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Remote Rapid Intraoperative Diagnosis Support System Using the Remote Desktop

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ABSTRACT

Background: A rapid intraoperative diagnosis is required for a wide range of clinical situations, and the results of the test determine the surgical procedure. In Japan, there is a shortage of pathologists who can perform pathological diagnoses. Therefore, in recent years, remote diagnosis using WSI with a virtual slide scanner has come to be used. Currently, it is difficult for Japanese medical institutions to employ a full-time pathologist or install a virtual slide scanner just to perform intraoperative rapid diagnosis from the viewpoint of hospital management. **Methods:** We selected 50 intraoperative rapid diagnostic specimens previously performed at St. Marianna University Western Hospital. The specimen images were displayed in real-time using a conventional microscope camera, and the results were viewed remotely from a remote location using a smartphone or laptop computer with a remote desktop system. The diagnosis time and the amount of communication were also measured. **Results:** The diagnostic accuracy was satisfactory regardless of the viewing environment, but the diagnostic time tended to be longer when smartphones were used. **Conclusion:** The possibility of remote intraoperative rapid diagnosis using a remote desktop system was demonstrated, but further improvement is needed to shorten the diagnosis time.

Keywords: Rapid intraoperative diagnosis, Whole slide imaging, Remote desktop system

ABBREVIATIONS: ITC: isolated tumor cells; RDP: remote desktop system; WSI: whole slide imaging

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INTRODUCTION

Rapid intraoperative diagnosis is one of the most important tasks performed in pathology departments in hospitals. A rapid intraoperative diagnosis is required for a wide range of clinical situations, including the evaluation of the margins of resected specimens, diagnosis of malignant and non-malignant lesions, presence or absence of lymph node metastases, and qualitative diagnosis of tumors. The common denominator is that obtaining an intraoperative rapid diagnosis is a diagnostic test required for patient treatment, and the test results determine the surgical procedure.

For example, an intraoperative rapid diagnosis of sentinel lymph node biopsy samples taken during breast cancer surgery is an important approach to determining the degree of lymph node clearance. Rapid intraoperative diagnosis of resection margins during surgery for gastrointestinal malignancies is also an important approach that determines the degree of surgical outcome. If the operation is terminated without rapid intraoperative diagnosis and the residual tumor remains at the resection margin, the operation itself loses its importance.

The first rapid intraoperative diagnosis was made by Dr. William Welch at Johns Hopkins Hospital in 1891 for breast tumors. However, due to factors such as the immaturity of the specimen preparation techniques at that time, a diagnosis could not be provided until after the surgery was completed [1]. This technique has a history of more than 100 years and is now available in general pathology departments across Japan. Nevertheless, there is a significant shortage of pathologists in Japan who can examine and rapidly diagnose diagnostic specimens. The actual number of pathologists working in Japan is approximately 2200, and the ratio of pathologists to the total population is very small, at 0.0016%, whereas the ratio of pathologists to the total number of physicians is 0.76%. Even in medical institutions that routinely perform surgery for malignant tumors, there are many cases where there is only one full-time pathologist or only one part-time pathologist [2,3]. In such facilities, there are limitations, such as the inability to perform intraoperative rapid diagnosis or the ability to perform such diagnosis only at certain times of the day. For some hospitals, the introduction of whole slide imaging (WSI) represents a major advance in pathological diagnosis in recent years [4-6]. WSI digitizes the entire slide glass allowing it to be observed freely on a computer screen. In addition, it is possible to browse data remotely through a network. Previously, a significant amount of time was required to scan a glass slide using WSI, and thus it found difficult application in routine diagnostic work.

