Papers

An experimental inter-expert telepathology network using static imaging

J H Tucker, C Busch, A Spatz, C Wells, G Brugal

Abstract

***Aims*—To set up a network for remote consultation using static imaging telepathology via Internet connection between pathologists in different European countries, and to collect some numerical and subjective impressions on the usefulness of this form of telepathology.**

***Methods*—A static image remote consultation network between 11 pathologists in nine European countries was set up; all pathologists were equipped with the same telepathology system. The pathologists formed three subject oriented subgroups concerned with prostate, melanoma, and soft tissue sarcoma pathology. Each pathologist sent and received a small number of cases, and data on each case were collected and analysed. The whole experiment was controlled through a World Wide Web site.**

***Results*—A total of 56 case consultations on 34 different cases were exchanged. The average case document contained seven images, and contained 1.97 Mbytes of data. For cases in which data were recorded, average case preparation and remote consultation time was 55 minutes and 9.2 minutes, respectively. Transmission times averaged 3.9 minutes. In subjective impressions, reservations were expressed in several cases regarding the confidence that could be given to the diagnosis from the images presented.**

***Conclusions*—Remote consultation by telepathology via the Internet is now technically feasible and reasonably user friendly, but is only suitable as a method of disease diagnosis in some cases.**

(*J Clin Pathol* 2001;**54**:752–757)

Keywords: telepathology; static image telepathology; telepathology network; remote consultation

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Accepted for publication
16 February 2001

Telepathology, for many years used only by a relatively small band of enthusiasts, is at last coming into more widespread use among the pathologist community. Originally conceived more than 25 years ago[1] for consultation between a general pathologist and a specialist pathologist at a remote station, it was heralded as a means of bringing expert opinion on difficult cases within the reach of all in the pathologist world. However, for many years this goal was not achieved in practice because of the technical limitations and high cost of the necessary equipment. Now, the very rapid technological advances made in fields such as electronic imaging cameras, displays, computers, image storage, and telecommunications (in particular the Internet and World Wide Web) have eased, or even removed, many of the technical limitations, and have made telepathology equipment more readily available, affordable, and reliable.

As this interest in, and practice of, telepathology has developed, so has the range of tasks to which it has been applied. In addition to the many remote consultation evaluations that have been made,[2–7] systems have been set up to provide frozen section diagnoses at remote hospitals with limited access to local pathology services.[8–14] Several interhospital or "public" consultation services are now available via telepathology.[15–17] Other applications incorporating telepathology techniques include online atlases (for example, Cambridge Department of Histopathology online atlas: http://www.his.path.cam.ac.uk/histop/onlineatlas.html), image banks,[18 19] and quantitative pathology.[20 21]

Today, two telepathology techniques are in widespread use. The first is static image telepathology, in which the remote consultant is shown a series of digitised images acquired by the referring pathologist from microscope fields from the specimen under discussion. The second is dynamic telepathology, in which a consultant is able to view a live image from a remote motorised microscope fitted with a video rate camera. Both types of system have different advantages and disadvantages, and "hybrid" systems are now available,[4 22] which allow both types of interaction. The different properties of static and dynamic technologies have meant that they have found favour in differing fields of application.

One area of telepathology that has so far received scant attention in the literature is that of inter-expert networks. Many regional, national, and international groups of experts in pathology specialities exist, mostly relying on occasional meetings for their activities. By providing groups with multimedia communications facilities, activities such as the discussion of interesting or difficult cases, grading scales, and other points of common interest between group members can be facilitated. In 1996, an

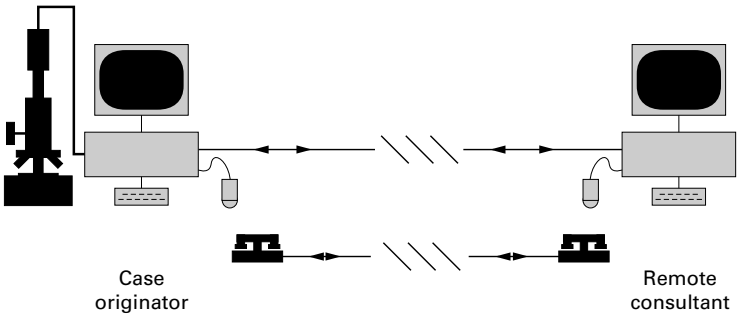

Figure 1 Equipment for static image remote consultation.

