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# The Role of Telemedicine in the Management of Acute Trauma Referrals to a Regional Plastic and Hand Surgery Unit in the South East of England

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## 1. Introduction

### 1.1 The Queen Victoria Hospital

The Queen Victoria Hospital (QVH) provides Burns and Plastic Surgery services, on a hub and spoke model, to the South East of England (4.5 million population), with a catchment area extending into the Southern aspect of greater London. Geographically the region is 50 by 70 miles; the transport links are primarily organised towards London, rather than East Grinstead where the QVH is situated, halfway between London and the coast. For some patients, travelling to the QVH can be time consuming and expensive.

The QVH receives about 400 acute trauma and burns referrals per month; our own audits demonstrate an increasing demand for trauma services each year. Hand injuries account for the majority of referrals to our service and the London and South East geographical region is under considerable capacity strain with 17% of hand surgery units being closed to referrals at any one time (Skillman et al. 2003).

### 1.2 Why we considered telemedicine

Telemedicine can be defined as “The practise of medicine at a distance”; it typically involves rapid access to remote medical expertise using telecommunication and information technologies. We had previous experience of many patients unnecessarily transferred to the QVH for specialist care after inadequate initial assessment, including some who had been transported at great expense by helicopter air ambulance. Besides cost implications there are clinical risks associated with inter-hospital transfer (Bledsoe & Smith 2004).

Numerous studies have shown that specialists improve the clinical assessment of hand (Nassab et al. 2007; Patel et al. 1998) and burn injuries (Collis et al. 1999; Hagstrom et al. 2003; Laing et al. 1991), our most frequent referrals. Therefore with a defined clinical need and available technology we believed that telemedicine could assist in the management of injured patients referred to the QVH from distant hospitals.

Telemedicine has been investigated since the 1970's (Murphy et al. 1972; Dunn et al. 1977) yet only from the late 1990's onwards do we see widespread pilot studies (Hailey et al. 2002;

Benger 2000). Numerous papers have reported Telemedicine technologies that have the potential to improve the accuracy of triage e.g. to correctly assess patients with burn injuries (Saffle et al. 2009; Saffle et al. 2004), patients who may be candidates for replantation surgery (Buntic et al. 1997), other soft tissue injuries (Pap et al. 2002; Wirthlin et al. 1998; Hsieh et al. 2004; Ong 2008) and also fractures (Ricci & Borrelli 2002; Jacobs et al. 2002). Guides to successful use of telemedicine suggest the clinical users are best placed to choose the type of telemedicine system for their requirement (Yellowlees 1997). The telemedicine team consisted of Consultants, Trainee surgeons, Nursing staff, Medical illustrators, Information Technology experts and audit personnel.

### **1.3 Store-and-forward or videoconferencing telemedicine?**

The two main types of telemedicine were considered for applicability to our need, Store-and-forward and real-time videoconferencing. Videoconference systems had already been demonstrated for Minor Injury Units (Tachakra et al. 2002), major trauma management (Rogers et al. 2001), Dermatology (Loane et al. 2000; Wallace et al. 2002), Orthopaedics (Harno et al. 2001), Intensive care (Rosenfeld et al. 2000), Psychiatry (Elford et al. 2000) and for educational purposes (Kingsnorth et al. 2000; Ward et al. 2001). Educational benefits can include a reduction in referrals (Darkins et al. 1996).

We were concerned about limited availability of the necessary technology at the many referring hospitals in our catchment area if we were to use videoconferencing systems, the cost of triple ISDN (Integrated Services Digital Network) lines for adequate bandwidth and line charges for each use, when no extra revenue was expected. In contrast Store-and-forward systems could allow review at any computer in our hospital, use existing technology and without any discernible cost per referral. In addition, the accuracy for diagnosis compared to face-to-face consultation (concordance) appeared to favour a Store-and-forward system rather than videoconferencing.

Studies on the use of telemedicine in dermatology have revealed greater accuracy for Store-and-forward telemedicine (70 to 95%), rather than videoconferencing (51 to 80%), when compared to face-to-face consultation (Wootton et al. 2000; Lowitt et al. 1998; High et al. 2000; Krupinski et al. 1999; Gilmour et al. 1998; Oakley et al. 1997; Taylor et al. 2001). At the QVH we chose a Store-and-forward application to allow encrypted email image transfer. We planned to pilot this on a limited basis and to carry out a qualitative review of the system.

## **2. Pilot study 1: Telemedicine at the QVH**

### **2.1 Overview of pilot**

Referrals were taken as usual by telephone call, supplemented by the transmission of clinical images via email over the NHS intranet from three referring hospitals. Details of all referrals were recorded on small cards (8 x 14cm) to facilitate hand-over for clinicians and provide an audit trail (Figure 1, see below). Specialty advice over the phone can be poorly documented by referring clinicians (Cartmill & White 2001), therefore this also provided a medico legal record of any advice given.

We maintained confidentiality during the trial by not including any images that could identify the patient. We used Joint Professional Expert Group (JPEG) image compression, which did not appear to compromise image quality (Roa et al. 1999). We provided digital

compact cameras and undertook training of the Emergency department personnel at the referring hospitals selected for inclusion in our pilot study.

Patient Address	QVH TRAUMA PATIENT SUMMARY		
	Doctor On Call:	Date:	Time:
	Patient Name:	DOB:	
	Referring Unit / Hospital:	Referring Doctor:	
	Referral Information:	RHD	LHD
		Smoker	Y N
		ψ	Y N
		Fit and well	Y N
		Occup.	
Further Information	Diagnosis / Management Plan		
Appropriate referral?      Y      N			
From the photo:			
Any change in plan? (Tick as appropriate)			
No change			
Confirmation			
Change in Advice/Treatment (Give details)			
	Action (More than one box may be Applicable)		
	Unable to accept	Assess in MIU	Admit (via MIU)
	Day Surgery Unit	Advice	Photo requested received
	Outlier	Dressing Clinic	Outpatients
Change in Priority (Give details)			

Fig. 1. QVH trauma card to collect data on all referrals

We were referred a wide variety of injuries such as burns, facial lacerations, and hand injuries including fractures, tendon and nerve injuries during the study period. Consultants and trainees compared the clinical assessment and prioritisation of 150 consecutive patient images with the face-to-face consultation. Injuries were grouped as follows: i. skin only ii. closed fractures and nerve injuries iii. open fractures and flexor tendon injuries iv. uncertain vascularity v. devascularised tissue and burn injuries requiring formal resuscitation. Clinical priority was organised into five groups of immediate, urgent (<6 hours), very soon (<24 hours), soon (<48 hours) and later (>48 hours). The correlation coefficient was 0.78 to 0.81 for grading of the injury and 0.87 to 0.93 for priority of injury (Jones et al. 2004).



Fig. 2. Flash reflection in an image of an X-ray taken on a viewing box

## 2.2 Analysis of first QVH telemedicine Pilot study

The results of the pilot study were judged to be satisfactory enough to continue with our plan to establish a Store-and-forward type telemedicine system at the QVH. Although the clinical priority was more accurately validated (concordant) than injury severity, the telemedicine images were judged to provide the receiving clinicians with greater confidence in managing referrals.

Only 82 images were analyzed of the series of 150, as 20 were unusable and there was incomplete data on a further 48, which further demonstrated the need for education at referring hospitals to improve the quality of images (see figure 2). When the pilot study was carried out digital systems for X-ray did not exist and particular problems were encountered recording images of hard-copy X-ray films on viewing boxes; we therefore created guidelines for photographing radiographs, specifically omitting the use of flash.

