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Teledermatology: a review

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Summary Teledermatology holds great potential for revolutionizing the delivery of dermatology services, providing equitable service to remote areas and allowing primary care physicians to refer patients to dermatology centres of excellence at a distance. However, before its routine application as a service tool, its reliability, accuracy and cost-effectiveness need to be verified by rigorous evaluation. Teledermatology can be applied in one of two ways: it may be conducted in real-time, utilizing videoconferencing equipment, or by store-and-forward methods, when transmitted digital images or photographs are submitted with a clinical history. While there is a considerable range of reported accuracy and reliability, evidence suggests that teledermatology will become increasingly utilized and incorporated into more conventional dermatology service delivery systems. Studies to date have generally found that real-time dermatology is likely to allow greater clinical information to be obtained from the patient. This may result in fewer patients requiring conventional consultations, but it is generally more time-consuming and costly to the health service provider. It is often favoured by the patient because of the instantaneous nature of the diagnosis and management regimen for the condition, and it has educational value to the primary care physician. Store-and-forward systems of teledermatology often give high levels of diagnostic accuracy, and are cheaper and more convenient for the health care provider, but lack the immediacy of patient contact with the dermatologist, and involve a delay in obtaining the diagnosis and advice on management. It is increasingly likely that teledermatology will prove to be a significant tool in the provision of dermatology services in the future. These services will probably be provided by store-and-forward digital image systems, with real-time videoconferencing being used for case conferences and education. However, much more research is needed into the outcomes and limitations of such a service and its effect on waiting lists, as well as possible cost benefits for patients, primary health care professionals and dermatology departments.

Key words: store-and-forward, teledermatology, videoconferencing

Teledermatology has been defined as the practice of medicine at a distance.[1] Recent years have shown a continual growth in the use of telemedicine, as emerging health and information technology becomes cheaper, as performance increases and as telemedicine becomes more clinically acceptable for both patients and doctors.[2] The introduction of telemedicine as applied to dermatology has, like in other specialties, met with professional resistance. However, patients increasingly express a desire for change in the delivery of health care and the traditional doctor/patient relationship, long regarded as the 'gold standard', is becoming challenged, whereas teledermatology holds promise as an alternative means of delivering health care.[2] This has led to some doctors, especially those with misgivings about technology, to see telemedicine as a threat, and to be concerned that the doctor/patient relationship will be eroded.[2,3]

Teledermatology offers an obvious method of service delivery directed towards improving access and decreasing cost, by eliminating travel for patients, physicians and nurses. Other specialties that have embraced and utilized the advent of telemedicine include radiology,[4,5] psychiatry,[6,7] cardiology,[8] pathology,[9] obstetrics,[10] surgery[11,12] and nursing.[13] At the practical

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level telemedicine has been used to provide medical services at a distance. Examples of telemedicine being utilized at a distance include Moscow providing a telemedicine service to Azerbaijan,[14] the British Armed Forces providing a telemedicine service in Bosnia[15,16] and its utilization in difficult situations such as in prisons,[17] at sea,[18] and from aircraft[19] and moving ambulances.[20]

Increasing interest in teledermatology has come at a time when there is an increased demand for dermatology services. In the U.K. there has been an almost 50% increase in dermatology referrals in the decade between 1981 and 1991. If the National Health Service (NHS) is to live up to its stated aim of achieving a truly equitable service, then research is urgently required into the relationship between need, supply and demand for dermatology services. Such research should be undertaken from the users' perspective.[21] To achieve an equitable service, 'outreach clinics' initially seemed attractive but, to be successful, an estimated fourfold increase in the number of dermatologists would be required.[22] In this respect, however, some teledermatology[23] trials have not shown teleconsultations to be faster or more economical than conventional consultations, although evidence suggests that low-cost store-and-forward systems of teledermatology may reduce waiting times for some patients.[24,25] There is evidence that patients are themselves looking to the internet to seek further information or advice regarding their illness. Increasingly, patients are connecting to databases or e-mailing physicians via the internet for advice.[26] Many patients sending unsolicited e-mails for advice to a dermatology department expressed frustration or lack of trust in their own physician or health care service; some patients were embarrassed or wanted to remain anonymous while still seeking expert advice.[26] Dealing with such unsolicited e-mails poses a number of problems, including privacy, confidentiality, security and medicolegal issues.[26] Furthermore, patients getting advice via the internet may increase their level of anxiety or reach spurious conclusions leading to poor outcome.[27] There is, however, evidence that patients can obtain relevant advice, in a way in which they will understand, by accessing sites such as the patient information leaflets provided by the American Academy of Dermatology (AAD) website.[27] As an indication of the public interest in such sites the AAD website received 800,000 'hits' from approximately 86,000 users in July 1998.[27]