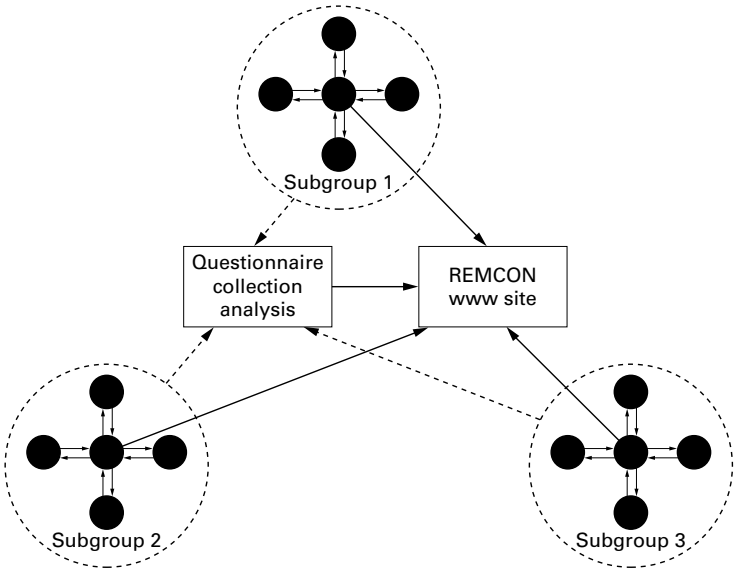

Figure 2 Organisation of experiment (group coordinators are shown at the centre of each group).

EEC funded project, EUROPATH,[23] was initiated to promote the use of telepathology among European pathologists, and as part of this an experimental inter-expert static imaging network facility, REMCON, was set up and subjected to preliminary testing. The aims of the tests were:

(1) To investigate the problems encountered in installing a telepathology network among typical pathologists chosen for their expertise in a particular field of pathology (rather than their interest in telepathology).

(2) To gather some preliminary data and subjective impressions on the use of static image remote consultation in this application.

(3) To gain experience in setting up and managing such networks using the World Wide Web.

This paper describes the REMCON network and the results of these preliminary tests.

Method

EUROPATH pathologists suggested some areas of pathology for initial tests; the selected areas were prostate sarcoma, soft tissue sarcoma, and malignant melanomas. Pathologists (both external and from within the EUROPATH consortium) were selected to form groups with a common interest in the use of telepathology in these branches of pathology.

Because there is at present no agreed interoperability standard between the range of different systems commercially available, a single commercially available telepathology system, the Alcatel EPS system*, was used by all the pathologists for the experiment. This system contains facilities for mailed static image remote consultation. Briefly, the system allows input from a microscope mounted, high quality CCD camera, a digitiser card, an IBM compatible personal computer running under Windows 95® or Windows NT®, and interconnections via modem, ISDN, or TCP/IP Internet (in this experiment all connections were made using the Internet). The details of the hardware facilities varied considerably between the different laboratories involved—a typical equipment arrangement is shown in fig 1.

The software allows the user to put together a "document" consisting of grabbed microscope field images and text from a case. This document can then be sent to another EPS connection either directly or indirectly via an electronic mail facility. In this experiment a third (non-proprietary) mailing option, the EUROPATH Multimedia Mailbox, was also used for the simultaneous distribution of case documents to several participants. At the start of the experiment, each participant filled in a questionnaire asking for exact details of the individual equipment setup used (for example, camera details, display monitor details, communication medium to be used, etc). All experimental and consultation information, data, and results were collected and presented in English. The experiment was arranged as an exchange of cases between the group coordinator and each other participant in the group (fig 2).

