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Invited article

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* *LT COL DAVID VASSALLO RAMC, Defence Medical Services Telemedicine Unit, Royal Hospital Haslar, Gosport, Hants PO14 2DL, United Kingdom*

MeSH

Telemedicine	Digital cameras	email
Defence medical services	Medical students	

Abstract

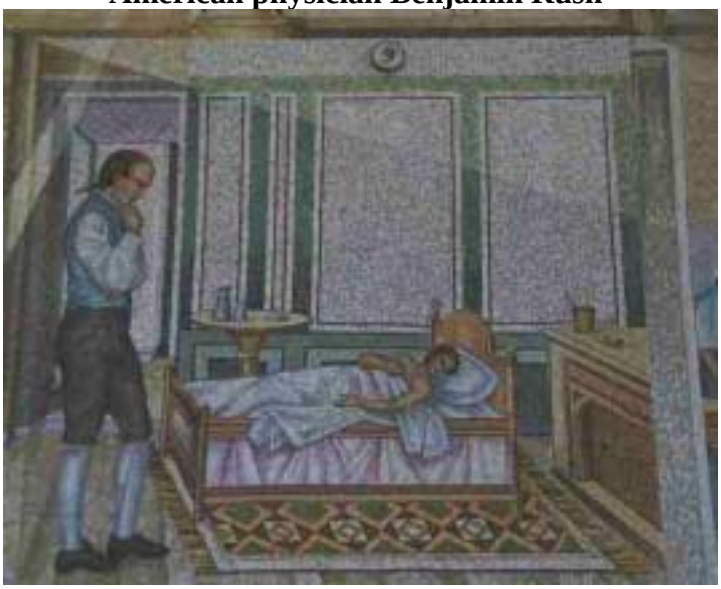
Telemedicine ("medicine from a distance") is about bringing specialist knowledge to a patient from afar, by the use of communication technology. This article is based on personal experience in helping set up a simple, versatile, cheap and effective store-and-forward telemedicine system for the British Defence Medical Services. This system uses readily available still digital cameras to record clinical, radiographic and microscopic images, which are then sent by electronic mail to an organised network of specialists for secondary or tertiary opinion. The system is in use in various countries throughout the world, and has also proven to have civilian and humanitarian uses. The system is now being emulated in civilian practice in the United Kingdom, the United States, and in previously isolated hospitals in the Third World. I also describe the active role played by a telemedicine charity and by medical students on elective in the Third World in setting up telemedicine links using this system. Readers are invited to co-operate in the setting up of a global outreach telemedicine programme, linking elective students, isolated Third World hospitals, and University Teaching Hospitals.

Article

Introduction

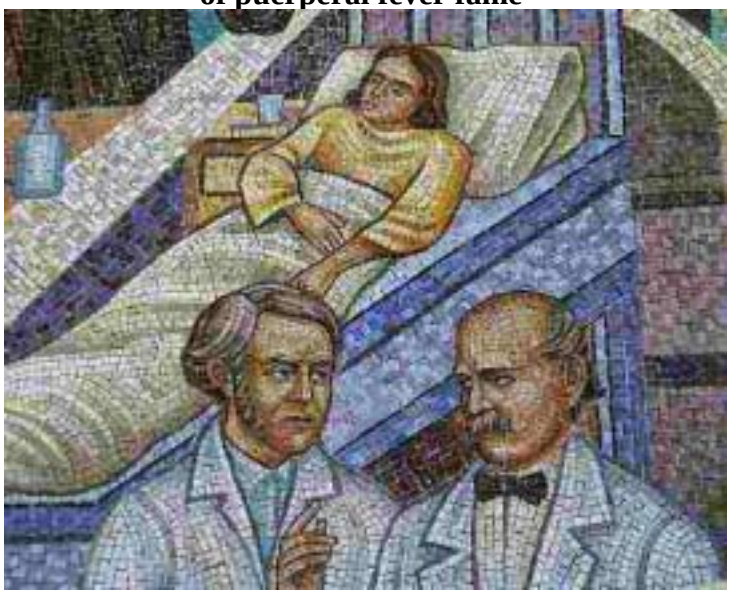
What is telemedicine? Derived from Greek, the word literally means "medicine at a distance". When a doctor is concerned about a patient, and is unsure about the diagnosis or the management of the patient's illness he would normally consult a specialist. But if the doctor is isolated (e.g. on board ship, on a remote island, in a small Third World hospital, on an overseas expedition, or in a country whose health infrastructure has been devastated by war or natural disaster), then how can he obtain such specialist help?

