Real-Time Dynamic Telepathology through the Internet: Evaluation of a New and Economic Technology at Taipei Veterans General Hospital

Wen-Yih Liang\textsuperscript{1}
Chin-Chen Pan\textsuperscript{1,2}
Huang Chiang\textsuperscript{1,2}

\textsuperscript{1}Department of Pathology, Taipei Veterans General Hospital; and
\textsuperscript{2}National Yang-Ming University School of Medicine, Taipei, Taiwan, R.O.C.

Key Words
computer; internet; prostate; telepathology

Background. Computer-aided, digitized telepathology was introduced about 10 years ago and is gaining acceptance as a mode of providing pathology to remote site. The usefulness of telepathology for remote diagnosis of histology, cytology and frozen section has been evaluated in USA, Europe and Japan. In Taiwan, the use of telepathology for pathological diagnosis is still rare. In order to evaluate the potential use of this technique, we undertook the study using commercialized and low-cost microscopy, personal computer and software on routine biopsy material.

Methods. Sixty prostatic sextant transrectal needle biopsies, including 30 cases of adenocarcinoma and 30 cases of benign lesions, were retrieved retrospectively. The real-time dynamic images were transmitted to the remote site via internet and reviewed by a senior uropathologist who was unaware of the diagnosis. The diagnoses made at the remote site were correlated to the final diagnoses of the cases.

Results. All malignant specimens (30/30) were correctly diagnosed by this method. Only one benign case (1/30) of nonspecific granulomatous prostatitis was misdiagnosed as poorly differentiated carcinoma.

Conclusions. Our results show that this method is a good way for teleconsultation. Further studies on other types of specimen warrant encouragement for both intra- and inter-institutional consultation.

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Correspondence to: Wen-Yih Liang, MD, Department of Pathology, Taipei Veterans General Hospital, 201, Sec 2, Shi-Pai Road, Taipei 112, Taiwan. Fax: 886-2-28757056; Email: wyliang@vghtpe.gov.tw

Telepathology was introduced about 10 years ago and is gaining accepance as a mode of providing pathology to remote site. Until August 2000, about 147 articles concerning telepathology have been published in the literature. In recent years, telepathology has been used in Scan di na via for remote diagnosis of frozen section and histology, \textsuperscript{1,2} and in Europe, \textsuperscript{4,6} Japan, \textsuperscript{7,9} and USA for his tology and cytology. Two major methods of telepathology are available: static and dynamic. The former is achieved by transmission of preselected images and the latter by real-time transmission of continuous images. Though economically, the static telepathology suffers from more personal bias in selecting representative fields. The dynamic one, on the contrary, is capable of providing the whole picture of a case but is more time-consuming and expensive. To the best of our knowledge, a similar study using telepathology as a diagnostic tool for consultation has...
not been available in Taiwan yet. Therefore we developed a real-time dynamic telepathology system using common microscope, personal computer and a low-cost commercial internet surveillance software to evaluate the feasibility of this technique.

**Methods**

**The image server**

A Y/C video camera was attached to a conventional light microscope (Nikon Optiphot-2) equipped with a phototube. The camera was connected to a personal computer (Pentium III 866 processor, 128 Mbytes RAM, Asus V3400 as display and frames grabber card). The computer was connected to the network of Taipei Veterans General Hospital, with direct access to the Internet (bandwidth: 100 Mbytes/sec). An Internet surveillance software (e-Lar, URL: http://www.chimat.com.tw, Taiwan, ROC) was installed. The software could create and transmit continuous motion images with four types of recording resolution (320 × 240, 400 × 300, 512 × 384, 640 × 480 pixels) at an adjustable record rate ranging from 1 to 15 frames per second.

**The clients**

In this study, the client site is in another building more than 100 meters away from the server site. The pathologist at the remote site could see the real-time motion pictures via internet at a given IP address, by using a usual web-browser, for example, Netscape Communicator 4.71® in current study. While reviewing the images, the pathologist could instruct the person at the server site to change field or magnification by telephone (Fig. 1).

