PHOTOGRAPHIC DERMATOLOGICAL IMAGING AND TELEMEDICINE

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INTRODUCTION

Light and colour were attracting the attention of philosophers, artists and scientists during the ages of reason and enlightenment. David Brewster, active in the formation of the British Association for the Advancement of Science, described "the power of bringing the remotest objects within the very grasp of the observer". Although photography was, and still is an art form, there are many technical applications in science, and, furthermore, it has established a significant rôle in medicine.

Skin cancer is an enduring national concern, with the Morecambe Bay area having one of the highest incidences of the problem in the north west of the country. The diagnosis of skin cancer, and other tumours of the skin, uses traditional methods, which often rely on simple observation and draw heavily on doctors' experience with different skin problems. With the increasing incidence of skin cancer and increased public awareness of the problem, screening of the skin can be a very important health measure, particularly since early diagnosis is often followed by cure.

Working in a unit with an active interest in the treatment of skin cancer, and aware of nationwide problems with dermatology waiting lists (not only for problems related to skin cancer, but also for dermatological problems in general), we have examined ways of enhancing access to dermatological expertise in the Morecambe Bay area. Although photography has been used educationally in medicine for many years, the use of photographic imaging for screening has only recently been addressed. The use of photographic images for screening dermatological problems in primary medical care has already been described and we have examined the introduction of a photographic service to enhance screening of skin problems, and also to help in waiting list management.

One way of improving dermatological management is to increase dermatological experience in primary care, but this may take time and it is recognised that the diagnostic accuracy concerning dermatological problems of primary care physicians may only be 50% at best, especially when dealing with pigmented skin lesions. It has been shown, however, that the viewing of dermatological images, rather than direct skin assessment, can achieve diagnoses with a high degree of accuracy, and the patient's problem is then brought directly to the specialist rather than indirectly via a primary care doctor. Better access to dermatological expertise can improve diagnosis and, thereby, management. Furthermore, we have previously shown that examining conventional photographic images of dermatological lesions can achieve a similar degree of diagnostic accuracy to that achieved clinically during standard outpatient consultations.

We have investigated telemedicine as a method of management of dermatological problems.

TELEMEDICINE

Telemedicine can be defined as the practice of medicine at a distance. More specifically, however, it is the use of electronic equipment or telecommunication techniques to facilitate medical information transfer from one site to another. Information can be audible (voice, eg telephone) or visual. Visual information can be written (eg case history) or pictorial (eg radiography, electrocardiography or dermatological images). The clinical applications of telemedicine include diagnosis, assessment, monitoring, treatment/management interaction and education. In the Morecambe Bay area the specialities of cardiology, radiology, dermatology and psychiatry have all been examining the use of telemedicine which may have beneficial applications (Table 1).

A & E/trauma
anaesthetics
cardiology
dermatology
intensive care
neurosurgery
ophthalmology
pathology
psychiatry
radiology

Table 1 Specialities suitable for telemedicine

In many clinical areas of medicine and in many parts of the world, telemedicine has been evaluated and introduced since it can bridge gaps in healthcare (between rich and poor nations) and equalise medical access where local geography may result in a relative underprovision. Furthermore, telemedicine can improve the availability of information and can be used in specialities where there may be too few specialists to provide care. Compared with some other nations, Britain has a relative underprovision of dermatologists. Telemedicine could be utilised to help with waiting list management and to enhance skin screening for certain dermatological problems.

A dichotomy exists in the field of telemedicine between live consultations carried out in real time (videoconferencing) and the transmission of data carried out subsequent to its acquisition (store-and-forward telemedicine). Although it is possible to view still images in real time, they are usually managed via store-and-forward systems (as in the case of teledermatology).

Videoconferencing can be used in a number of specialities and usually involves the use of computer equipment to enable interactive discussions or consultations to take place between individuals on different sites. Visual information (moving or still images) or data in the form of text or voice is transmitted electronically, usually down telephone lines. ISDN (integrated system digital network) is a digital network enabling faster data transmission than the standard telephone line. The band width, and hence the amount of data and quality of image transmission, depends on the number of lines which will give rise to a faster speed of transmission. ISDN at 128 Kbyte/s (ISDN2) is slower than and inferior in quality to ISDN6 (584Kbyte/s) but may be suitable for many telemedicine applications. When dealing with images for diagnostic purposes, however, the wider band width and high speeds may be necessary to achieve high resolution.