Initially, a test EPS document was sent by the project manager to each participant to eliminate any problems with availability or operation of the software. Then the group coordinator sent his cases, via the EUROPATH Multimedia Mailbox, to each of the other group members, asking them to act as remote consultants for the cases.

Next, each participant was asked to send his/her cases (via the internal EPS interconnection facilities or the EUROPATH Multimedia Mailbox) to the coordinator so that he could act as remote consultant. Thus, each participant was able to test the system both for case document generation and as a remote consultant. For each remote consultant consultation, both participants were asked to complete a questionnaire with details, timings, and subjective views of the session.

The overall management and information exchange for the experiment was carried out using a specially constructed World Wide Web site. Initially this site contained the aims, protocols, patient contact details, and questionnaire forms; as the experiment progressed it was updated with case information, progress of evaluation, questionnaire analyses, and results. In addition, a monthly email newsletter

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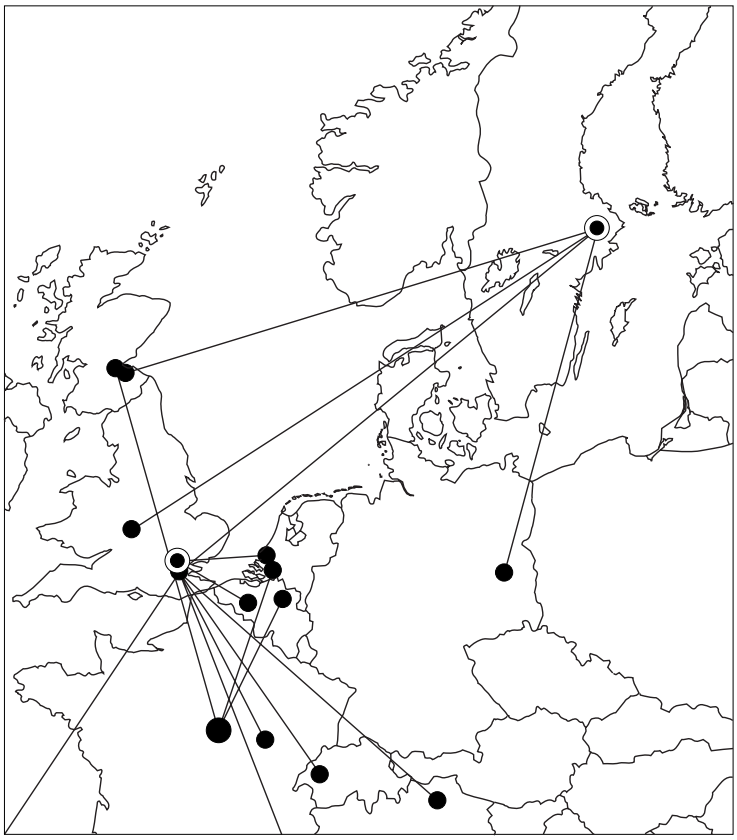

Figure 3 Geographical distribution of participants.

was distributed by the project manager to all participants.

Results

In the experiment, a total of 56 remote consultations occurred, in which 34 different cases were exchanged between 11 different pathologists in nine countries. Figure 3 shows the geographical distribution of the individual group participants. The case images and text, and details of the questionnaire responses received, are available for viewing on the REMCON World Wide Web site (http://pathconsult.imag.fr/remcon/). Figure 4 shows the details of the case documents produced for the 34 cases.

The mean number of images/case was approximately seven, and the mean file size was 1.97 Mbytes (note that in all cases the "high quality" image compression ratio of 90% was used for the jpeg image files incorporated in the documents). It was noted that the files from some laboratories were much smaller than those from others.