Figure 1: Mosaic of a doctor contemplating an ill patient from the Medical School, Emory University, Atlanta, Georgia USA. This is purported to depict the American physician Benjamin Rush



The answer is, through telemedicine. Telemedicine is about bringing such specialist knowledge to the patient and doctor from afar, through the use of communication technology.

Figure 2: Two specialists discussing a patient, from a wall mosaic in Emory University, purporting to show Semmelweiss and Holmes, of puerperal fever fame



This article on telemedicine is drawn from my experience in helping set up and develop a simple yet effective store-and-forward telemedicine system for the British Defence Medical Services (DMS), together with my radiology colleagues Surg Cdr

Peter Buxton and Wg Cdr John Kilbey in the DMS Telemedicine Unit. This system has been in use around the world since November 1997. The British Computer Society awarded the DMS Telemedicine System its Special Award for 1998 (http://www.bcs.org.uk/awards/medal-98/win98.htm) (http://www.rowe.dircon.co.uk/medical/bcspics.htm).

British forces are deployed in locations as diverse as the jungles of Belize and Sierra Leone, the mountains of South Georgia, the deserts of Kuwait, the seas and oceans of the world, and war zones such as Bosnia, Kosovo and Sierra Leone. Wherever they are the Defence Medical Services aim to provide a standard of medical care comparable to that available in the UK. It is clearly impossible to provide all of the specialists of a modern hospital in every location, which is why telemedicine is being used to fill this gap. The DMS telemedicine system is already being used in civilian practice in the UK, in the USA, in Bangladesh, the Solomon Islands, and Nepal.

The needs

The essential elements of a telemedicine system are:

1. Availability of advice from secondary or tertiary hospital specialists
2. Referrals from varied sites, containing clinical images and text
3. A simple, versatile yet effective solution
4. A portable and robust system
5. The hardware and software utilised must be cheap and easily replaceable - ideally from local sources
6. Minimal training requirements - doctors must be able to use it easily

Needs which cannot be satisfied by a simple telemedicine system

1. **Need for immediate care:** The doctor on the spot must be adequately trained in basic first aid and advanced life-saving measures and not worry about having to hold a camera steady when the bullets are flying, or an artery is spurting.
2. **Live telesurgery:** Similarly, a surgeon must be able to staunch haemorrhage and to cope with common emergencies, without worrying whether another surgeon, perhaps in a different time zone, is linked up to an overhead video camera. Live telesurgery is very much an educational activity restricted to First World University and tertiary hospital practice, or to well-equipped Third World teaching hospitals, for it requires a great deal of technological input and synchronised activity.
3. **Live videoconferencing:** This requires two people in different locations to synchronise their activities in advance. This may work fine in the business world for scheduled meetings, or in a minor injuries unit linked to a major accident unit elsewhere, but it does not work well for most hospital specialties. Moreover, the quality of images transmitted by video cameras is inferior to the diagnostic quality obtainable by the better still digital cameras. Immediate care telemedicine, live telesurgery and videoteleconferencing require the following expensive resources:

    1. High bandwidth telephone lines
    2. Technicians

3. Complex technology
4. Heavy, relatively immobile equipment
5. Considerable expense.
6. Synchronous activity

The DMS System

The DMS system requires modest resources, which include:

1. A still digital camera
2. A tripod which is used when taking photos of xrays on a viewing box, or with microscopes
3. A computer, and a laptop or notebook computer is ideal for doctors on the move, whereas a desktop suffices in more static circumstances
4. An email account, with store-and-forward transmission of text and images. In urgent cases, an additional phone call is made to alert the necessary specialist
5. A telephone and modem
6. A network of hospital specialists

Figure 3: DMS Telemedicine System, Kosovo, 1999

http://www.emergency-medical.com/case01_01.htm
http://www.rowe.dircon.co.uk/medical/bcspics.htm