Education needed to be a continuous program due to the turnover of junior medical staff in referring Emergency departments. We also found that technical problems were highly discouraging to both the referring and receiving clinicians and that they were often given a low priority by IT departments at referring hospitals; a software designer was therefore employed to provide a bespoke application for encrypted email image transfer. A plastic surgery trainee was employed to supervise and drive the project forward.

## 3. Store-and-forward encrypted telemedicine for acute plastic surgery

### 3.1 Transmission of images

Encryption software was installed at the QVH and several referring units (DISTAR Telemedicine; Digital Image Storage And Retrieval, and TM Client®). The software provided users with 5 simple screens to capture the appropriate images from digital cameras, check the images, allow demographic data entry, provide a record of patient consent, and initiate transmission (see figures 3 to 7). The file size was 500 to 700 KB, with 24-bit colour and 1600 x 1200 pixel resolution. We provided an Olympus, C-3020 or a Nikon Coolpix 4500 (minimum 2048 x 1536 pixels) digital compact camera on our own site and at



the units with the encryption software installed. These cameras were chosen for their reasonable cost (approximately £200 / \$300), simple operation, easily replaceable AA batteries, and good image quality.

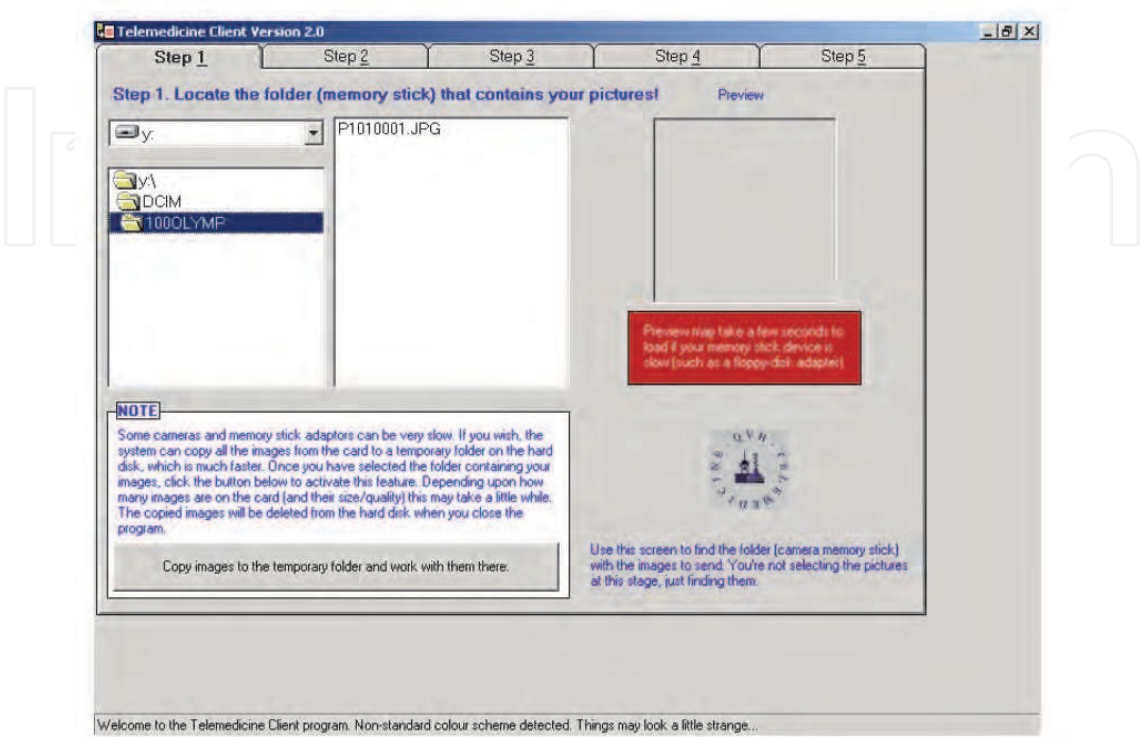


Fig. 3. Locating the images

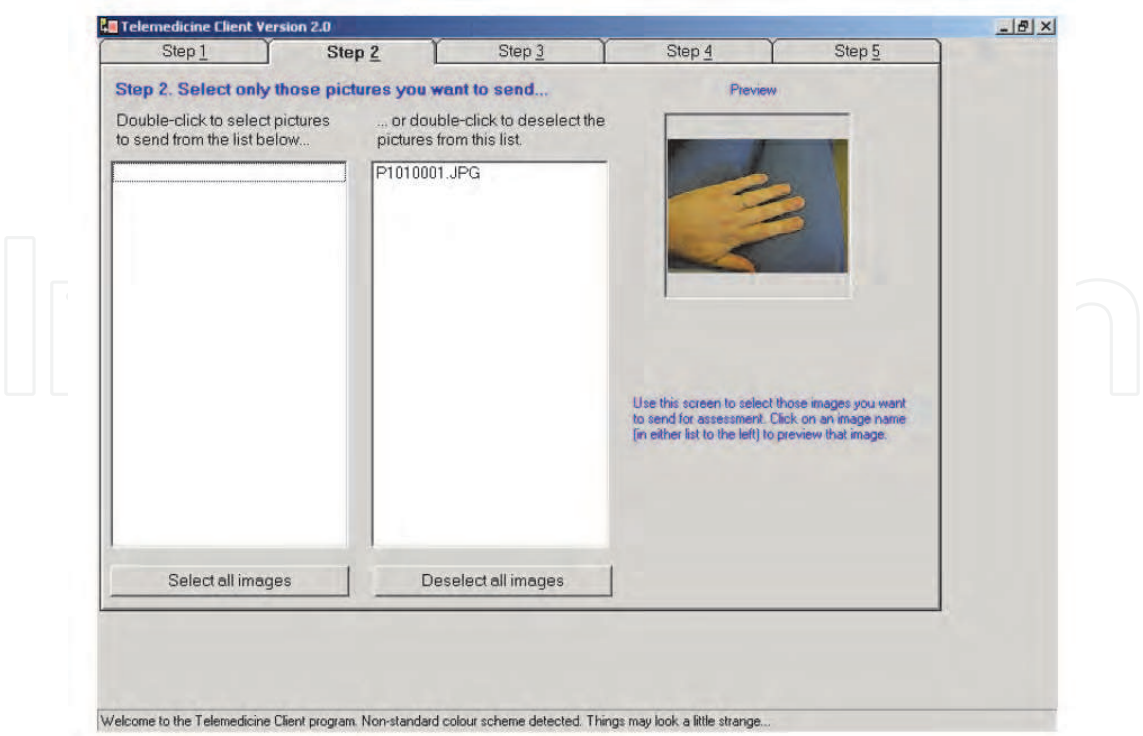


Fig. 4. Selecting the correct images

The screenshot shows the 'Step 3. Demographic and injury details' window of the 'Telemedicine Client Version 2.0'. The window has a title bar with standard OS controls and a tabbed interface with five tabs: Step 1, Step 2, Step 3 (active), Step 4, and Step 5. The form is divided into three main sections: 'Demographic and injury details', 'About the Injury', and 'Contact and Priority'. The 'Demographic and injury details' section includes input fields for 'Forename(s)', 'Last name', and 'Hospital No', and a 'Date of Birth' field. The 'About the Injury' section has a 'Description' text area, a 'Date and time of the injury' field with 'I' and 'Y' sub-fields, a 'Cause' dropdown menu, and an 'Assessment of damage' section with eight checkboxes: Skin, Nerve, Joint, Muscle, Tendon, Vessel, Ligament, and Bone. The 'Contact and Priority' section includes fields for 'Referring Doctor', 'Specialty' (dropdown), 'Location' (with 'QVH MIU' selected), 'Staff grade' (dropdown), and 'Priority requested' (dropdown). A status bar at the bottom reads: 'Welcome to the Telemedicine Client program. Non-standard colour scheme detected. Things may look a little strange...'.

