers but is impractical for remote consultations [17]. Another option is using e-mail service to send imaging to the consultant/registrar. Compared to MMS, higher resolution images can be sent *via* email and an integrated service digital network which are usually expensive and not portable [10]. Compared to these options, MMS teleradiology provides a portable, cost effective communication method by utilising already existing infrastructure and technology.

Subsequent to the promising results of this study, MMS teleradiology has been implemented as standard practice in the Modbury Public Hospital Emergency department. In order to address the discrepancy of technical knowledge of MMS messages, all ED staff and orthopaedics staff are given regular tutorials on how to send and receive MMS messages. This ensures that all staff have a base level of training and competency. Every month, new staff members are briefed on the protocol and given an opportunity to acquaint themselves with the phone. Further to the training sessions, posters are displayed across the emergency department with instructions on how to use the phone and the phone numbers of the Orthopaedic staff on call. When an orthopaedic patient presented though the ED, handover process will involve MMS transfer of radiographs followed by verbal reporting of the presentation.

CONCLUSION

MMS teleradiology incorporates a day to day communication tool into professional practice. MMS teleradiology has the potential to;

- Enhance level of confidence in clinical decision making
- Increase depth of information compared to verbal reporting alone
- Enhance communication between senior and junior staff
- Speed up decision making and reduce patient waiting time in the emergency department

However the benefits of MMS teleradiology may not be as evident in the following situations:

- Diagnostic tool
- Paediatric cases
- Undisplaced fractures
- Soft tissue swelling
- When accompanied by insufficient/no clinical synopsis

Despite the improvement in telecommunications, MMS teleradiology by itself is not suitable as a remote diagnostic tool. High rates of misdiagnosis were recorded in fractures that would have significant morbidity if poorly managed. MMS teleradiology however adds a visual component for that has so far been a verbal handover process and Incorporating it into existing clinical practice would enhance the confidence in remote decision making.

CONFLICT OF INTEREST

None of the authors had any relevant financial relationships pertinent to this study.

APPENDIX 1

Admission criteria into Department of Orthopaedics and Trauma

- Acute skeletal trauma
  - Major skeletal fracture
  - Pelvic/acetabular fractures
  - Compound fractures
  - Open fractures
  - Unstable fractures
  - Any fracture with suspected neuro-vascular compromise
  - Fracture or dislocation with severe swelling
  - Injuries requiring regular observation
- Limb compromise
  - Compartment syndrome
  - Suspected dislocations
- Acute infections
  - Paediatric limb cellulites
  - Painful limp in children
  - Suspected osteomylitis/septic arthritis
- Social admissions- Patients with orthopaedic presentation who does not normally fit admission criteria
  - Unstable home environment
  - Home environment likely to exacerbate injury
  - Home environment likely to harm patient's medical status
  - Evidence of domestic violence/child abuse
- Spinal fractures

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