Telemedicine technology

Image transmission

The research and delivery of a teledermatology service has usually been by means of teleconferencing equipment or store-and-forward, computer-based, systems. While live video images can be sent via conventional telephone lines, these are usually slow and poor quality so digital lines are preferred, e.g. Integrated Services Digital Network (ISDN) lines. These lines allow enhanced digital transmission. Furthermore, increasing the number of ISDN lines increases the data-carrying capacity or bandwidth from 128 kbps (one ISDN line) to 256 and 384 kbps (two and three ISDN lines, respectively). By comparison, the average conventional telephone line can transfer 33·6–56 kbps, so motion handling in video pictures is usually poor. By increasing bandwidth using ISDN lines, motion artefacts are reduced.[28] The key question regarding the transmission of digital images for teledermatology is whether still images will suffice or whether real-time video is required. The requirement of bandwidth will be a function of size and resolution of images sent, the turn-around time and the expectation of peak use.[28]

Teleradiology has perhaps led the way in telemedicine because many of the images created are already in a digital form and because images are usually interpreted on their own, without needing to see the patient. In teledermatology, the images transmitted have been in two forms: still images captured by a digital camera or moving images from a video camera.

Videoconferencing equipment

Modern videoconferencing equipment allows real-time consulting between two or more parties. This equipment enables the dermatologist to see the patient through the video link, while the patient has contact with the dermatologist through a small digital camera mounted on the videoconferencing unit (Figs 1 and 2). This allows direct interaction between the dermatologist, the patient and the person conducting the video imaging, usually either a general practitioner (GP) (Fig. 3) or nurse. Loane *et al.*[29] showed that the colour and temporal resolution of live video images could be improved by changing from a hand-held single-chip video camera to a tripod-mounted three-sensor (red, green, blue) chip camera.

Figure 1. Videoconferencing unit in use. A small digital camera, seen mounted on the top of the unit, transmits an image of the dermatologist to the general practitioner and patient's unit.

Still picture-based teledermatology equipment

Digital cameras have become readily available with resolutions ranging from 640 × 480 to 4096 × 2736 pixels and 24-bit colour. In practice, the minimum resolution for dermatology would now be considered to be 1024 × 768 pixels,[30] with resolutions of 1280 × 1024 becoming very affordable. In this context it is useful to know that the resolution of a normal 35-mm slide can be in the order of 4096 × 2736 per frame, which, although now achievable, is prohibitively expensive for normal usage. The other consideration is to decide which form of digital camera to use. Digital cameras, like conventional cameras, come in two main forms. The first, and by far the most common, is the 'point-and-shoot' form, with its single lens and built-in flash. Much less common in digital photography is the single lens reflex camera which, like conventional cameras, has removable lenses and flash, and allows more control over focus, exposures and manual settings. Such cameras are usually some five to 10 times more expensive than the 'point-and-shoot' type. The latter are also smaller and more portable.

Another feature of digital cameras, which allows instant review of pictures taken, is a liquid crystal display. This also allows picture shows to be set up and edited immediately, allowing instant discarding of unsuitable views. Images from digital cameras can be transferred to computer by means of a cable or in some instances via a floppy disk.

Manipulation of digital images is easy and can be carried out using programs such as Adobe Photoshop® or other widely available programs. This allows alteration in colour and light balance, thereby improving image quality for educational purposes. This, however, could be used to undertake falsification of photographs[31,32] for publication, litigation or