Optional extra

The DMS use specially developed software for receiving, archiving and replying to email referrals. This software is called Tmed2000 , developed for Windows and Linux operating systems by Surg Cdr Peter Buxton and Wg Cdr John Kilbey at the Royal Hospital Haslar. This is freely available via http://www.bktelemed.com

Educational extra

"*Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it.*" Samuel Johnson. Haslar's Librarian, Michael Rowe, has catalogued the best medical internet sites, including electronic journals and books,

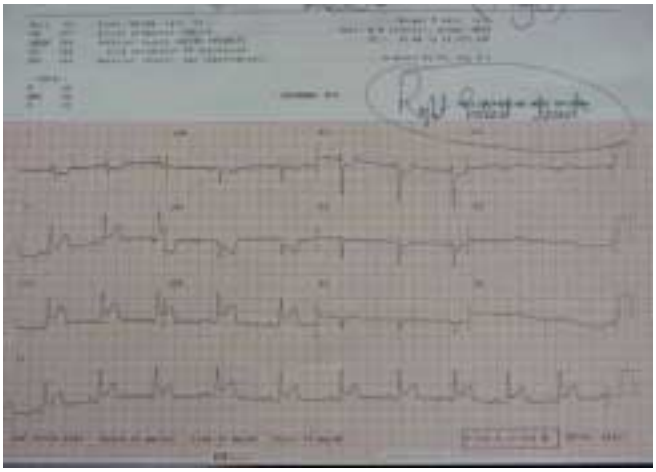
using the National Library of Medicine Classification. These sites can be accessed via the Medical Bookmarks section of The Royal Hospital Haslar Library Website. http://www.haslib.demon.co.uk/library.htm

Digital cameras

A digital camera suitable for telemedicine must produce high resolution (minimum: one megapixel) diagnostic quality still images. Ideally the camera should also be of SLR-type, and have a screw fitting capable of adding further macro filters for close-up photography. The first commercially available megapixel camera which met these requirements was the Olympus C1400L (1.4 megapixels – released in November 1997), and has been used in Bosnia by the DMS since January 1998. This camera and its successors have proven to be more than satisfactory for clinical purposes, as well as for photographing ultrasound images and radiographs. The only difficulty arises with full size chest radiographs, for the fine soft tissue detail is only captured with separate lung field views. Since November 1999 the DMS have commenced using the Olympus C2500 (2.5 megapixels – cost approximately £600 inc VAT) in Bosnia, Kosovo and Sierra Leone, because this gives much higher resolution, which is particularly useful for chest radiographs.

Figure 4: Chest Xray photographed with Olympus C2500 digital camera, Bosnia Dec 1999

Figure 5: ECG showing inferior myocardial infarction, photographed in Bosnia, December 1999



A particular advantage of digital cameras over ordinary cameras is that the resulting image can be viewed immediately, whether to form part of a telemedicine referral, or to include in a teaching presentation, or to review a particular event as a part of critical incident stress debriefing. They are particularly useful in trauma scenarios.

The following scene was photographed in Kosovo on 17 Jul 99, and records the final moments of a 14 year old boy who had been involved in a cluster bomb explosion one month after cessation of hostilities. He succumbed from his injuries, despite all efforts. This article is dedicated to the child victims of landmines and cluster bombs, and to all who care for them.

Figure 6: Attempted resuscitation on a fourteen year old boy who sustained massive trauma from a bomb explosion

Historical Notes

The first telemedicine link for the British Forces was set up in Bosnia in January 1998. [1,2] Since then, further links have been established. These include the Royal Naval Hospital in Gibraltar (http://www.haslib.demon.co.uk/gibpics.htm), The Princess Mary Hospital in Cyprus (http://www.haslib.demon.co.uk/tpmh.htm), Belize (the first link there being with a Maltese RAMC doctor, Lt Col Bonnici, in November 1998), a military general practice and a civilian hospital in the Falkland Islands, and South Georgia.[3-7] Other links include HMS Invincible, Kuwait, and more recently Macedonia, Kosovo,[8] and Sierra Leone. Where possible ordinary telephone lines are used, but satellite telephones have to be used on board ship and in war zones such as in Bosnia and Kosovo.