Fig. 1 Equipment to enable videoconferencing (utilising "live" and interactive rather than store-and-forward transmission)

In the Morecambe Bay area there is now an ISDN-based videoconferencing system which has been established primarily for nurse education, but this is also suitable for medical education and with a little adaptation would be suitable for large audience participation. Videoconferencing has enormous potential for medical education to improve information access to geographically diverse populations, and has been introduced in many parts of the world. In dermatology, videoconferencing holds more potential for the diagnosis and management of rashes than tumours, as patient history is often of greater importance in these cases. But it is in specialities such as psychiatry that videoconferencing may have the greatest potential. It has been demonstrated that some patients may prefer consultation via videoconferencing (with the anonymity of the camera) to a live or face-to-face consultation. Some other dermatological centres have been investigating videoconferencing and its diagnostic potential in dermatology; our interest has focused primarily on still imaging and photographic methods of enabling diagnosis at a distance.

In the Morecambe Bay area the population is widely distributed. The population is concentrated in the three major towns of Kendal, Lancaster and Barrow. There is also a large rural population with people located in many small villages spread over a large area. Consequently, communication is often not ideal and there exists much potential for poor access to centralised medical services. The population of approximately 300,000 is served by two dermatology consultants based at Lancaster (main centre with inpatient facilities), Kendal (outpatient facilities) and Barrow (outpatient facilities). Increasing referrals for dermatological advice and a local high incidence of skin cancer have led to an examination of the use of telemedicine to improve dermatology at the interface of primary and secondary care.

RESEARCH WORK

Our research began with the intention of developing a digital, ISDN-based system within the Morecambe Bay area. Although other workers have examined video conferencing, we have focused primarily on a still image, store-and-forward system. Videoconferencing has some advantages over still imaging in some areas (such as the potential for real time interaction) but such systems also have inherent disadvantages. On the whole, these problems fall into two categories; technical (problems associated with poor image quality) and practical (problems associated with the time required for real time consultations, as well as the lack of opportunity for image manipulation and artificial intelligence-aided diagnosis). Still image store-and-forward systems, on the other hand, are not subject to these disadvantages.

As a prelude to a digital system, we introduced a pilot system, based on conventional photography, for patients with tumour-related skin problems. Because dermatology is a visual subject and image quality and definition are important for telemedicine applications, it was relevant to examine links between our own project in telemedicine and dermatological illustration.

HISTORY OF DIGITAL PHOTOGRAPHY

Although photography was developed over 100 years ago, digital photography is a recent innovation and a large number of digital cameras is now available. Digital photography uses a CCD (chargecoupled device) which is the equivalent of a standard photographic film in the focal plane of the camera. Light falling on the CCD enables the computer to form an image which can be seen on the computer screen or printed out as a hard copy to give the equivalent of the photographic print. A pixel is a picture element and the greater the number of pixels, the greater the picture definition. A 35mm high definition slide film picture is approximately equal to 18 million pixels and high quality digital cameras are now being produced with an image potential approaching the conventional photograph.

We have had experience with the Kodak DCS (digital camera system) which was introduced in 1991, and is based on the Nikon F3 camera body. In particular, we have used the Kodak DCS200 and DCS 420 and it is evident that this equipment can produce high quality images of skin lesions which are suitable for telemedicine. Furthermore, other

workers comparing analyses of digital images with diagnosis from standard photographic images showed no significant differences in diagnostic potential between the two methods. On this evidence, it appears that image definition is not necessarily critical for telemedicine applications when dealing with images at high resolution. This provides a stark comparison to early pictorial dermatological images, whose diagnostic efficacy was hampered by 'artistic interpretation'. Since these improved images are now available, it is important that the effects of image quality on diagnosis are carefully analysed, with respect to the future potential of the implementation of digital image telemedicine systems in clinical service.

Fig. 2 A digital image of a benign but pigmented skin tumour. The differential diagnosis is compound papilloma with junctional activity, moderate or severe (most likely diagnosis), but melanoma would need exclusion by histology, therefore removal of the lesion would be indicated as soon as possible to enable histological examination.

DERMATOLOGICAL DIAGNOSIS UTILISING CONVENTIONAL PHOTOGRAPHY: A PRELUDE TO DIGITAL IMAGE INTERPRETATION

Important questions can be answered, for example "what is the diagnostic accuracy for dermatological diagnosis through images?" and "do patients support the introduction of telemedicine or are there any problems?"

If conventional high definition photographic images can be used to achieve good diagnostic accuracy (similar to that achieved in standard clinics) then, rather than have a patient always attending clinics, one can use photographs to help in patient management by introducing digital technology and the electronic transfer of information.