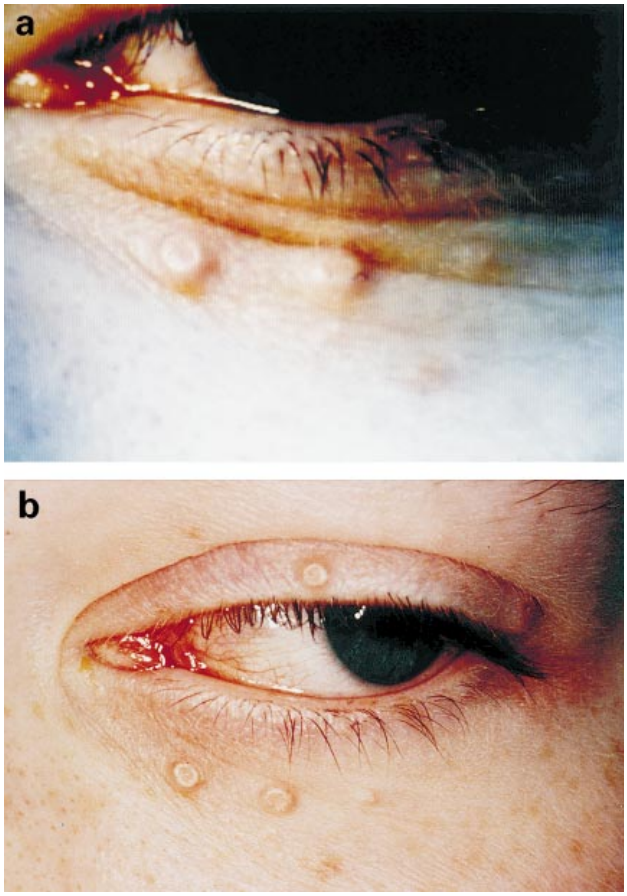

Figure 2. Comparison of (a) a 'frozen' image on a videoconferencing unit, with (b) that taken at the face-to-face consultation.[41]

Figure 3. General practitioner using a JVC KY-F55B camcorder with motorized zoom lens.

commercial reasons, and has to be guarded against by editors of journals. For example, the American Society for Dermatological Surgery regards the manipulation of patient images to deceive an audience or the publication of such as unethical and requires a statement that such alteration has not taken place.[33]

Information display

Digital images are usually displayed on digital monitors; the main parameter to affect the quality of display is the number of pixels and the number of bytes per pixel. In teleradiology a 1760 × 2140 pixel display, or greater, has been used. Videoconferencing systems and computer display systems can, to some degree, compensate for inadequate contrast resolution by using a scroll and zoom on the image and the ability to adjust display characteristics. Ideally, computers need to be capable of dealing with large image-based files, and typically need to be Pentium II or greater, have 128 MB of RAM, and a large hard disk, usually greater than 10 MB (or a removable storage system) and a large (19-inch) high-resolution monitor.

Digital storage systems

Photographic films have served as a storage and display medium for over 100 years. The current expansion in digitally acquired radiology images has required increased capacity in digital storage systems and led to the development of picture archiving and communication systems (PACS).[34] For PACS to work, pictures must be captured, stored, retrieved and displayed when required. Software should also allow for patient details, a short case history and other relevant data to be filed in an ordered fashion, with the digital image. One problem is that digital images are often very large. This requires compression of the data files, resulting in some loss of picture detail. For example, if a digital image is produced with resolution similar to that of a normal photograph, then a file of some 34 MB may be produced, which is equivalent to some 24 floppy disks. In practice the only way to deal with this problem is to select much less resolution coupled with compression, although both of these lead to poorer picture quality. Ideally, images that are to be held in this way should be duplicated, backed up and stored off-site.[35–38] For smaller systems, suitable storage back-ups can be made to removable media storage systems such as zip drives, rewriteable CDs or tape drives.

Teledermatology studies

Videoconferencing in teledermatology

Both videoconferencing and store-and-forward teledermatology enable GPs to refer patients to a dermatologist of their choice at a considerable distance. The largest studies carried out into the use of videoconferencing equipment to provide diagnosis and clinical management of patients with dermatological conditions have been carried out using real-time videoconferencing. A summary of the pros and cons of teledermatology is shown in Table 1.

Several studies have examined the diagnostic accuracy of videoconferencing equipment; their results are summarized in Table 2. Diagnostic accuracy ranges from 54% to 80% total agreement between conventional and face-to-face consultations.[39–44] This diagnostic agreement, however, assumes that face-to-face consultations, usually taken as the 'gold standard' of diagnosis, are always correct. Table 3 and Figures 4–6 show the diagnostic and treatment agreement for one such study, and the range of conditions diagnosed.[41] It was generally found in the studies that about 50% of dermatology could be adequately and safely managed by means of videoconferencing equipment and could significantly reduce patients having to come to hospital, for example, for management plans, where the diagnosis was not in question, or for reviews.