Fig. 5. Demographic data entry

The screenshot shows the 'Step 4. Specify Patient Consent Level for images' window of the 'Telemedicine Client Version 2.0'. The window has a title bar with standard OS controls and a tabbed interface with five tabs: Step 1, Step 2, Step 3, Step 4 (active), and Step 5. The form is divided into two main sections: 'Consent' and 'Information about Digital Image Storage'. The 'Consent' section includes three radio buttons for consent levels: '1: Clinical Record only.' (selected), '2: Clinical Record and Teaching purposes.', and '3: Clinical record, Teaching purposes and Publication.'. There is a 'Select one.' label to the right of these options. Below the radio buttons are checkboxes for 'Consent is by proxy' and a text field for 'Consent given by'. The 'Information about Digital Image Storage' section is highlighted in yellow and contains a text area with the following text: 'Before sending, please confirm that patient consent for storage of digital images has been granted at the appropriate level.', 'Images are sent via the NHSNet and stored on a secure server at QVH, accessible only by authorised staff.', and 'If consent has been given by proxy, please specify details, which will be recorded at QVH with the images.' A status bar at the bottom reads: 'Welcome to the Telemedicine Client program. Non-standard colour scheme detected. Things may look a little strange...'.

Fig. 6. Recording patient consent

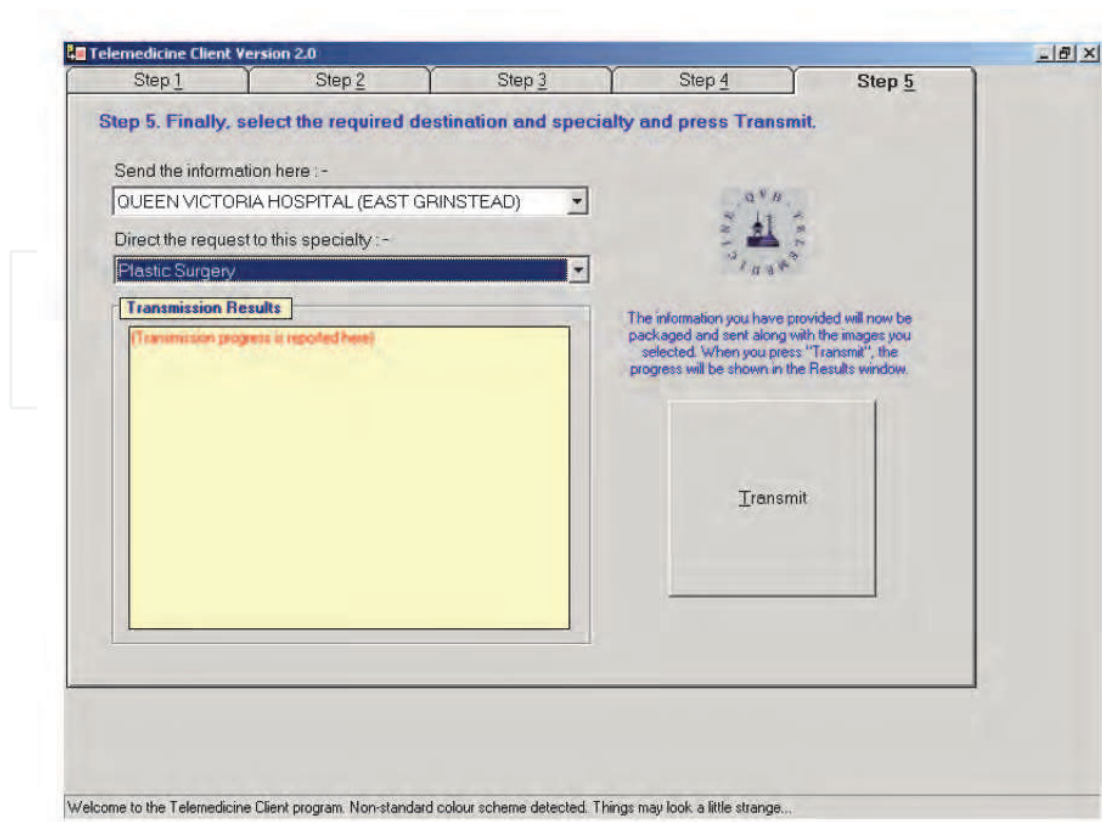


Fig. 7. Initiation of transmission

### 3.2 Received images

All encrypted email referrals from external units arrive at the QVH server (Pentium 4 256MB RAM and RAID-1 mirrored 14GB disks – these have been upgraded since 2002). Each email is decrypted by the software and is then available on any computer in the QVH to a logged on clinician (see figures 8 & 9). Every operating theatre at the QVH has a computer thus allowing a surgeon to remain scrubbed and view images during surgery. The hospital computers operated Windows NT and were a minimum of Pentium II, 64 RAM in 2002. These have now been upgraded to Windows XP professional and 2G RAM with Dual Core 3GB Pentium. Our monitors were routinely set to 800 x 600 pixels in 2002; now the minimum is 1024 x 768 pixels.

### 3.3 Pilot study 2: Ten week retrospective evaluation of the telemedicine system (DISTAR software)

We conducted a retrospective evaluation of the DISTAR encryption software. Over a ten-week study period we received 973 referrals (644 male and 329 female; 730 adults and 174 children). Telemedicine was used in 42% of referrals during the study period, according to protocols for trainee surgeons indicating when images should be requested. Telemedicine was available in three referring units and was also used at the QVH by the trainee surgeons to facilitate communication with other members of the on call team.

Qualitative feedback confirmed that the software was “user friendly” and facilitated the referral process. Following review of the second pilot study the telemedicine team were satisfied with our encryption software. We then supplied cameras, encryption software and



training to further accident and emergency departments and minor injuries units in our catchment area.