Figure 7: The author, using a satellite telephone, Bosnia, January 1998

This simple telemedicine system is particularly useful in a Third World setting. The DMS Telemedicine System is being used to link Southeast Asia's main spinal injury hospital, the Centre for the Rehabilitation of the Paralysed in Bangladesh (http://www.emergency-medical.com/case06_01.htm), as well as a hospital in Nepal and another in the Solomon Islands, with consultants in the UK and the USA. All of these links have been instituted by a new charity specialising in the establishment of simple telemedicine links (based on digital cameras) to the Third World, namely The Swinfen Charitable Trust (http://www.emergency-medical.com/case06_18.htm) (swinfen@dene73.freeserve.co.uk).[9]

Particular concerns in telemedicine

1. **Clinical responsibility:** This is important for medicolegal purposes. It is crucial to realise that the clinical responsibility for the patient remains with the referring clinician, who is the only one with physical contact with the patient, and who has access to the whole clinical picture. Telemedicine replies are dependent upon, and therefore limited by, the quality and reliability of the text and images transferred.
2. **Diagnostic quality of images:** Modern digital cameras can reproduce diagnostic quality images of clinical features, such as wounds, burns and rashes, of ECGs, and of microscope films. They can also reproduce high quality images of most radiographs. However, formal radiological reporting has to comply with the guidelines of The American College of Radiologists. These state that for medicolegal reporting, a digital image of a radiograph must have a resolution of 2000 x 2000 pixels. This is achievable with fully digitised xray machines, but it is not achievable with digital cameras. Radiological reporting of radiograph images taken with digital cameras must therefore be accompanied by the proviso that the report is not the final

medicolegal report. Nonetheless, the quality of images with modern cameras is sufficiently high for most practical purposes.

3. **Patient confidentiality:** Electronic mail is an insecure means of communication. The DMS therefore issue local code letters and sequential numbers to each referral, and do not identify the patient by name or other identifiable feature. Thus, GIB007 in the subject header or text of the email referral refers to the seventh telemedicine referral from Royal Naval Hospital Gibraltar. There is therefore no need to encrypt the message, and ordinary email can suffice.
4. **Mechanics of referral:** For example, the DMS use a standard format for sending email referrals. The key is the Subject Header of the email.

   This is written in the following format: tmed xray GIB007. The word tmed differentiates the referral from all other emails. This is followed by a 3 or 4-letter code denoting the specialist opinion sought, e.g. xray, orth, derm, plas, surg, ENT, eyes, med, paed, maxf, urol, path. After this is the local code and sequential number, e.g. GIB007. Images are sent as attachments to emails containing the clinical details, addressed to the DMS Telemedicine Unit at Haslar, which forwards them to the relevant specialist. The specialist copies his replies to the same address. There is therefore no need for the doctor at the sending-site to keep track of individual specialists' email addresses, and all referrals are thereby archived centrally together with the replies. Store-and-forward emails alone are used. In the case of urgent referrals, the referring doctor also rings up the relevant specialist directly to alert him to the case.

5. **Choice of software:**
   1. ***Image manipulation:*** Digital cameras are supplied with their own image manipulation software. No further software is required. Referring clinicians have only to ensure that the images they send are in focus, that they are cropped in size as necessary, that radiology images are converted to grayscale in order to reduce file size, and that the relevant pathology is clearly demonstrated. No further image manipulation is necessary at the receiving-site.
   2. ***Telemedicine email software:*** Ordinary email (as supplied by any internet service provider) can suffice. However, keeping track of email referrals within one's email archive is difficult. The DMS Telemedicine Unit has therefore designed its own software, Tmed2000. This is freely available via www.bktelemed.com It automates the sending, receiving, archiving of text and images, and replying to telemedicine referrals, based on the standard email Subject Headers (e.g. tmed xray GIB007)
6. **Size of images versus transmission times:** Image sizes with 1.4 megapixel cameras range between 30 kbytes (for microscope images) to 200 kbytes. Images taken with a 2.5 megapixel camera are up to 500 kbytes in size, though the size can be reduced considerably by changing the colour to grayscale (for radiographs), or by renaming and cropping the images. Image size is important for two main reasons. The first is the space limitation of a computer's hard disk or floppy disk. A rewritable CD-ROM should seriously