From the users' points of view positive aspects of videoconferencing include a high degree of patient and physician satisfaction,[41,42,45,46] although physicians tended to express a greater confidence about their face-to-face diagnoses (98%) than their videoconferencing diagnosis (85%).[43] A minority of patients preferred direct contact with the dermatologist. Dermatologists expressed some frustration in technical

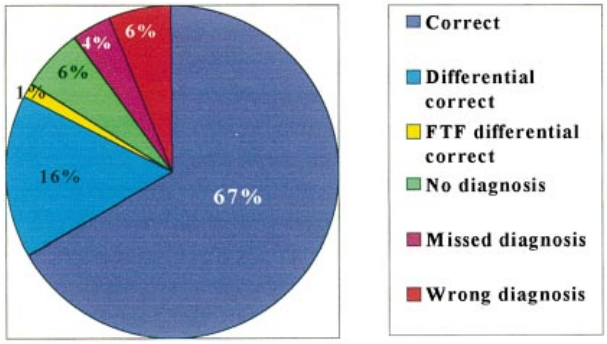

Figure 4. Diagnostic accuracy of teleconsultation compared with face-to-face (FTF) consultation.[41]

Table 1. Summary of advantages and disadvantages of teledermatology

	For	Against
Teledermatology in general	Management plans as good as those in conventional consultation	Some patients will always require outpatient appointment
	Equitable service provided especially to remote areas	Tendency to focus on presenting lesion instead of patient as a whole
	GPs can refer to centre of their choice	Uncertainty/incorrect diagnosis
	Generally high acceptability to patients	Minority of patients who prefer to see dermatologist
	Decreases costs to patients, e.g. travel and time off work	Should be only one facet of dermatology service and not a 'quick fix' for deficiencies of NHS
	Could save dermatologist time doing frequent remote clinics	Professional resistance to change
	Equipment costs steadily decreasing with increasing image quality	Security, privacy and legal liability issues
	Could result in shorter waiting lists for conventional consultation	
Live videoconferencing	Interactive consultation enables three-way discussion between patient, GP and dermatologist	Not cost-effective over short distance
	Diagnostic and management accuracy effective and more effective than store-and-forward	Less favoured by elderly, shy or young patients
	Greater clinical information available compared with store-and-forward techniques	Poorer picture quality when compared with store-and-forward
	Educational value to GP	Difficulty of synchronizing patient, GP and dermatologist to be present at same time
	Useful for monitoring treatments at a distance, e.g. phototherapy	Equipment failure leads to wasting expensive medical time
	Cost-effective over long distance and/or using specialist nurse to take images	Videoconferencing is as time-consuming as a conventional consultation
Store-and-forward	Cheap and effective way of giving diagnosis/ management plans	Dermatologists find it repetitive and boring
	Accuracy shown to be adequate	Unable to get information directly from GP and patient
	Good triage tool for those who may need hospital-based appointment or treatment	Loss of rapport with patient
	Large number of images can be reviewed at a time convenient to dermatologist	Loss of educational component for GPs
	May be faster than conventional referral	Images may be misappropriated to another patient

GP, general practitioner; NHS, National Health Service.

problems regarding the establishment and maintaining of the audio and video connections.[43] However, the immediacy of the interaction meant that a reasonable management plan could be instituted quickly for the patient[43] in some 89% of cases. The discussion was often referred to as educational by GPs.[41]

It is widely acknowledged in these studies that, irrespective of telemedicine, there will be some patients who will require an outpatient hospital appointment.

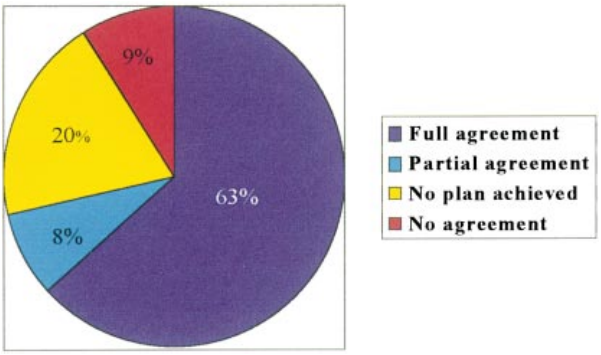

Figure 5. Extent of agreement between management plans achieved by teleconsultation and at face-to-face consultation.[41]

Table 2. Accuracy of major teleconferencing studies

Study	No. of patients and lesions	Equipment type	Diagnostic agreement
Oakley *et al.*[39]	104 patients 135 lesions	Vtel 127 videoconferencing	75%
Gilmour *et al.*[40]	126 patients 155 lesions	VC7000 with ISDN 2	54%
Loane *et al.*[41]	351 patients 427 diagnoses	VC7000 with ISDN 2	67%
Lesher *et al.*[42]	60 patients 68 lesions	Panasonic 3-chip with T1 link	78%
Lowitt *et al.*[43]	139 patients	JVC 3-chip	80%
Phillips *et al.*[44]	51 patients 107 problems	Panasonic 3-chip and Canon VC-C1	59%

ISDN, Integrated Services Digital Network.