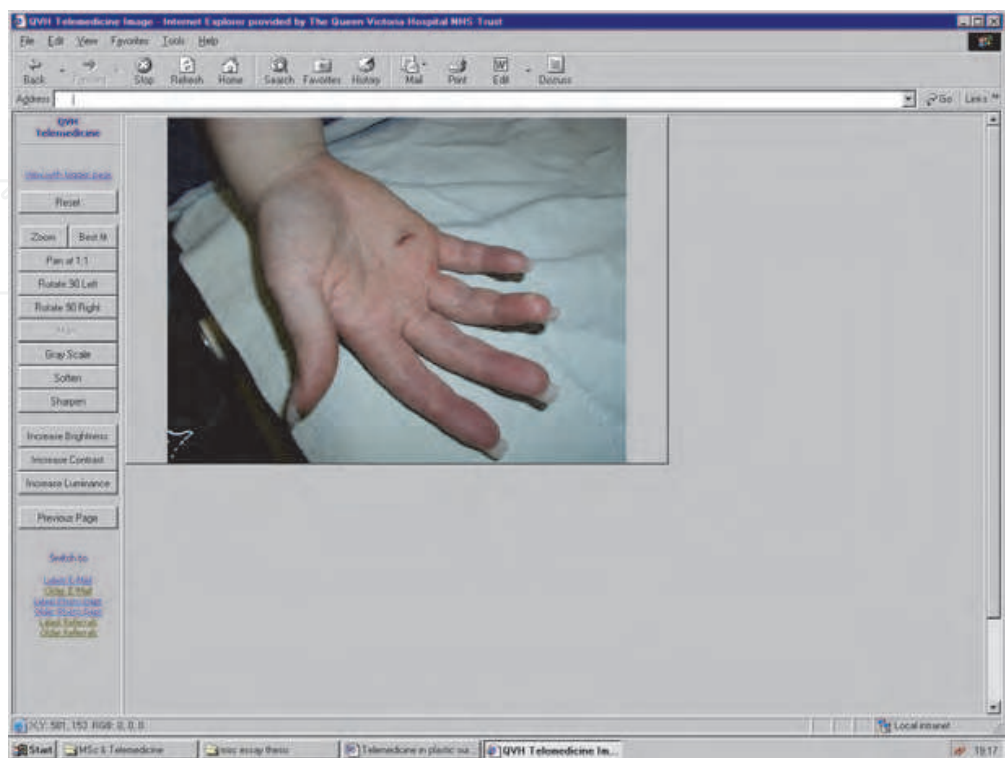


Fig. 8. Software for the receiving clinician at QVH

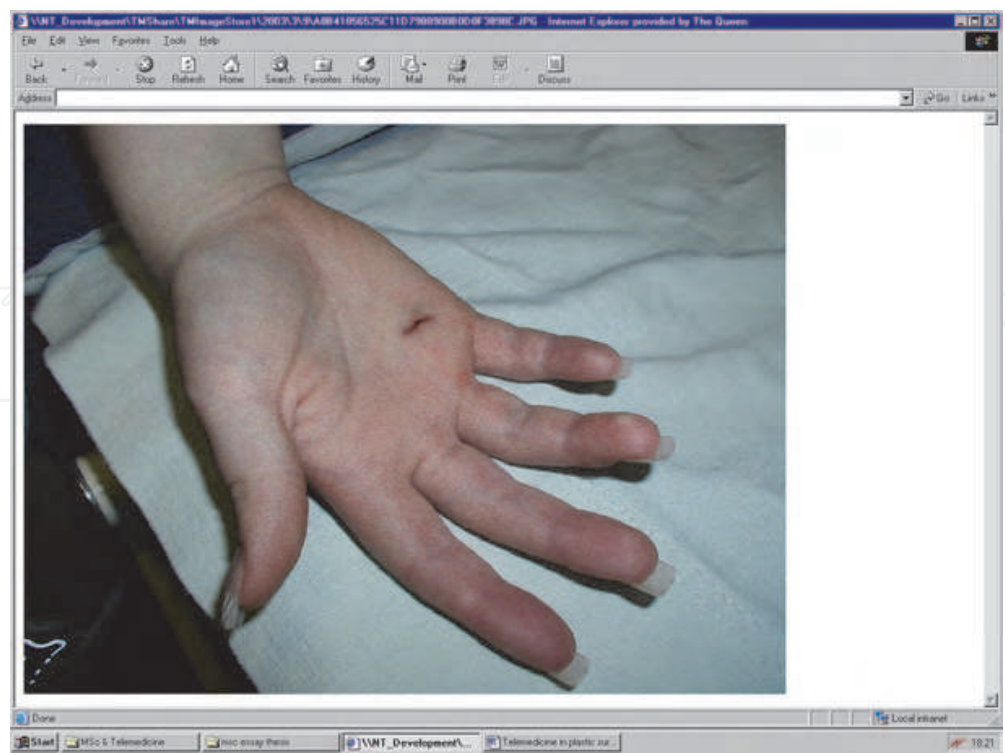


Fig. 9. Image can be enlarged to fill the screen

4. Pilot study 3: Twelve week prospective cohort study of the telemedicine system

4.1 Method

A prospective study was designed to determine the role of telemedicine in assessing different types of injury referred to the regional Plastic Surgery service at the QVH and to find out whether the information gained from telemedicine had any impact on the medical management, for example in prioritization of care. We classified injuries into 3 groups; closed, tidy and untidy. Closed injuries had no cutaneous wound e.g. closed hand fractures, dislocations or ligament injuries. Tidy injuries were defined as cuts and lacerations without loss of skin or subcutaneous tissue. Untidy ‘injuries’ included burns, wounds caused by crush or avulsion, wounds involving devascularization and infections. Management options included transfer to the QVH for review and treatment as an in- or out-patient/day-case, review at an out-patient/ dressing clinic (possibly at a peripheral hospital) or to decline the referral having giving appropriate advice on wound care/ further management. Referrals assisted by telemedicine were compared to telephone only referrals with regards to initial clinical management for all trauma referrals to the Plastic Surgery service at the QVH during the study period. Further specific analysis was undertaken of burn injury and hand surgery patients provisionally scheduled for (day-care) surgery on the basis of the referral details alone. Results were analyzed with SPSS version 10.0.

4.2 Results

There were a total of 996 referrals to the Plastic Surgery service at the QVH (711 male and 285 female) during the twelve-week study period (March to May 2003), with established telemedicine links in eleven hospitals. The telemedicine system was used for 246 referrals, 63% of the 389 referrals for which the system was available. Due to a lack of ready access to a computer terminal at night 4% of telemedicine images were not reviewed immediately. We saw a significant difference (P 0.004) in the management of referrals overall, see figure 10 (Wallace et al. 2008). The Telemedicine group had fewer attendances for clinical review,

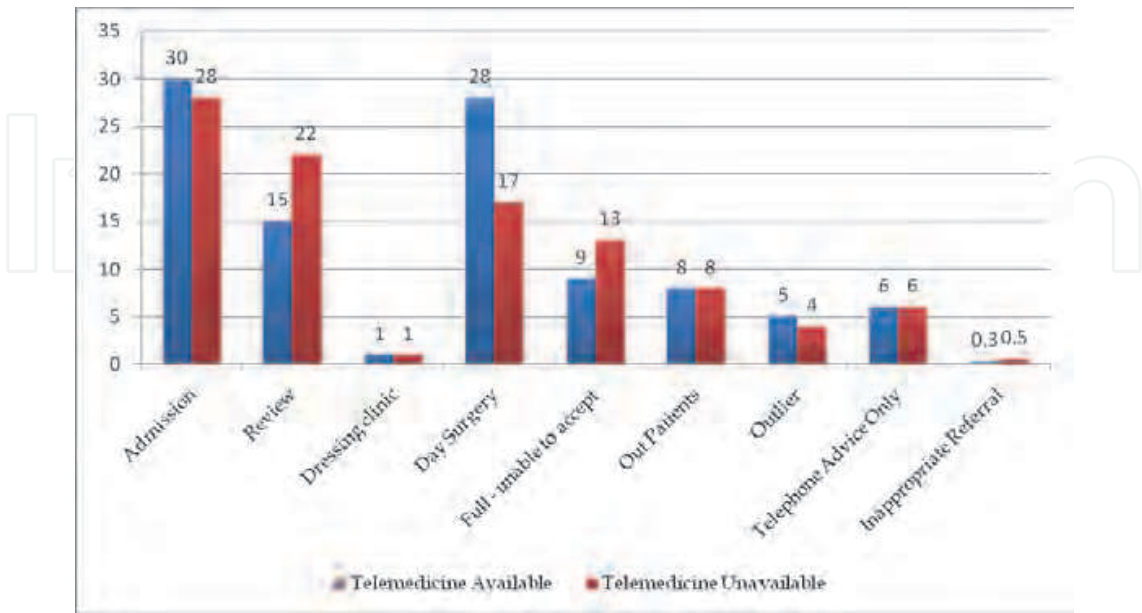


Fig. 10. Management choices of referrals with and without telemedicine availability (P0.004)

fewer referrals declined and increased use of day surgery. This significant difference was found in each of the three groups of closed, tidy and untidy injuries with the availability of telemedicine (Wallace et al. 2007).