**Materials**

Sixty prostatic sextant transrectal needle biopsies, including 30 cases which were signed out as minimal adenocarcinoma and 30 cases of a variety of benign lesions, such as nodular hyperplasia, adenosis, atrophy and non-specific granulomatous prostatic tissue, were retrieved retrospectively from the surgical pathology archive at Veterans General Hospital-Taipei from July, 1998 to May, 2000. All malignant cases were confirmed by two senior pathologists. Immunohistochemical stains for high molecular weight cytokeratin (34BE12) were done in difficult cases to support the diagnosis. The study was a double-blind test. Neither the pathologist at the server site nor at the client site involved the case selection or knew the final diagnosis.

**Results**

The average number of tissue cores in each specimen was 3.2 (2~5 tissue cores). In the 30 malignant cases, 28 cases were Gleason’s score 3 + 3 = 6. Two cases were Gleason’s score 4 + 3 = 7. In 25 malignant cases, the tumor occupied less than 5% of the involved tissue core. Though a little bit blurred, the color and resolution of the images seen on the screen at the client site were adequate for diagnosis either at low magnification (Fig. 2A) or high magnification (Fig. 2B). The nuclear details were readily discerned.

All malignant lesions (30/30) were correctly diagnosed by this method. Only one benign case (1/31) of

![Fig. 1. The server acquires the microscope image from the conventional microscope via a color CCD camera and transmits dynamic images automatically to the connected client via the Internet or intranet. The pathologist at the client site can instruct the person at the server site to change field and magnification via telephone.](image-url)
Table 1. Correlation of telepathology and final diagnosis for individual foci

<table>
<thead>
<tr>
<th>Final Diagnosis</th>
<th>Telepathology Diagnosis</th>
<th>Final Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benign</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>No pathological diagnosis</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Chronic prostatitis</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Atrophy</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Adenosis</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Non-specific granulomatous inflammation</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Carcinoma</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>3 + 3</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>4 + 3</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Kappa = 0.97; Sensitivity = 100%; Specificity = 96.7%.

Fig. 2. (A) Telegraphs of minute focus of adenocarcinoma of pros tate Gleason grade 3 + 3 = 6 can be identified in the low magnification (the circle area). (B) These atypical glands reveal nuclear anaplasia with prominent nucleoli at high magnification.

Fig. 3. Te leg ra phy of non-specific granulomatous pros ta ti tis misdiagnosed by telepathology as high-grade pros tatic adenocarcinoma. Clus ters of epithelioid cells with clear cytoplasm and prominent nucleoli mimicking adenocarcinoma.

nonspecific granulomatous prostatitis (Fig. 3) was misdiagnosed as poorly differentiated carcinoma due to the pseudoinfiltrative pattern and the prominent nucleoli in the reactive epithelioid cells. The correlation between the telepathologic diagnosis and final histologic diagnosis is tabulated as Table 1.

The time spent in each case ranged from one minute 20 seconds to 6 minutes (mean: 3 minutes 50 seconds).

Discussion

In 1987, Weinstein et al.\textsuperscript{10} did important early works in establishing that video images of easily attainable resolution are of sufficient quality to permit accurate histopathological diagnosis.\textsuperscript{10,11} In the ensuing years, investigators have used telepathology to transmit microscopic images of varying magnification of material. The use of telepathology for diagnosis continues to expand. It is now being used to diagnose gastrointestinal pathology,\textsuperscript{12,13} breast cancer,\textsuperscript{14} prostate cancer,\textsuperscript{15} skin lesion,\textsuperscript{16,17} breast fine-needle aspiration cytology,\textsuperscript{18} and cervical smears.\textsuperscript{19,20} The motivation to develop telepathology into a practical technique can be seen in two circumstances. One is the case in which a remote site can not support a full-time pathologist, but surgical
phology services are needed there. Frozen-section con sul tation is such an ex am ple. The sec ond cir cum stance is that ev ery sur gi cal pa thol o gist has ex pe ri enced the need to con sult an ex pert in the field which he/she is not pro fes sional of. Of ten the de sired con sul tant is dis tant enough to pro hibit meet ing in per son. In the past, such consulta tion could only be ac com plished by mail ing the spec i mens that not only en tailed a de lay in di ag no sis but also had the risk of dam age or los ing of the ma ternal dur ing the mail ing. With the ad vance of com puter and in ternet sci ence, the ap peal of nearly im me di ate and se cure elec tronic trans mis sion of im ages can not be more ev ident.