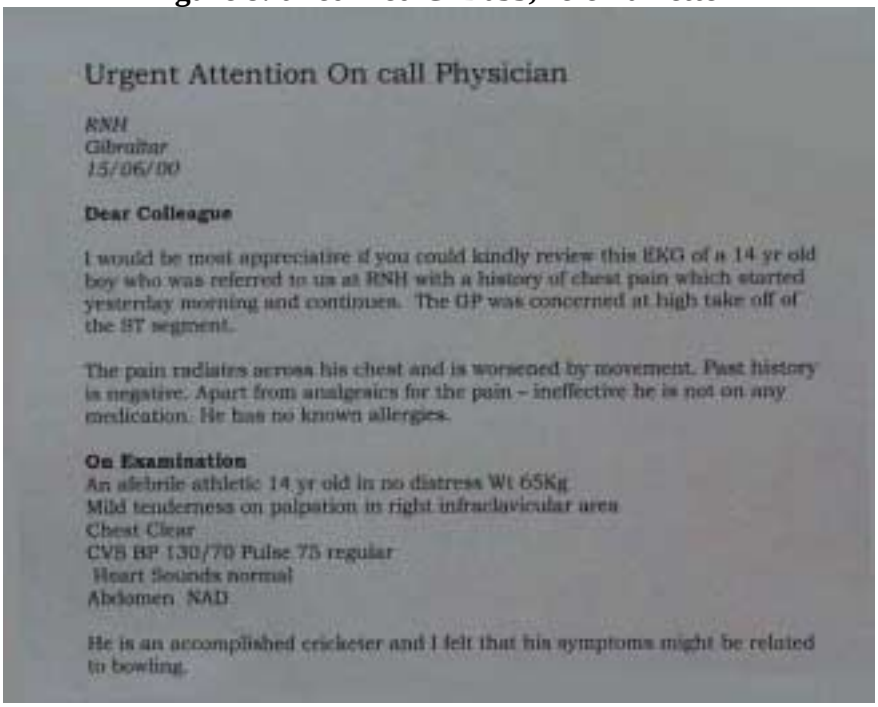
be considered for archiving purposes. The second is the speed of transmission of the email – this primarily depends on the speed of the modem. For instance, an image of about 500 kbytes will take about two minutes with a 56.6kbps modem.

Sample referrals

A paediatric cardiology referral from Gibraltar

The following referral, with accompanying ECG, was sent on 15 June 2000 from the Royal Naval Hospital Gibraltar to the on-call physician at Haslar. The reader is invited to form his own opinion based on the clinical history and sample ECG.

Figure 8: tmed med GIB053, referral letter



Urgent Attention On call Physician

RNH
Gibraltar
15/06/00

Dear Colleague

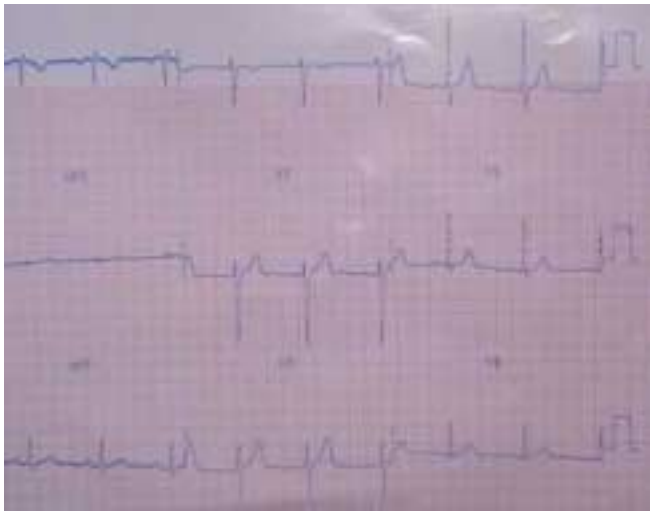
I would be most appreciative if you could kindly review this EKG of a 14 yr old boy who was referred to us at RNH with a history of chest pain which started yesterday morning and continues. The GP was concerned at high take off of the ST segment.

The pain radiates across his chest and is worsened by movement. Past history is negative. Apart from analgesics for the pain – ineffective he is not on any medication. He has no known allergies.