In total, 15 case originator questionnaires were received; in addition, some other information was provided informally by participants. Figure 5 shows histograms of document preparation times and document transmission times (to the EuroPath Multimedia Mailbox) for the 15 consultations; the means were 55 minutes and 3.9 minutes, respectively. In all but one of the cases the case originator

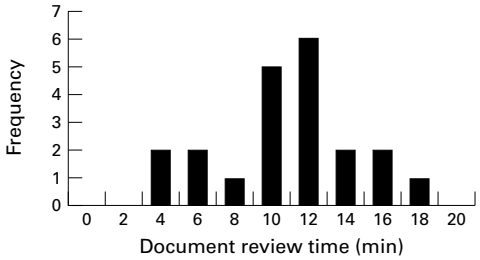

Figure 6 Histogram of document review times.

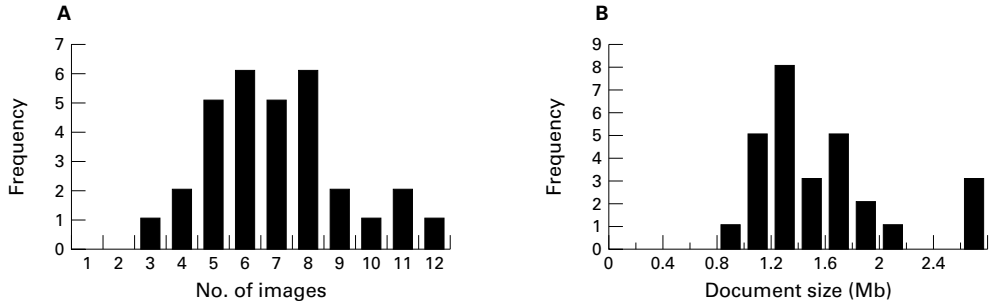

Figure 4 Histograms of (A) number of images and (B) file sizes for case documents.

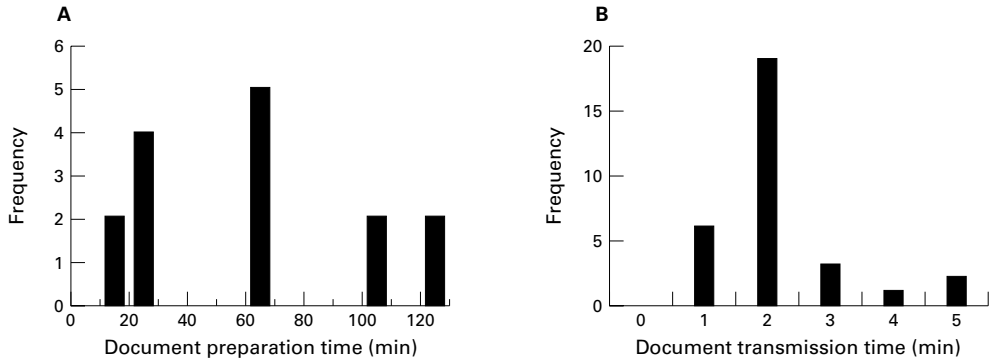

Figure 5 Histograms of case originator times for (A) document preparation and (B) document transmission.

Table 1 Remote consultants' responses to subjective questions (number of cases)

	Bad	...	...	...	Good
Question	*1*	*2*	*3*	*4*	*5*
How clear was the diagnostic problem?	1	0	4	6	14
How good was the image quality?	1	3	4	6	11
What was your confidence level in answering questions asked?	1	5	5	8	6
How good was telepathology for this case (compared with other ways of consulting)?	2	3	7	5	8

classified the selection of the images to send as "easy" or "very easy".