Table 3. Diagnostic accuracy of videoconferencing consultation compared with face-to-face consultation. From study[41] with permission of the publisher and authors

Concordance	*n* (%)
Correct diagnosis	285 (67%)
Differential correlation	67 (16%)
Face-to-face differential	6 (1%)
No diagnosis	26 (6%)
Missed diagnosis	17 (4%)
Wrong diagnosis	26 (6%)
Total diagnoses	427

In addition, when performing teledermatology there is a tendency to focus attention on the presenting skin condition alone, rather than having the opportunity to screen the 'whole skin' for other relevant lesions.[40] Further difficulties can be encountered with the shy or retiring patient who does not wish to be 'on camera' or in young infants who tend to be mobile, making it difficult to transmit accurate pictures to the dermatologist.[29] The incidence of wrong diagnoses in videoconferencing studies was generally about 4%.[39,40] This may have been partly due to picture quality, which may improve with improvements in technology. However, evidence suggests[43] that dermatologists making diagnosis over video links tend to be conscious of the limitations of the equipment. They are more likely to express uncertainty through a differential diagnosis or no diagnosis, and consequently request a face-to-face consultation to clarify the diagnosis.

While less easy to evaluate in scientific terms, a few other studies are interesting and give an insight into how teledermatology can directly benefit patients. Teledermatology as applied to the Highlands of Scotland[47] showed a high degree of patient and GP satisfaction with the teledermatology consultation. Patients on remote islands, served by dermatology clinics every 2 months, found that they received rapid opinions and initiation of treatment. Here teledermatology acted as a filter, reducing the number of patients needing to be seen in a face-to-face consultation, and keeping the waiting lists down. The main conclusions from this pilot project were that the link could be used to screen patients who needed to be seen at a normal clinic and that the project itself had definite educational value for the GP. A similar situation pertained in northern Finland where, within the Arctic Circle, teledermatology consultations were made from the main centre at Tromso to a remote area in Kirkenes some 800 km away.[48] Again, the GP and specialist felt that they could work together to arrive at a diagnosis and to recommend appropriate treatment. Particular advantages were seen in monitoring patients receiving phototherapy locally on a daily basis. The dermatologists, however, felt that they had to work harder to develop a rapport with the patient. Recently, this group[49] has introduced teledermatology implemented by sending still images via e-mail, so that the diagnosis can be made during 'spare time' later in the day and is independent of time. However, the technique is seen as losing rapport between the patient, specialist and GP.

Other studies which deserve mention and give insights into possible uses of videoconferencing teledermatology include those by Norton *et al.*[17] at the dermatology service at the Tripler Army Medical Center, Honolulu, Hawaii. The centre provides teledermatology consultations to the Republic of Marshall Islands, comprising some 60 atolls (low coral islands) in the centre of the Pacific basin.[17] Similarly, a telemedicine programme was introduced into the North Carolina prison system[17] where it was felt that there could be a reduction in the enormous cost and difficulty of transporting shackled patients together with armed escorts on a 1-day round visit to hospital.

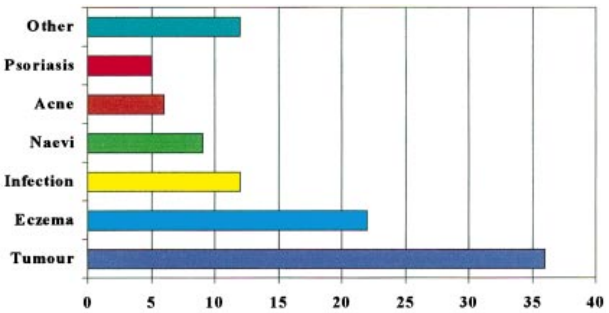

Figure 6. The range of conditions diagnosed at the face-to-face consultation.[41]

Store-and-forward systems

It is a common view that the future of teledermatology will probably advance most in the area of store-and-forward techniques. The advantage of these is that they avoid the logistical difficulties of setting up videoconferencing consultations, and allow the dermatologist to evaluate large numbers of captured images quickly (Fig. 7).