Hand injury patients were triaged directly to Day Surgery with significantly greater accuracy, see figure 11. Upon arrival at the Day Surgery Unit 13% of telephone only referrals and 3% of telemedicine assisted referrals were redirected.

Figure 12 shows the significant difference ( $P\ 0.007$ ) in the management of the 103 patients attending the Burns Unit who were expected to be managed by assessment, treatment and discharge, i.e. minor burns not requiring admission. All of the telemedicine referrals were sent home, while 21% of the telephone-only referrals required unexpected admission. Figure 13 gives the management choices of 121 burn referrals (given as percentages), which did not reach significance ( $P\ 0.11$ ). As with the whole cohort there were fewer referral declined.

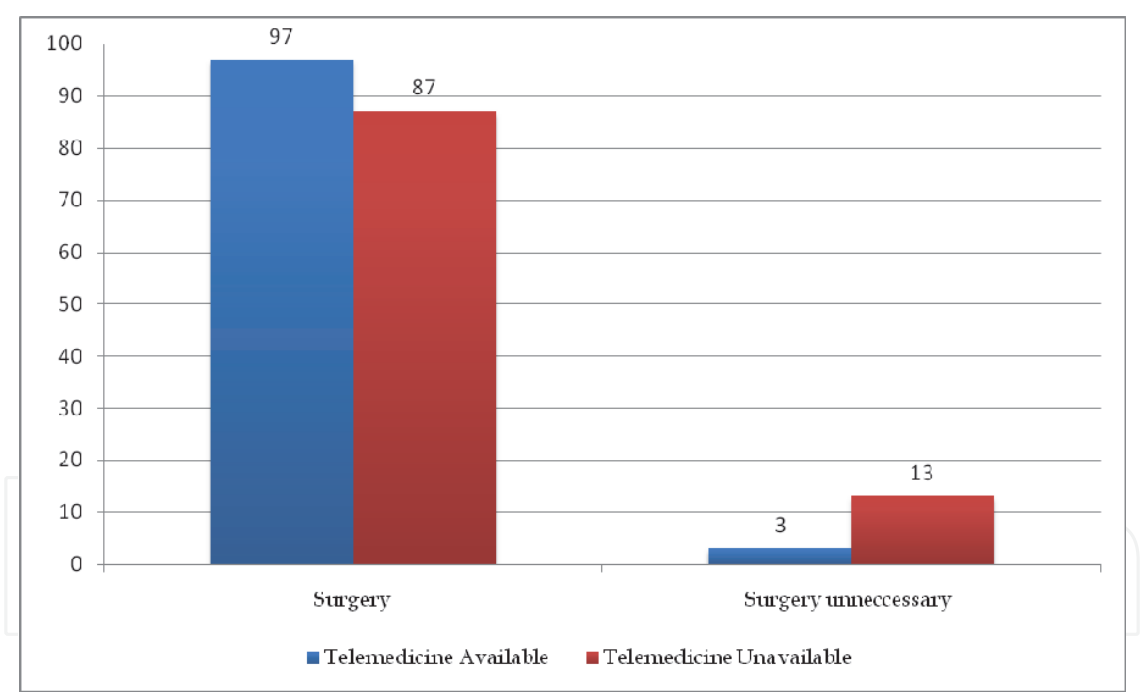


Fig. 11. Management of patients triaged to the Day Surgery Unit for definitive surgery ( $P\ 0.007$ )

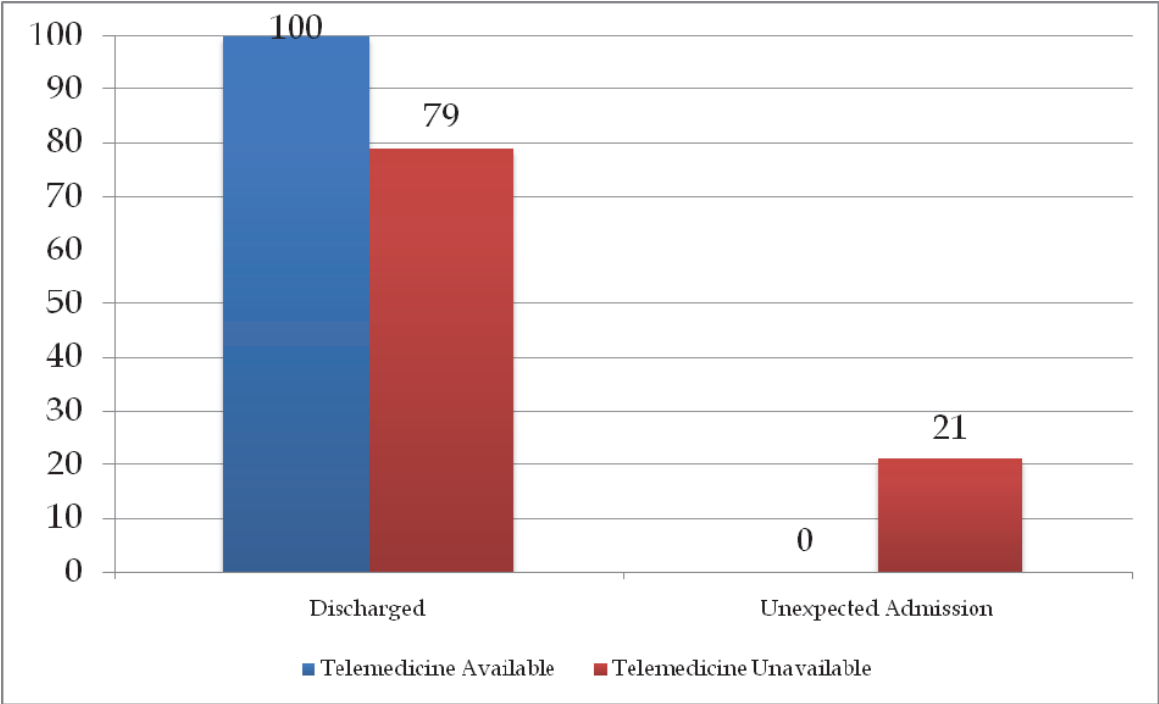


Fig. 12. Burn Injuries attending the Burns Unit for review (P0.007)