During 1996, we undertook a study in which dermatologists examined high definition standard photographic images and compared the diagnostic accuracy of the images with the final histological diagnosis. One hundred and thirty-seven patients attending the Morecambe dermatology department had high quality photographic images taken of a variety of dermatological lesions, utilising a Nikon F1 135mm camera with a 105mm F4 micro nikor

lens, giving a final print magnification of 1.5 times. Patients were randomly selected from those attending clinics over a six-month period. There were 59 males and 78 females, age range nine months to 92 years (mean 56.4 years). The patients were referred from 25 general practices in the Lancaster, Kendal and Morecambe areas. Before being seen by the consultant dermatologist, the medical photographer obtained conventional photographic images of patients' problems (primarily tumours) and completed data specifying the tumour site and size, general practitioner (GP) diagnosis (as indicated on the hospital referral form), and additional information relating to the nature of the lesion. The photographic images were seen by the consultant dermatologist prior to the patients being seen in clinic. Images were seen initially without clinical information, then later with clinical information supplied by the medical photographer. Photographic diagnosis was compared with the GP diagnosis and then, later, when the patient was seen in the clinic, final diagnosis was compared with photographic diagnosis, usually after histological assessment following tumour removal. The initial GP diagnosis only agreed with final histological diagnosis in 51% of patients, consistent with other studies. The photographic diagnosis determined by the consultant dermatologist, however, agreed with the final histological diagnosis in 84% of cases. At the same time, a questionnaire in 100 patients indicated that at least 95% of patients would be satisfied having dermatological problems assessed through images as an alternative to attending hospital clinics.

DERMATOLOGICAL MANAGEMENT USING PHOTOGRAPHIC IMAGE INTERPRETATION

Since we were able to show that conventional images can achieve a high degree of diagnostic accuracy in dermatological assessment, and that patients would accept this method of dermatological management, we introduced a pilot scheme for skin screening and waiting list management. Over a six-month period, from December 1996, the Lancaster medical illustration department was used as an image acquisition area. Patients were invited to attend the medical illustration department, Royal Lancaster Infirmary, as an alternative to a standard dermatology outpatient clinic appointment. They were given the option to attend a clinic if they did not wish to attend for imaging. Those with primarily tumour-related problems received imaging. The referral card details were used to indicate which type of dermatological problem might have been suitable for imaging as a prelude to patient management.

As well as the pilot service introduced in Lancaster, photographic clinics were introduced in Barrow and Kendal. From the referral card details, the medical photographer photographed the skin and, where necessary, other dermatological problems. The photographs underwent standard photographic processing and were then available, together with the referral card details from the GP, and the patient's notes, usually within five working days for the dermatologist to issue a management plan for the patient's problem. Since most of the problems were tumours in this study, most patients subsequently attended for surgical intervention when histology was obtained which permitted assessment of the diagnostic accuracy of this method of patient management. Furthermore, an audit has been

undertaken of two hundred patients attending the Lancaster photographic clinic and one hundred patients attending the Barrow clinics.

At the end of the study, 650 patients had been managed using high quality conventional photographic images. The initial diagnostic accuracy, (210 patients) was 71%, the later diagnostic accuracy, (219 patients) was 82%, which is approaching that achievable in a live or face-to-face consultation. Furthermore, when the method was examined to ascertain its ability to determine whether the lesion was benign or malignant (ie can it detect skin cancer?), the accuracy rose to 94%. Thus the stage is set for the next phase of the study, which is to examine digital imaging since we have shown that conventional photographic imaging, with high quality images, can work as a management tool, and for screening of dermatological problems. During the six-month period, waiting lists for tumour-related problems were reduced from six months to two months, and this was largely attributable to imaging. Furthermore, no important tumours were misdiagnosed, and all melanomas were detected, including one which had been misdiagnosed by the referring GP.

DERMATOLOGICAL DIGITAL IMAGING

Although the aim ultimately might be to link all general practices digitally, the first aim of our study is to pilot image transmission between Lancaster and Manchester, and then to link some pilot general practices.

An earlier digital study we undertook examined 100 digital photographs obtained by the trainee specialist registrar in dermatology on unselected consecutive new patients. The lesions were photographed with a Kodak DC40 digital camera fitted with close-up lens, and a portable multimedia computer with a 32 byte RAM was utilised, enabling image capture with a spatial resolution of 756 x 504 pixels. Although this was less than that achievable with the Kodak DCS200 (1.54 million pixels), the images viewed by the

consultant dermatologist and trainee registrar enabled diagnostic accuracy of 92%. Lesions were generally simpler than the more recent larger conventional photographic study and there were two doctors discussing the images which improved the diagnostic accuracy.