The im ages can be trans mit ted ei ther as a static or dy na mic mode. Trans mis sion of static im ages in volves field se lec tion by the sender and in ter re lay by the pa thol o gist who re ceived the im ages. On the other hand, dy na mic video im ages trans mit ted by a low reso lution con trol of the mi cro sco pic stage by the pa thol o gist at the re mote site. This greatly re duces the prob lem of sam pling er rors. Due to the pro gress of the in ternet technol ogy, the com munication speed or the band width has been mark ed edly im proved, mak ing the qual ity of dy na mic telepathology more ac cept able and less time-con sum ing. Based on these con cepts, we set up the cur rent rather in ex pen sive sys tem to test the sen sitiv ity and ac cur acy of this meth od ogy. In select ing cases, we think that pros tatic sex tant trans rectal needle bi opsy quite suit able es pe cially when the tu mor le sions are min ute and their atyp ism min i mal. It is rea son ably pre sup posed that if those min ute foci of atyp i cal glands were not missed in the telepatholog cal di ag nosis, the sen sitiv ity and spec i fic ity would be high en ough for other le sions which were more ad e quate in qual ity and quan tity. In ad di tion, since we chose the real-time dy na mic trans mis sion, the sus pected fields were se lected by the con sul tant in stead of the con sul tor, thus elim inated the per sonal bias of the con sul tor.

The re sults of this piv otal study were good. All mal nigan cases in volves the 25 cases con taining so lely min ute foci, were cor rectly iden ti fied and di ag nosed through telepathology. Only one case with di ag nosis of non-spe cific gran ulo ma tosus pros ta ti tis was mis di ag nosed as high grade (grade 4 + 4) adeno carci noma. The same kind of er ror was also noted in the re port of We in st and Ep stein,15 who used static rather than dy na mic im ages in their study. Over all, an es sen tially cor rect di ag no sis was given in 98.3% of cases. This fig ure is sim i lar to, even bet ter than, past stud ies us ing other ma terial. Com pared with pre vi ous stud ies, our sys tem has more ad van tages. Our sys tem is in ex pen sive for the server site. Aside from the con ven tional mi cro scope and per sonal com puter, the sys tem costs ad di tional US$ 300 for the im age server soft ware and US$ 1000–$2000 for CCD cam era, adapter and im age grab bing card. No ro bot sys tem is em ployed to ma nip u late the mi cro sco pe. It is even more eco nomic for the cli ent site. There is ba si cally no ex tra ex pen di ture or de vice for the cli ent site. Any one who has a per sonal com puter to con nect with in ternet is able to ac cess the im ages us ing a com mon web-browser such as Netscape Com mu ni ca tor® or In ternet Ex plorer.®

How ever, there are still some pos si ble draw backs in our de sign and as in other dy na mic sys tems. First, the con nec tion speed be tween server and cli ent de term ines the speed of frame trans mis sion. In our sys tem, the re sult is best when con nect ing with T1 (1.5 Mb/sec, 640 × 480 pix els and 15 frames per sec ond). With this speed, it did not take long (av er age three min utes) to di ag nose a case. If the con nec tion speed be tween both sides falls lower, the trans mis sion speed will be less than 15 frames per sec ond, that will cause stag na tion or inter ruption of the im age flow. Fortu nately, the qual ity of sin gle frame is not af fected. There fore, the prob lem could be over come by slow ing down the mo tion of chang ing fields and spend ing more time to go around all fields of the slide. The cor rect di ag no sis can still be made. With our trial at dif fer ent con nec tion speeds, in clud ing 56 Kb/sec, 128 Kb/sec, 384 Kb/sec and T1. The same di ag no sis could still be reached at with all avail able speeds. Sec ondly, the pix elized im ages seen on the screen of a com puter is not the same as what is used to see in the mi cro sco pe. The pa thol o gist in the cli ent side has to ad just to the sub tle dif fer ence. This can be achieved by more prac tice.