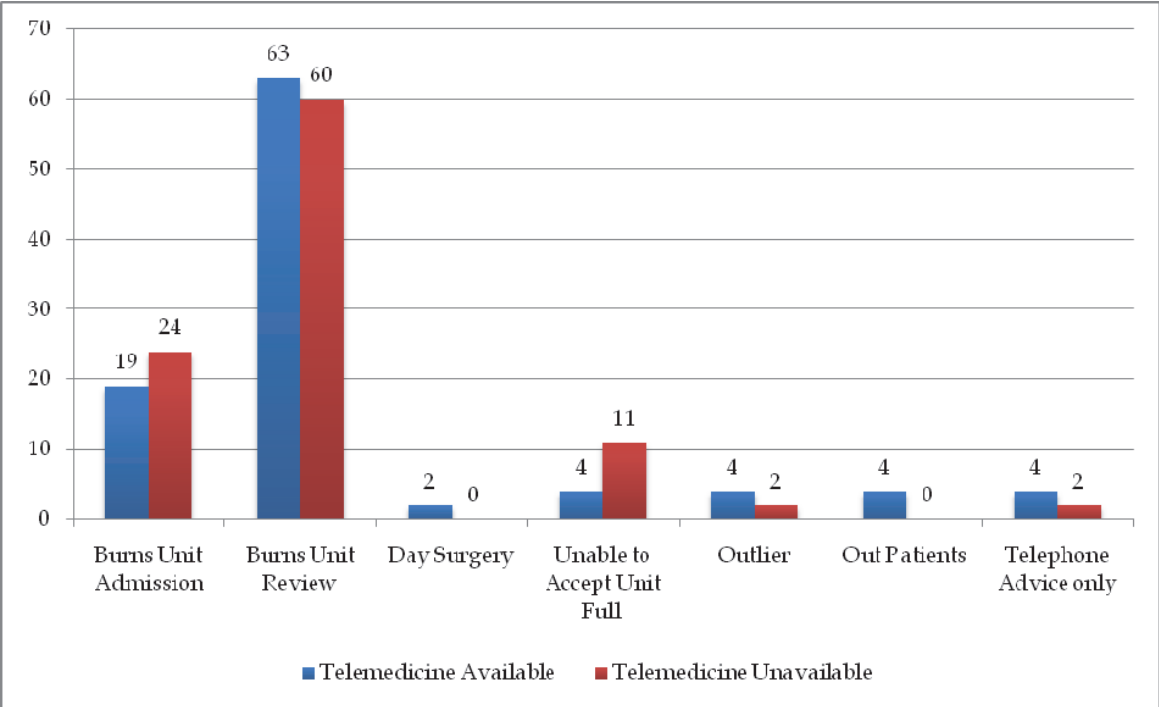


Fig. 13. Management of burn injuries with and without telemedicine availability

### 4.3 Illustrative case vignettes

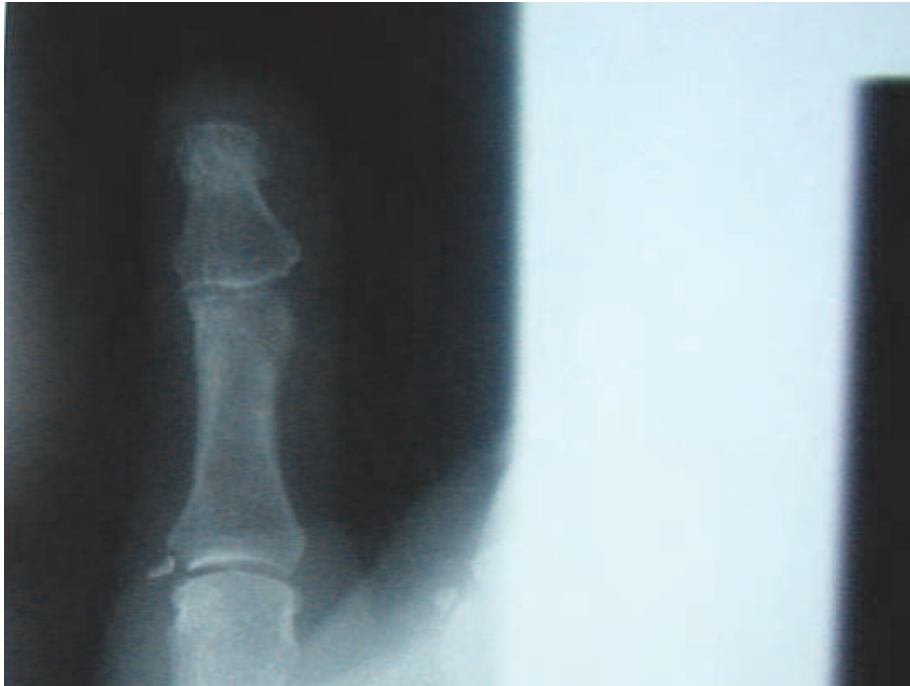


Fig. 14. Referring clinician had difficulty describing the radial avulsion fracture. Receiving clinician able to book directly into the Day Surgery Unit for a specific Hand Consultant.



Fig. 15. Patient sustained a small chemical burn to the tips of several digits, thoroughly washed, and pH neutral. Referring clinician requested blue light transfer. On review of the images the receiving clinicians were able to down-grade of the urgency of transfer.





Fig. 16. Patient suffered facial abrasion and lip laceration after fall from bicycle. Abrasion not initially mentioned in telephone referral conversation. Referral priority upgraded to ensure urgent scrub to avoid gravel tattoo.

## 5. Discussion

### 5.1 What we have achieved?

We have developed a Store-and-forward encrypted telemedicine system to assist in the management of injured patients referred to the Plastic Surgery service at the QVH. Its use has increased over the last decade to become a routine part of the care pathway for the management of injured patients, see figure 22. We have published evidence of the change in management of our patients due to the system, with improved triage and efficiency of our acute services (Wallace et al. 2007; Wallace et al. 2008). Use of the telemedicine system has now become part of routine acute trauma management, see figure 17.

### 5.2 Why have been successful?

Changing clinician's behaviour can be challenging (Foy et al. 2001; Cabana et al. 1999; Grol & Grimshaw 2003), and requires a full appreciation of the potential problems associated with a change of practice. We were ultimately able to successfully introduce telemedicine to the QVH and to engage fellow clinicians at referral centres by starting with a limited number of collaborating units, i.e. few partners, then, by a process of evaluation involving the various pilot studies described we were able to iron-out technical and other problems and roll the program out to all key referrers in our catchment area. Also, we were strongly supported by QVH management because telemedicine allowed us to run a more efficient and cost effective service for injured patients.