Most of the studies to date have, understandably, used lower-resolution cameras. Using a simple digital camera with a close-up lens (resolution 765 × 504 pixels) and a multimedia notebook computer, Lyon and Harrison[50]

Figure 7. Image sent via e-mail: by general practitioner using 1600 × 1200 pixel camera, as seen on dermatologist's screen, with increasing zoom (a, 33%; b, 100%) obtained using computer software.

evaluated presenting lesions of 100 unselected consecutive new patients. Digital photographs were taken by a doctor and, together with a one-sentence summary of the patient's symptoms, were assessed by a consultant dermatologist. The 'gold standard' diagnosis was by a face-to-face clinical review of every patient, with a confirmatory biopsy in 81 patients. The consultant's initial telemedicine diagnosis and final diagnosis led to approximately 95% agreement. The authors concluded that this system provided an effective low-cost primary diagnostic facility. This group also examined conventional photographic images taken by a medical photographer seen together with the referral letter, and reached a preliminary diagnostic accuracy of 71% (as compared with 49% by the referring GPs).[25] They have now presented their 5-year experience with 1441 patients. This work describes a clinical service that was provided on the basis of conventional photographs and, at a later stage, digital images in store-and-forward systems, in managing dermatological patients with skin tumours. A mean accuracy of 84% was achieved, with excellent prediction of treatment (up to 96%; sensitivity 87%, specificity 77%).[51] In two further small studies on 29 patients using still images from video images sent with patient history[46] and 12 patients with digital camera images,[52] there was 88% and 63% agreement on diagnosis, and 90% and 96% agreement on management, respectively.

Whited *et al.*[53] studied 168 skin images from 129 patients, captured using a digital camera capable of taking images of resolution 1280 × 1000 pixels. Two clinic-based dermatologists and three consultant dermatologists independently assessed the patients and the digital images. The diagnostic accuracy between the clinic-based and image-based dermatologists in this study was 68%, while the agreement on the single most likely diagnosis for the clinic-based dermatologists was 63%. For the clinic-based dermatologists, diagnostic agreement went up from 63% to 92% when the ratings included the most likely differential diagnosis.[53] The authors of this study concluded that digital image consultations and clinic-based examinations were of comparable diagnostic reliability. In another study[54] using consumer-grade digital camera systems, concordance between face-to-face dermatologists and teledermatologists using store-and-forward images was high, ranging from 81% to 89% for three dermatologists. When above-average image quality cases were analysed separately, diagnostic agreement went up to 84–98%. These authors concluded that existing digital imaging systems could be used to construct an accurate store-and-forward teledermatology system, and suggested that additional investigation of the accuracy of diagnosis of benign tumours should be undertaken. Such a preliminary study has now been undertaken comparing face-to-face and digital images. A preliminary analysis revealed clinical agreement between the teledermatologist and face-to-face dermatologist in 93% of cases when each was asked to assess if a tumour were benign or malignant, and the authors concluded that remote management of skin tumours using low-cost equipment was possible for the NHS.[55] Other smaller and less detailed studies similarly suggest that a variety of digital store-and-forward systems can work[56–59] and can provide cost-effective teledermatology to rural patients.[56,59]

One study in 194 patients used video store-and-forward systems in an outpatient clinic.[60] The patients

were initially seen by a consultant dermatologist and then by a nurse who used a hand-held camcorder to provide video images of 768 × 288 pixels. These images were then minimally compressed and stored. After an interval of some 13 months, the consultant dermatologists reviewed the images separately from the patient histories. In this prospective study there were high levels (81%) of inter- and intraobserver agreement between the diagnoses of dermatologists using the system and those who saw the patients. Consultants reviewing the images recommended fewer patients to be called for urgent appointments (33% compared with 45%). Had the system been in active use, 19% of patients conventionally assigned non-urgent appointments would have been seen more urgently after review of the images, and 32% of patients would not have needed to be seen. However, in 15% of the cases (5% of the total) the diagnosis differed significantly from that provided by the consultant who saw the patient in face-to-face consultation. The consultants carrying out the review of the images found it time-consuming, tedious and unsatisfying. It was concluded that a lot of work is required before a reliable easy-to-use system can be introduced. This study showed store-and-forward technology to be no better than using a medical photographer to submit photographs at the time of referral and using the resulting images to triage the urgency of referrals.[60]