On Examination
An afebrile athletic 14 yr old in no distress Wt 65Kg
Mild tenderness on palpation in right infraclavicular area
Chest Clear
CVS BP 130/70 Pulse 75 regular
Heart Sounds normal
Abdomen NAD

He is an accomplished cricketer and I felt that his symptoms might be related to bowling.

Figure 9: One of several photos of an ECG sent from RNH Gibraltar on 15 June 2000



A referral from South Georgia

In November 1998 a mountaineer in South Georgia (a mountainous island in the South Atlantic, 8500 miles from the UK, with no airstrip, and two days' sailing distance from the nearest land) fell into a crevasse, breaking his ankle. He limped for 14 hours to reach the lone military general practitioner on the island, who xrayed his ankle and confirmed the fracture.

Figure 10: tmed orth SGE001 – South Georgia, November 1998

The next ship was not due to call into the island for a fortnight, but could be diverted to call sooner if really necessary. The doctor therefore used the DMS Telemedicine system, photographing the xray, and sending the digital images by email to Haslar. A senior orthopaedic surgeon reviewed the images and replied that the ankle definitely needed internal fixation, and that this ought to be performed within 14 days or so (making allowance for the distance the patient had to travel). This reply was received in South Georgia within 24 hours of the patient breaking his ankle. It initiated an aeromedical and shipborne evacuation chain, resulting in the patient receiving surgery at Haslar within 11 days.

The Three Georgias link

Since 1992, following the end of the Cold War, Emory University (in Atlanta City, Georgia USA) has participated in a health information exchange and development programme with Tbilisi University (Republic of Georgia). In November 1998, the DMS Telemedicine Unit at Haslar, representing South Georgia, began collaborating in telemedicine with Atlanta and Tbilisi, thus forming the Three Georgias link.

Figure 11: The Three Georgias Telemedicine link

A referral from the jungle - use of the three Georgias link

On a Saturday in February 1999, shortly after the setting up of the Three Georgias link, the lone military general practitioner (RAMC doctor, Lt Col Bonnici) in Belize reviewed a thirty year old Belizean working with the British Forces. The patient lived in the jungle, and in the previous two weeks he had developed five large encrusted ulcers on his legs. The general practitioner provisionally diagnosed leishmaniasis, but he was unsure how to confirm the diagnosis. He therefore photographed the lesions and sent a telemedicine referral to Haslar, where it was forwarded to the Professors of Medicine in Emory and Tbilisi.

Figure 12: lesions on inner thigh, tmed derm BEL010, November 1999, prior to treatment

This was the first referral of the Three Georgias link. Emory discussed the case with the Centres for Disease Control and Prevention (also in Atlanta), whilst Tbilisi discussed the case with the local Institute for Tropical Medicine & Parasitology. The specialist diagnosis in each case was that of cutaneous leishmaniasis. The replies (suggesting confirmatory tests and proposed management) were forwarded to the general practitioner in Belize by Tuesday, within 72 hours, and he promptly confirmed the diagnosis and initiated treatment.

Figure 13: healing lesions on thigh, tmed derm BEL010, during treatment

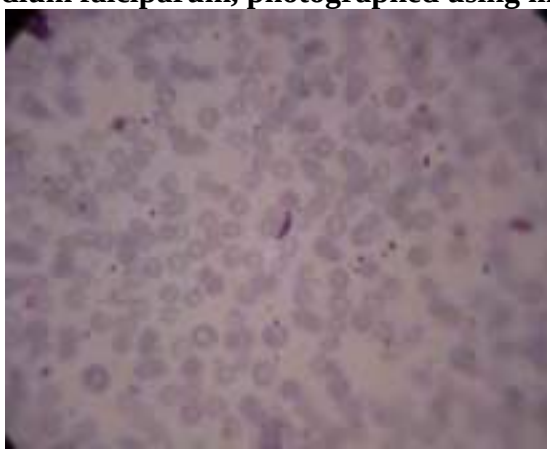
Simple telepathology

SLR-type digital cameras, steadied on a tripod, can be directly focussed down a microscope to take images of abnormal cells. This was done for the first time in Bosnia in February 1998, with consultant haematological opinion thereby being obtained from Haslar on a patient with suspected leukaemia. Since then, the DMS Telemedicine Unit has procured simple adaptors (manufactured by Olympus Microscopes in Prague)[10] to attach these digital cameras to microscopes, thus improving the resolution and ease of taking the images.