So far, 17 remote consultant questionnaires have been received. Figure 6 shows a histogram of the case review times; the mean case review time was 9.2 minutes. Note that this did not include the time required to email the reply to the case originator. A summary of the problems noted by the consultants included:

- unclear about the diagnostic problem
- poor image quality
- insufficient images to make a diagnosis
- unsuitability of case for telepathology consultation.

Regarding the adequacy of the images selected, in two cases the remote consultant felt that the images selected by the case originator were not sufficient to make a diagnosis. In five cases the remote consultant was unsure of the question to be answered; the images were sometimes considered to be of insufficiently high quality, and one case was considered definitely unsuitable for remote diagnosis by telepathology. Table 1 summarises the stratified replies to the subjective questions in the remote consultant questionnaire.

Discussion

This experiment demonstrated the feasibility of an international inter-expert telepathology network based on static imaging techniques, using the Internet as the telecommunication medium and the World Wide Web for network management. The experimental network connected three international subgroups of pathologists sharing expertise in common pathology specialities, and quantitative and qualitative evaluation data were collected after the transfer of typical case documents.

Static imaging was used for this test primarily because of the high cost of setting up a network of dynamic installations. The number of specimens prepared or reviewed by any one pathologist was insufficient to give a representative review of the accuracy of telepathology for the cases involved. However, these preliminary tests did provide basic information on the characteristics of such consultations, and of the subjective impressions of the pathologists after using a system. In general, the test results confirmed the usefulness of static image telepathology for many cases, but highlighted two problems.

The first concern was that the remote consultant can only view the images selected by the case originator. Although only two cases were officially marked as "too few images" in this test, in more than half the cases the remote consultant was unable to express complete confidence in the diagnosis. Informally, the view was expressed by several participants that they would be reluctant to make a formal diagnosis on some of the cases presented with only the evidence of the preselected images sent. This confirms previously reported results.[7 15] However, this problem may ultimately be less constraining in a well established inter-expert network than in public consultation networks because case originators, as experts, can be relied upon to provide a representative selection of the problem fields from a slide. Furthermore, it is entirely possible in such cases for the remote consultant to contact the case originator to ask for more or better images.

The second problem noted for static image remote consultation is that the time taken to prepare case documents is too long for routine use. Although the average times taken to transmit documents (3.9 minutes) and review cases (9.2 minutes) were acceptable, the document preparation time averaged 55 minutes according to the questionnaire results. This was unexpectedly long compared with previous reports in the literature.[3 8 10 14] Much of the time was spent in selecting good fields, choosing the most appropriate magnification; in digitising the fields (often several times to improve factors such as focus, colour balance, light level, etc), and in editing the document to incorporate these corrections. Some users cited the acquisition of good images at low magnifications as being particularly difficult. To some extent, these times reflect the inexperience of some of the users with the telepathology software used for the tests; the results confirmed earlier reports that average times were noticeably lower for users with previous experience.[10] Nevertheless, these results highlight the importance of incorporating simple and rapid image grabbing and amending facilities in telepathology software.

In general, the use of the Internet for mailing purposes was successful, confirming previous reports[24 25] of the value of this medium for telepathology. Most documents were sent using the mailing facilities within the EPS software; although these contain autonomous transfer facilities, in practice most users first telephoned the recipient to ensure that their computer was switched on before sending documents. Transfer times for the EPS documents were relatively short because all participants had the benefit of high speed access to the Internet via local intranets; independent tests showed that it requires approximately 7.6 minutes to transfer a typical (seven image) document to a computer using a "28.8 K" modem. The Multimedia Mailbox facilities in the EUROPATH World Wide Web server were also found to be a convenient and user friendly method of transmitting the EPS documents between participants, and were used for most multirecipient transfers. Several participants commented favourably on the automatic emailing feature, which informs the recipient that there are documents awaiting collection. One problem not dealt with in our study was that of security on the

Internet[26 27]; but Internet security facilities are now being used extensively in other developments such as e-commerce.