Much concern has been voiced regarding the diagnostic accuracy of teledermatology for pigmented skin tumours. In one study, 31 clinically difficult melanocytic lesions, comprising both dysplastic naevi ($n = 22$) and early melanomas ($n = 9$) were chosen from a pre-existing database. Both conventional 35-mm transparency slides and dermatoscopic features were prepared, and four dermatologists independently viewed compressed digitized images sent via the internet. There was a high degree of concordance both in clinical diagnosis and dermatoscopic diagnosis of dysplastic naevi and early melanoma (87%, concordance 0·735, and 92%, concordance 0·817, respectively).[61] The authors compared their results with studies that showed the clinical accuracy for dermatologists in the diagnosis of melanoma to be about 65%. Their data suggested that internet transmission of digitized images of malignant melanomas and dysplastic naevi, both clinically and dermatoscopically, retained sufficient information for diagnostic purposes and for the creation of an international dermatoscopic diagnostic network for pigmented cutaneous lesions. A similar study on the diagnostic accuracy of teledermatology for pigmented lesions compared face-to-face evaluation of pigmented lesions, mostly melanocytic in nature, with e-mailed clinical and dermatoscopic details of 43 lesions.[62] The teleconsultations showed a similar degree of diagnostic accuracy to face-to-face consultations, suggesting that teleconsultation would be a reasonable diagnostic tool when expert face-to-face diagnostic services were not locally available.

There are now emerging various relatively small teledermatology health care delivery systems. One consultant dermatologist has left the NHS and developed teledermatology services commercially,[63] and other small systems are being evaluated.[24,64]

Patient satisfaction

High patient satisfaction with teledermatology, especially of the videoconferencing type, appears to be a recurring theme throughout a number of studies.[43–45] Most patients are pleased that their condition is being diagnosed and treated as soon as possible and almost 90%[45] agreed that a teleconsultation saves time and expenditure in travelling to hospital. In general, younger patients are more accepting of the new technology than the elderly.[42] Patients who probably are less tolerant or do not do so well include the elderly, small infants, those who are shy and embarrassed at being videoed, and those with genital rashes.[48]

Doctor satisfaction

GPs seem to report greater satisfaction with teledermatology than do their dermatologist colleagues.[23,44,57] In the U.K., GPs reported very high levels of satisfaction (> 80%) with real-time consultation and stated that 75% of teleconsultations were of educational benefit.[40] In a larger study, GPs estimated the knowledge transfer effect of real-time consultation to be the equivalent of 6 days training per year.[23] By comparison, dermatologists' criticisms were usually concerned with picture quality, lack of rapport with patients, inability to palpate lesions or carry out diagnostic tests and that the systems were time-consuming and unsatisfying.[29,44,57] In a study using high bandwidth videoconferencing, where image quality is likely to have been better, dermatologists were highly satisfied with the interpersonal aspects of videoconsultations and tended to be surer of their diagnoses.[43]

Cost-effectiveness

With the ever-increasing cost of health care provision, some have looked to teledermatology to reduce waiting lists and costs. In addition, teledermatology systems are likely only to be used by GPs[65] and dermatologists[57] if they are easy to use, efficient and reliable. Many studies have shown that interactive real-time teleconsultations take longer than conventional consultations.[40,41,57,66]

Recent studies[23,66,67] comparing the cost-effectiveness of real-time teledermatology with conventional hospital outpatient appointments showed advantages for the patients in terms of time off work, loss of income to the patient or productivity by the employer as well as time and expense of travelling to hospital. Real-time teledermatology was less advantageous to the health care system, being more expensive (£132·10 vs. £48·73) and time-consuming for the GP and dermatologist.[23] However, with more efficient use of the teledermatology equipment and increased distance of travel for the patients, real-time teledermatology could become cost-effective.[23]

In the opinion of several authors,[24,25] store-and-forward teledermatology could be more cost-effective than real-time consultation due to its speed and convenience. In a recent cost-effectiveness study comparing real-time videoconferencing with a conventional referral letter to a hospital department accompanied by a Polaroid photograph, the net social cost of real-time consultation was significantly greater than that of simply submitting a photograph (£132·10 vs. £26·90).[67] It was concluded that the store-and-forward photographic consultation was much more economical, but less clinically effective, than real-time videoconferencing consultation because, in the latter case, the dermatologist could extract clinically useful information through talking to the patient.[67] This study reported, like previous studies,[49,50,57] that submission of photographs might be an economical triage tool in prioritizing patient appointments. Using store-and-forward methodology, Burgiss *et al.*[59] showed that teledermatology can decrease the cost of care of the diagnosed dermatological condition when treating a patient in a rural U.S. community, and teledermatology has also been shown to be cost-effective in northern Norway.[58]

Other preliminary cost studies into the use of store-and-forward teledermatology seem to indicate that such systems, using consumer-grade digital cameras, are likely to be both accurate in diagnosis and a cost-effective method of delivering teledermatology.[53,56,58]