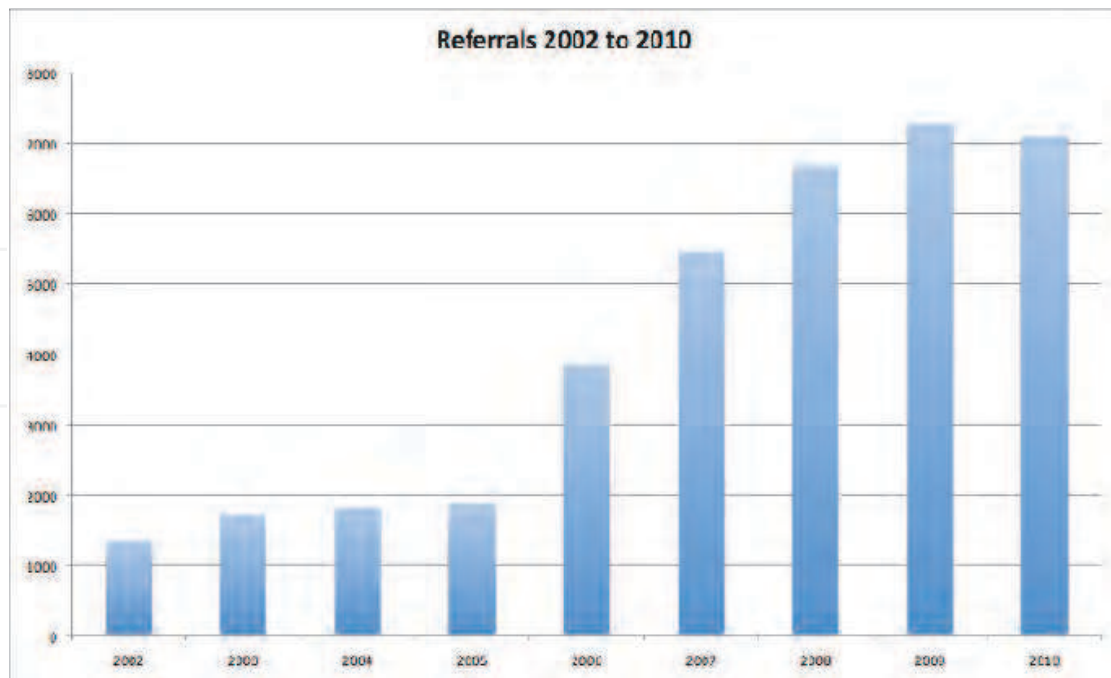


Fig. 17. Usage of Telemedicine system at QVH 2002-2010

### 5.2.1 Evidence base

An adequate evidence base is essential to demonstrate to clinicians that proposed changes offer benefit and are not detrimental to their patients (Yellowlees 2005; Tanriverdi & Iacono 1999; Stronge et al. 2008). Unfortunately throughout telemedicine (Roine et al. 2001; Whited 2006; Whitten et al. 2002), Burn injury management (Al-Benna et al. 2010) and Plastic surgery (Chung et al. 2002) numerous reviews bemoan the lack of high quality and randomised controlled trials. Our large prospective cohort study (pilot study 3) provides the current best level evidence for acute plastic surgery trauma management with a telemedicine system. Our studies combined with extrapolations from similar specialities (e.g. dermatology) have provided a useful evidence base (Levin & Warshaw 2009; Warshaw et al. 2009) to inform clinicians of the value of our system.

#### 5.2.1.a Image resolution

Good quality images are vital in telemedicine; resolution must be adequate, perspective correct and focus sharp. Poor image quality can affect a clinician's ability to make a clear diagnosis (Briggs et al. 1998; Stutchfield et al. 2007); if necessary additional images should always be requested. Our own pilot study (pilot study 1) demonstrated 800 x 600 pixel resolution was adequate for diagnosis and grading of urgency of transfer (Jones et al. 2004). This concurs with other telemedicine studies of wound assessment (Wirthlin et al. 1998; Murphy et al. 2006) and dermatology (Eedy & Wootton 2001; Krupinski et al. 2008). Resolutions of greater than 1024 x 768 pixels does not appear to benefit the viewer for burn images (Jones et al. 2003), whilst limited file compression (JPEG) does not negatively affect confidence or accuracy (Jones et al. 2003; Roa et al. 1999). Lower resolution systems (mobile phone screens) can result in discordance between face-to-face management and telemedicine assisted referrals (Hsieh et al. 2004). We found no discordance for acute burn management (see figure 12) and a 3% discordance for hand injuries at 800 x 600 pixel resolution, see figure 11 (Wallace et al. 2007). Compact digital cameras have now surpassed

this threshold, so that concerns over resolution obscuring subtle findings on computer screens are of historical relevance (Scott et al. 1993; Jacobs et al. 2002), although there may be a contemporary relevance if images are viewed on mobile phone displays.

Mobile phones were a relatively novel technology when we planned our system originally. Mobile phones are now ubiquitous, and restrictive use policies are being removed within the NHS (2009b). Therefore reports of mobile phones being used to view telemedicine images for neurosurgery (Waran et al. 2008), hand injuries (Hsieh et al. 2004) and burns (Shokrollahi et al. 2007) are of interest but at QVH we have no plans to use mobile phones for telemedicine purposes. Data protection cannot be safeguarded, nor can we keep patient information on the hospital computing system for audit purposes (Wallace & Durrant 2005).

#### **5.2.1.b Legal & security concerns**

Anonymising all data transferred by telemedicine can allay concerns over patient confidentiality, and has been used in early UK military telemedicine systems (Scerri & Vassallo 1999). In Plastic Surgery though, many images would be patient identifiable, e.g. facial images, and the volume of referrals we deal with would preclude such an anonymised system from having any practical value. We use the NHSnet, which is in effect a very large intranet for NHS hospitals; when combined with image encryption this meets legal requirements for data protection.

In the UK data protection compliance has been noted to be (woefully) inadequate (Webb 2002; Mole et al. 2006). Therefore ad hoc procedures and reliance on staff knowledge of data protection would be insufficient. Documentation of patient consent was made integral to the data entry with the QVH telemedicine system, which satisfied the requirements local Data protection.

#### **5.2.2 Clinical ownership**

At the start of the project we formed a telemedicine team that included clinicians who were involved in trauma management and who were users of the system. We have maintained their involvement to ensure that the system can be usefully changed, as demonstrated by our early recognition of the need for bespoke encryption software. We delivered both top-down and bottom-up pragmatic style management, rather than rigid idealism, to optimize change of clinical practice (Yellowlees 2005; Grol & Grimshaw 2003). We used plastic surgical trainees to lead the installation and education process since they were judged to be familiar with the demands of the acute service and could be seen to be assisting with rather imposing a new working practice upon colleagues that demanded extra work for the referring clinician.

#### **5.2.3 User friendly systems**

We considered whether to opt for a videoconferencing interactive system, or for a Store-and-forward system. Videoconferencing systems can provide good support for acute referrals needing expert review in the UK (Tachakra et al. 1998; Tachakra et al. 2002). Unfortunately videoconferencing systems usually require a designated room, and consultations can take substantially longer, often two to three fold longer (Benger et al. 2004; Tachakra & Rajani 2002). The flexibility of a Store-and-forward system is well suited to the multiple locations of the acute surgical team at the QVH. The receiving clinical team can be in different locations within the hospital, communicating by telephone, while viewing images on the nearest computer screen. This assists not only the patients at a distance from

QVH, but also those already on site to facilitate senior involvement in decision making, even if scrubbed in theatre. Recently we have begun to incorporate clinical images downloaded from our telemedicine database directly into patient's clinical records and we also include telemedicine images in power point presentations that form the basis of daily hand-over discussions for the duty trauma team. Furthermore, all images are stored in databases that are easily accessible for clinicians who wish to view them for clinical purposes and teaching. Clinicians have responsibility for ensuring the best care of their patients, and if the technology does not assist in this then one cannot expect it to be used (Yellowlees 2005). One early Store-and-forward system could only process twenty cases in an hour (Taylor et al. 2001), which is clearly inadequate. Technology projects are expected to give substantial benefits, occasionally even mortality reductions (Longhurst et al. 2010). However this is not always the case, with extra clinical work required (Jones 2003), or even adverse clinical outcomes (Han et al. 2005). Clinicians naturally seek solutions for technology that does not meet their needs (Andersen et al. 2009). We were very keen to install a simple system that could be easily used even without specialist training. We conducted a feedback survey, which demonstrated very high satisfaction amongst referring clinicians, with 33 of 34 happy to recommend the system to others.