Another study involving 50 consecutive patients selected by the GPs for referral had their presenting lesions digitally photographed using a Kodak DC 40 digital camera and these images were subsequently transmitted together with a referral message on the standard telephone network to the Morecambe dermatology department using a secure encryption system. The image and text were reviewed by the consultant dermatologist who provided a diagnosis, management plan and an opinion. Image-led diagnoses were then compared with the final diagnoses (based on progress and investigations) and each patient also subsequently attended an outpatient clinic for face-to-face consultation with the dermatologist. The diagnostic accuracy in this study using the same lower resolution/definition camera was 97% but like the other digital study, the problems were generally easier than in the conventional photographic study. Currently we are re-evaluating this study with a local general practice looking at Internet image transmission.

A current study is examining an ISDN-based system which has been established at Lancaster and Manchester dermatology departments which also links medical photography at Lancaster with the department of radiology and imaging science at St Martin's College. Work is now being undertaken to examine image quality and the minimum image information necessary to achieve effective dermatological diagnosis and management. The differing diagnostic accuracies in various studies has been described, not only in our own work but in that of other workers. If telemedicine is used to achieve accurate diagnoses, then the method should have a diagnostic accuracy approaching a clinic situation. But if it is to be used for screening (tumours for example), that might mean that the method only has to distinguish between benign and malignant.

Fig. 3. Still digital image equipment using a Kodak DCS 420 digital camera with computer equipment suitable for transmission of the image via ISDN transmission (store-and-forward system).

A TELEDERMATOLOGY SERVICE IN MORECAMBE BAY

There may be a number of pressures from different areas to establish a clinical service. There is no doubt that telemedicine can be enormously successful in allowing more rapid access to dermatological expertise. In the pilot study using conventional photography, the dermatologist can issue management plans from a pile of notes and images over seven times quicker than when patients attend the clinics. However, virtual medicine is not necessarily ideal medicine and we have to be absolutely clear about the aims of teledermatology and what level of diagnostic accuracy is acceptable for patients. A preliminary analysis of the audit of patient satisfaction with the pilot service using conventional photographic images indicates an 85% satisfaction with the service and, furthermore, that the service was preferable to clinics to 83% of patients (primarily because of time efficiency, it being quicker to take a photograph and more easy to keep to timing than when people attend clinics). However, even if diagnostic accuracy is greater than that of the GP, it ideally should be similar to a clinic situation. The ISDN-based system will be interpreting information from both Lancaster and Manchester to cross-check diagnostic accuracies to give us a more accurate picture of the situation.

Although some centres are enthusiastically launching new initiatives, we would recommend that one should start at the centre and grow outwards, rather than giving cameras to a lot of people and expecting them to get on with imaging. The other point is that imaging does bring its own problems. It can be so effective in introducing extra patients to quicker specialist opinion that there may be secondary pressure on waiting lists for extra surgical procedures. Our view is that skin cancer can be effectively screened using telemedicine and in our own studies we have shown that melanoma and non-melanoma skin cancers can be effectively distinguished from benign lesions using imaging. However, telemedicine does not necessarily substitute for real or face-to-face patient consultations. Teledermatology can effectively reduce the need for many patients to visit clinics prior to dermatological operation but it may be more useful as a screening method or can be used as a waiting list management module rather than be expected to ascertain small or subtle differences between individual or complicated skin lesions. Teledermatology can be used to help in the prioritisation of patients before management, and so save patients' time and travelling. But if it is to be fully effective in the overall management of patients, investment needs to be made in staff who will enable more treatments as well as more diagnosis. Furthermore, medico-legal aspects of telemedicine need to be clarified both to safeguard patients and to protect doctors involved in telemedicine. These safeguards are necessary to ensure that telemedicine has the same standards of care as a conventional clinic setting.

THE FUTURE

In the future, other methods of information transfer could be examined and digital data can be used to examine artificial intelligence-assisted diagnosis. Current studies in conjunction with Lancaster University are examining computer-aided diagnosis and perhaps that is where the real potential may lie – to have the computer doing the work rather than always expecting the GP or the dermatologist to give answers! We

have been examining neural network analysis and algorithms to facilitate dermatological diagnosis. Soft and hard decision-making processes may enable computers to automate some dermatological diagnosis. It may, however, be some time before the need for dermatological referral to a consultant is replaced by a computer and meanwhile telemedicine can potentially help to manage more dermatological referrals.

SUMMARY AND CONCLUSIONS

We have been examining telemedicine for dermatology in the Morecambe Bay area. Historical data on dermatological images has been analysed and research undertaken on still images, both conventional and digital. We have shown that teledermatology can be useful as an adjunct to patient management in standard dermatology clinics. Although more work is necessary (examining, in particular, diagnostic accuracy and the potential of telemedicine), we are now at a stage where a clinical service can be introduced.

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