Figure 14: Olympus C2500 camera with microscope adaptor, Kosovo, April 2000

British Forces doctors have successfully used these adaptors in Bosnia, Kosovo, and Sierra Leone to photograph blood films, different species of malaria parasites, bacteria (including tubercle bacteria), trypanosomes, stool parasites, and histology specimens.

Figure 15: Plasmodium falciparum, photographed using microscope adaptor



Post-conflict recovery and humanitarian telemedicine

In the direct aftermath of the conflict in Kosovo, a British field hospital was set up in June 1999 outside the capital Pristina. Several severely wounded children and adults

presented to the hospital in search of reconstructive surgery for their disfiguring and disabling wounds. They had been unable to receive such help beforehand because of the destruction of Kosovo's health infrastructure.

One young man in particular, who had been shot in the face three months previously and who had lost his right eye, his nose, and half his right maxilla, presented to this hospital. Digital photographs of his wounds and details of his clinical history were transmitted by email to a maxillofacial reconstructive surgeon in the UK, thereby initiating a Government-funded aeromedical evacuation for him and up to 50 other such wounded patients, for reconstructive surgery in the UK.[8] This patient's story and subsequent progress were documented in the cover story of TIME magazine in March 2000,[11] on the KFOR website in April 2000 (http://kforonline.com/news/reports/nr_15apr00.htm). This humanitarian use of simple store-and-forward telemedicine in a post-conflict recovery role is just as applicable to refugee medicine and other disaster scenarios, and is now being adopted by the Leonard Cheshire Department for Post-Conflict Recovery at University College Hospital London.

A new concept – Telemedicine by medical students

A final year medical student, Simon Irving, of Hope Hospital, Salford, UK, had plans to spend a two months elective period in Gizo Hospital, Gizo, the island next to New Georgia. The Swinfen Charitable Trust therefore decided to take this opportunity to establish a preliminary link with Gizo, and provided Simon with the camera and a tripod. He was also taught how to send telemedicine referrals.

On the 10th March 2000, a 40 year old woman was examined and suspected to have lung carcinoma and bony metastases. A telemedicine referral was sent to Haslar and Emory by the medical student on behalf of the lone doctor in Gizo. A consultant radiological report was despatched from Emory within three hours of the original referral being sent, confirming the clinical suspicion, and the patient was therefore sent to a referral centre for further management.

Global telemedicine outreach – via medical students

The successful establishment in March 2000 of a telemedicine link between Gizo Hospital in the Solomon Islands and The Three Georgias through the active participation of a final year medical student on elective led to the conception of a Global Telemedicine Outreach programme.[12] If each medical school in the Developed World aimed to set up simple telemedicine links between its specialists and hospitals in the Developing World where students go on elective, then there would be a tremendous dissemination of specialist knowledge to isolated patients and their doctors. The students would help transport the donated digital cameras and tripods, they would train the local staff in telemedicine, and then leave a unique legacy behind them in the form of a functioning telemedicine system. I shall leave the reader with this thought in mind – can you, perhaps as a specialist in a University Teaching Hospital, help set up such telemedicine links to places where they are needed most, so that you can help bring specialist knowledge to patients from afar?

Telemedicine – it changes your practice.

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Chris Bowen, Olympus UK Digital Division Manager, very kindly loaned an Olympus C1400XL and an Olympus C2500 digital camera to the author for trial purposes with the Defence Medical Services. Olympus UK also donated six Olympus C1400XL digital cameras to the Swinfen Charitable Trust to help establish telemedicine links with Bangladesh, Nepal and the Solomon Islands. The author is a trustee of The Swinfen Charitable Trust.

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Contact information
http://www.haslib.demon.co.uk

Dr. David Vassallo
LT COL David Vassallo RAMC
Defence Medical Services Telemedicine Unit
Royal Hospital Haslar
Gosport
Hants PO14 2DL
United Kingdom
DJVassallo@aol.com