On each occasion during the prospective cohort trial that a referring clinician reported that the telemedicine was faulty, the system was inspected on site either the following day or next working day. Technical faults were reported on 91 occasions, yet less than 10 were validated on inspection. These issues highlight the need of designing systems around the clinician (Yellowlees 2005).

#### **5.2.4 Training & support**

Initially we anticipated that once the telemedicine system was installed minimal support would be required, but where staff turnover is high the training needs to be continual (Blignault & Kennedy 1999; Krupinski et al. 2003). We also found, like others (Lian et al. 2003), a significant percentage of images inadequate for diagnostic needs ((20 of 150; e.g. bad views, poor focus). Guidance was needed for taking images (see figure 2); Plastic Surgery trainees taught both technical use of the system and clinical topics (such as burn and hand surgery management) at the referring hospitals. From both experience and the literature (Jakowenko 2009; Whitehouse 1999) we recommend cleaning the injured area thoroughly. Then, with the flash on, a general image for zoning the area and a close up of the injured part are routinely requested. When taking images of non-digital X-rays on a backlit screen the flash should be off. We distributed a handout of tips for good image acquisition and use of the telemedicine system.

We assumed that the referring clinicians would be the most useful personnel to teach in each referring department. However, experience suggested the entire clinical staff, including nurses, should become familiar with the system, thereby increasing the likelihood of a trained member of staff being on duty when the need arises. To retain the camera in a secure and accessible place we recommend the Controlled Drugs Cabinet; ideally with rechargeable batteries available.

One of the few drawbacks of our Store-and-forward system is the limited educational potential when compared to videoconferencing systems. In Minor Injury Unit support in the UK such systems can lead to decreased referral rates due to clinical education of the staff (Tachakra et al. 2000). When we evaluated the 996 referrals in the prospective study we determined only 1% to be inappropriate, therefore we do not expect to see a drop in referrals (see figure10).



### 5.2.5 Cost analysis

We received central government assistance with the capital outlay for the purchase and installation of computer equipment and cameras, network lines and software of £70 000 (\$110 000). We continue to employ a clinical telemedicine officer at the QVH to ensure support, ongoing education and promotion of the system. We have not charged referring units for such telemedicine training. We believe this would be detrimental to encouraging the use of the system, which benefits the patient and our efficient use of resources, but does not assist the referring unit more than the standard phone call. We have shown an overall 10% decrease in the need for face-to-face review prior to treatment since the introduction of telemedicine at the QVH.

Cost savings have rarely been demonstrated from the use of telemedicine systems (Whitten & Buis 2007; Whitten et al. 2002) although reducing patient transportation costs may be possible (Saffle et al. 2004) and has been demonstrated by several telemedicine systems (Tsai et al. 2007; Goh et al. 1997). Typically only when the health care provider also pays for the transportation does this occur, i.e. in the military and prisons (McManus et al. 2008; Brunicardi 1998).

### 5.3 Why does telemedicine help?

There are several possible reasons why telemedicine images help in the referral process. Firstly the receiving clinician is able to validate any information already given over the phone. Secondly, there may be additional information from the images supplied. This may be important for non specialists referrers, whose lack of knowledge may lead to an incomplete or incorrect assessment (Kruger & Dunning 1999). In casualty departments the infrequency of burn injuries precludes the ability for most emergency clinicians to become confident in their burn-wound assessments (Chipp et al. 2008). Without adequate clinical experience expertise is difficult to gain (Ericsson 2008), and without feedback learning is very challenging (Croskerry 2000). Decisions are made in an environment that is vulnerable to error (Croskerry & Sinclair 2001). We know that Hand (Patel et al. 1998; Nassab et al. 2007) and Burn injury (Collis et al. 1999; Hagstrom et al. 2003; Laing et al. 1991; Irwin et al. 1993) assessment is suboptimal by non specialists, and the role of the referring clinician is to “sell the patient” to the receiving unit (Nugus et al. 2009).

Burn beds are such a precious resource in the UK that we have a national bed bureau that contacts all burn centres twice daily to update on capacity. This facilitates the management of the acutely injured burn patient if the nearest provider is unable to take the referral. We studied patients attending the QVH Burns unit for clinical review (figure 12). These were patients who, on the basis of the referral information, we would anticipate to be treated and discharged home. All of the telemedicine assisted referrals were reviewed and discharged home; whereas 21% of the telephone only referrals could not be safely discharged home and required an unexpected admission (Wallace et al. 2007). We also noted a decrease in the proportion of referrals we were unable to accept, as the unit was full, though this did not reach significance.

Thirdly, with better quality communication, there should be fewer errors for clinicians involved in the process of referring injured patients for specialist care (Sexton et al. 2000; Foy et al. 2010; Coiera 2000). Finally, one of the unexpected but significant benefits of introducing telemedicine to the QVH has been the almost routine involvement of senior clinicians in key management decisions for trauma cases due to the ease of access to telemedicine images at computer terminals throughout the hospital, plus access via the



NHSnet to X-rays taken in referring hospitals. The involvement of senior medical staff in trauma management should, logically, be accompanied by improved standards of care and greater efficiency (Wyatt et al. 1999; Treasure 2007).

## 6. Future developments

In the UK provision for trauma care has been shown to be suboptimal (Anderson et al. 1988). Trauma networks are being introduced throughout the UK (Treasure 2007; 2009a; Celso et al. 2006). Telemedicine applications for ambulance crews to assist with cardiac patients have led to mortality benefits (Bjorklund et al. 2006). For certain specific injuries that are attended by ambulance crews the possibility exists now for patients to be referred with telemedicine directly to the QVH without having to be taken to another hospital's accident department; it may be possible for advice to be given on treatment to paramedics attending injured patients, which, in turn, saves an unnecessary hospital attendance. With telemedicine, ambulance crews can take injured patients to the most appropriate facility, rather than the nearest.

## 7. Conclusion

We introduced a secure encrypted email telemedicine system to our unit, having identified a need for increasing objective information to assist in the management of acute burn and plastic surgery injuries. We maintained clinical ownership by convening a group of clinical users and information technology experts to assess the requirements, specify the type and design, and assess the clinical impact of the system. The systematic and staged evaluation allowed clinical confidence to grow and encouraged the involvement of all users of the system. We have demonstrated significant improvements in clinical management with the use of the system. This has led to the successful integration into routine practice for acute plastic surgery referrals. As technological applications continue to develop we look to move forward by involving the pre hospital personnel in improving the initial triage by direct contact with ourselves, facilitating expert and senior guidance at the pre hospital site.

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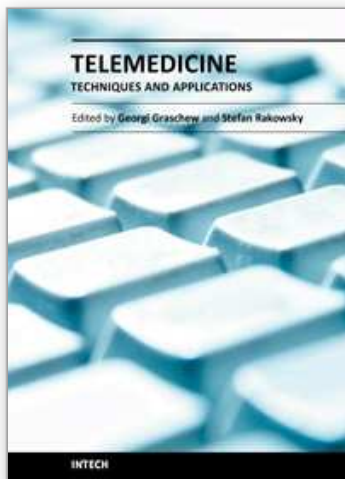
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Telemedicine is a rapidly evolving field as new technologies are implemented for example for the development of wireless sensors, quality data transmission. Using the Internet applications such as counseling, clinical consultation support and home care monitoring and management are more and more realized, which improves access to high level medical care in underserved areas. The 23 chapters of this book present manifold examples of telemedicine treating both theoretical and practical foundations and application scenarios.

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