Security and legal issues

As the capture, transmission and storage of patient record information shifts from a paper base to a digital one, new security concerns arise. The encryption of information sent via the World Wide Web regarding patients is considered essential to maintain the privacy and confidentiality of medical records.[68] While both common and statute law can prevent the unauthorized interception and disclosure of medical data and protect patients' rights within the U.K., the sending of teledermatology information across borders presents real dangers for maintaining confidentiality. Harmonization of laws under the European Union, together with the increasing right of the citizen to obtain medical services in other parts of the European Union,[69] will undoubtedly bring more comprehensive regulations.[69] Breaches in the confidentiality of sensitive medical information could cause distrust in telemedicine generally.[70] Patients should, at the very least, know what information is being collected about them, how it is going to be transmitted, to whom, and how it is going to be used.[71] It would be considered good practice to obtain written consent for storing and transmission of patient information, and certainly this is mandatory when the data collected are to be used for research.[72] When records are used for administration, audit or performance review, care must be taken to remove an individual's identity.[72] Care must also be taken to ensure that the information collected by the physician or institution is effectively protected against improper disclosure at the time of disposal, storage, transmission or receipt.[70,72,73] Furthermore, unauthorized interception and thereby modification of telemedicine transmissions could bring potential harm to the patient. While the protection of data from unauthorized users is required, it is equally the legal right of the individual to access data and to request rectification where it is found to be inaccurate. Independent supervisory authorities will be established in member states of the European Union to supervise the application of these provisions.[69] Regular audits of security procedures should be carried out, and suitable encryption may be used where regular monitoring of security is not considered feasible.[70]

A physician could not escape liability on the grounds that, if something went wrong, it was 'the computer's fault'. With the increasing use of emerging technologies, liability may then be shared between those involved in the development of a telemedicine system and the system subscribers, such as health care providers in

hospitals, GPs, or those in remote clinics, on board ships, aircraft, etc. The physician acting as the 'data controller' is likely to be the person held responsible should confidentiality break down. However, as electronic transmission of medical records takes place across political boundaries and between institutions it may become increasingly difficult to ascertain who is responsible for protecting what data at each stage. Medicolegal implications of telemedicine are ultimately probably going to be decided by the courts.[74] The principles likely to apply in conventional face-to-face doctor–patient interactions are equally valid in any other form of consultation, be it by telephone, telemedicine, photographic image or letter. Where two doctors discuss the management of a patient at a distance, for example when a GP telephones a specialist, the GP is responsible for giving accurate information to the specialist, who in turn is responsible for taking the appropriate history and giving sound advice. The same principles are likely to apply to all forms of teledermatology. It is absolutely essential that teledermatology, before becoming widely implemented, is rigorously evaluated, with a firm basis in peer-reviewed literature, if it is to withstand medicolegal challenge.

Clinical pathological conferences

Given the advances in videoconferencing equipment, it is surprising that more conferences are not conducted by means of telemedicine equipment. In Japan, clinical histories, images and histopathology have recently been put on the internet[75] and can be accessed by other dermatologists using a password. This information can then be opened and edited by other dermatologists, enabling multiple opinions. An Internet World Congress on biomedical science held in 1994 demonstrated the practical use of images and data. A dermatologist mailing list, initiated in 1995 with 180 members, had achieved 1800 postings by February 1999. The online clinicopathological conference was felt in Japan to be really useful to dermatologists. However, as the data were only protected by a password distributed through the mailing list it is highly unlikely that such a level of security would be deemed sufficient in a European or U.S. court.

Conclusions

Teledermatology holds promise as an alternative means of delivering health care. Equipment is becoming financially accessible, easier to use and more widely available for health care workers and patients alike. Digital imaging, in its many forms, together with the World Wide Web, is likely to transform patient–doctor interactions in the future, and we will increasingly need to embrace this technology if we are to meet patient and government expectations. Teledermatology has been advocated as a mode of health care delivery that may diminish inequalities in the provision of an overstretched service and improve access to dermatological care, especially for remote or isolated communities. While we know a great deal about bandwidths and resolution, we know less about the human dimensions that will be needed if teledermatology is going to make a significant impact on the delivery of effective health care.[76] To date, trials in teledermatology have been modest in size, and deficiencies still remain as to what types of consultations will be most suitable for this mode of health care delivery. Further research into the outcomes and limitations of teledermatology is required if purchasers of health care are to make informed decisions about the appropriate use of teledermatology.

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