The overall management of the experiment was carried out by the technical coordinator and the subgroup medical coordinators, using the World Wide Web site as a tool. It seems essential that any inter-expert telepathology network should have both an identifiable medical coordinator to design the purpose, methodology, and overall control of the network, and a technical coordinator whose tasks are to design and implement the necessary tools and procedures to be used over the network, and to provide technical training and assistance to all participants as required. The sending of a "test document" from the technical coordinator to each participant before the case exchange proper was found to be a useful method of ironing out initial technical problems and ensuring that methodology was clearly understood by the participant. The World Wide Web site was found to be invaluable as a means of distributing aims, protocols, questionnaires, and dissemination of results. However, the generation and constant updating of this site proved to be a substantial and time consuming task. Ways of reducing this workload for future networks are now being investigated.

From the experiment some practical recommendations for the basic requirements of static image telepathology software for inter-expert networks may be listed. These include:

- easy and pathologist intuitive user interface
- good help facilities
- facilities to input important patient details
- facilities to make explicit the question to be answered by remote consultation
- easy grabbing of high quality camera images
- easy image annotation (both by drawing and by associated text notes)
- easy image and text editing
- easy document mailing (address books)
- mechanism for the remote consultant to reply to the case originator (for example, email).

These features could usefully be augmented by more advanced features such as image shading correction, image focus assistance, user recorded macros/sequence scripts (wizards), automatic call logging, and html interfacing. It should be stated that most commercial systems provide the basic facilities: in particular the latest versions of the EPS system used for this experiment incorporate most of the basic features listed above. Lastly and most importantly, there is an urgent need for industry wide standards; although these have been proposed,[27–29] they have yet to be accepted by the industry as a whole, and the field is currently severely hampered by the lack of inter-operability between the many systems available.

The experience obtained in setting up and evaluating this experimental network confirms that static imaging telepathology can play a useful role in certain situations, but that guiding rules should be observed. First, there must be a clear and well defined aim for the network; all participants will need to exert a considerable effort in learning to use the facility effectively, and the aim to be achieved must be sufficiently attractive to all participants to reward this effort. Second, it will not solve all cases; it must be used in conjunction with other methods of case exchange. Third, there is a need for continuous management of such a network; the World Wide Web can be a valuable tool for this, but this is a substantial task.

Conclusions

It has been shown that the EPS software facilities for mailed remote consultation using static images, in conjunction with the EUROPATH World Wide Web server facilities, can be used in principle by pathologists to obtain second opinions on pathology cases over the Internet. However, certain practical and other problems have emerged during the tests, which suggest that this mode of remote consultation is not suitable as a method of disease diagnosis in all cases. In spite of these limitations, it appears to have a potentially valuable role to play in augmenting other modes of remote consultation, and in other special more specialised telepathology applications.

The authors wish to thank the members of the REMCON subgroups for their time and effort, in particular: Dr C Barranco, Hospital del Mar, Barcelona, Spain; Dr D Berney, St Bartholomew's Hospital, London, UK; Dr F Collin, Centre Georges Francois Leclerc, Dijon, France; Professor M Cook, Royal Surrey County Hospital, Guildford, UK; Dr K Grigor, University of Edinburgh, UK; Dr J Leong, John Radcliffe Hospital, Oxford, UK; Dr K McLaren, University of Edinburgh, UK; Dr King Lam, Erasmus University, Rotterdam, The Netherlands; Professor D Ruiter, St Radboud Hospital, Nijmegen, The Netherlands; Dr I Salmon, Universite Libre de Bruxelles, Brussels, Belgium. Thanks are also due to the EUROPATH Project Coordinator, Professor D Kunze (TU Dresden, Germany); to Dr C Sowter (St Bartholomew's Hospital, London) for his help and advice; and to many other consortium members for their helpful comments. In addition, we wish to thank Samba Technologies for the loan of software for use in this experiment. The work was funded by the EEC framework IV healthcare programme grant no. HC1038.

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