In con clu sion, we con sider the real-time dy na mic telepathology through in ternet is a sat is fac tory and pea ple of nearly im me di ate and se cure elec tronic trans mis sion of images can not be more ev ident.
ri als such as cy tology and frozen sec tion from dif fer-
ent or gans, and also with co op er a tive hos pi tals at long
distances.

References

1. Nordrum I, Engum B, Rinde E, Finseth A, Ericsson H, Kear-
ney M, et al. Re mote sec tion ser vice: a telepathology pro ject

2. Tor JE, Nordrum I. Frozen sec tion ser vice via the tel-
enetwork in North ern Nor way. *Zentralbl Pathol* 1992;138:
405-7.

3. Elford DR. Telemedicine in north ern Nor way. *J Telemed

4. Martin E, Dusserre P, Fages A, Hauri P, Viellefond A,
Bastien H. Telepathology: a new tool of pa thol ogy? Pre sen-
tation of a French na tional net work. *Zentralbl Pathol* 1992;
138:419-23.

5. Miaoulis G, Protopappa E, Skourlas C, Deldis G. Telepa-
thology in Greece. Ex pe ri ence of the Metaxas Can cer In sti-

6. Steffen B, Gianom D, Winkler C, Hosch HJ, Oberholzer M,
Famos M. Frozen section diagnosis using telepathology. *Swiss Surg*

7. Ito H, Adachi H, Taniyama F, Fukada Y, Dohi K. Telepa-
thology is avail able for transplanta tion-pathology: ex pe ri ence
in Ja pan us ing an in te grated low cost and high qual ity sys-

8. Takahoshi M, Mernyei M, Shibuya C, Toshima S. Pres ent

Con structing a lo cal dis trict telepathology net work in Ja
pan. Di ag no sis of intraoperative frozen sec tions via telepa-
thology over an in te grated ser vice di g i tal net work and the
Na tional Tele vi sion Stan dard Com mit tee Sys tem. *Anal Quant

10. Weinstein RS, Bloom, KJ, Rozek L.S. Telepathology and the
net work ing of pa thol ogy diag nostic ser vices. *Arch Pathol

per for mance stu dies of the video mi cro scope com po nent of a
dy namic telepathology sys tem. *Zentralbl Pathol* 1992;138:
399-401.

Palma P, et al. Telepathology us ing in ternet mul ti me dia elec-
tronic mail: re mote con sul ta tion on gas tro in tes ti nal pa thol-

13. Singson RP, Natarajan S, Green son JK, March e sky AM.
Vir tu al mi cro copy and the in ternet as telepathology con sul-
1999;111:792-5.

14. Nordrum I, Isaks en V, Arvola L. Breast car ci no ma di a g nos ed

15. Weinstein MH, Ep stein JL. Telepathology di a g nos e of pro-

anal y sis of skin spec i mens: the ap pli ca tion of telepathology
to frozen sec tion eval u a tion. *Hum Pathol* 1997;28:30-5.

al. Ex pert pa thol ogy con sul ta tion through the Inter net: mel a-
noma ver sus be nign melanocytic tu mours. *J Telemed Telecare*

18. Della Mea V, Puglisi F, Bonzanini M, Forti S, Amor oso V,
Visentin R, et al. Fine-needle as pir a tion cytol ogy of the
breast: a pre lim i nary re port on telepathology through Inter-
net mul ti me dia elec tronic mail. *Modern Pathol* 1997;10:
636-41.

“small cells” in cer vi cal-vaginal smears: a new tool for di ag-

20. Marsan C. The cervico-vaginal smear. What is new with the