In recent years, scanning speed has greatly improved, and it has been reported that primary diagnosis using WSI is a possibility in the routine diagnostic workup. Following the approval of some WSI platforms by the Conformité Européenne (CE) in Europe, studies evaluating primary diagnosis based on WSI have been reported [4-7]. In the United States, the College of American Pathologists established guidelines on the evaluation of devices to be used for primary pathological diagnosis [8], and the U.S. Food and Drug Administration has permitted the marketing of digital pathology systems as medical equipment [9]. In Japan, the inclusion of medical costs for pathological diagnosis by digitalization was approved starting in the 2018 fiscal year [10]. Most previous reports comparing the accuracy of conventional microscopic diagnosis and WSI-based diagnosis were limited to the primary diagnosis. Tanabe et al. reported that a primary diagnosis based on WSI was comparable to the primary diagnosis by conventional microscopy in terms of precision with some pathologists [11]. However, a virtual slide scanner is extremely expensive, and although it is expected to become less expensive in the future, it is currently difficult for small- and medium-sized medical institutions to easily adopt this technology.

In this study, we describe a simple remote intraoperative rapid diagnosis system that does not require a large additional capital investment, using a conventional microscope, a microscope camera, a commercially available computer, a smartphone, and a remote desktop system, all of which are relatively commonly used in pathological diagnosis departments.

MATERIALS AND METHODS

System overview

The system we developed for this study was as follows. First, an intraoperative rapid diagnostic specimen prepared by a routine method is placed on an optical microscope equipped with a microscope camera that can be connected to a PC, and the tissue image of the rapid diagnostic specimen is displayed on the PC screen. The PC screen is then shared with other PCs and smartphones via a remote desktop system (RDP).

Attributes of the operator and diagnostician

Microscopic examination was performed by a pathologist with more than 7 years of diagnostic experience and certified as a pathologist by the Japanese Society of Pathology. On the microscope operation side, a clinical technologist with more than 10 years of experience operated the microscope stage and revolver according to the pathologist's instructions to allow monitoring of the live image of the specimen. Pathologists with the same experience as remote pathologists operated the microscopes in the same way, and whether there was a difference in diagnostic accuracy was also examined.

Materials

Fifty rapid intraoperative diagnostic specimens obtained at St. Marianna University Hospital in Yokohama Seibu in 2015 were selected. The average number of samples per case was 3.4. The characteristics of the cases are shown in Table 1.

Table 1. Type of cases diagnosed.

	Organ	
Intra-operative diagnosis	Breast (cut end)	20
	Breast (lymph nodes)	12
	Stomach (cut end)	5
	Esophagus (cut end)	4
	Pancreas (cut end)	3
	Brain	3
	Ureter	3
		50

Diagnostic equipment and environment

The microscope used in the study was an Olympus BX41 manufactured by Olympus Corporation (Tokyo, Japan), and the microscope camera was an Olympus DP21. The computer used to operate the microscope camera was an LM-iG430XN5-SH2 computer manufactured by Mouse Computer Co. This computer uses Microsoft Windows 10 Professional Edition, an Intel Core (TM) i7-6700 processor, and 16 GB of memory. The resolution of the display used for the remote desktop was 1920x1200 pixels.

A remote desktop was used with a smartphone and laptop computer to determine whether there were any differences in observation accuracy. The smartphone was an Apple iPhone XS (display size: 5.8 inches, resolution: 2436×1125 pixels) and the notebook computer was a Lenovo ThinkPad X1 Yoga 3rd generation. The computer was equipped with an Intel Core (TM) i7-8650U processor and 16 GB of memory. The display size was 14 inches with a resolution of 1920×1080 pixels.

The network environment consisted of a wired LAN connection on the microscope camera side with a 100 Mbps link up. The upload and download speeds of this connection were 89.6 Mbps and 89.2 Mbps, respectively, according to a speed test provided by Google Inc.

On the remote side, the connection was made via a wireless LAN using the IEEE802.11n standard for both smartphones and notebook PCs. The upload and download speeds of the connection were 15.0 and 29.7 Mbps, respectively, according to a speed test provided by Google Inc.

Remote desktop system

In this study, we used the remote desktop system provided by Microsoft Corporation, which is a standard feature of the Windows 10 Professional edition.

Measurement of data volume and connection time

To measure the amount of data consumed by the remote desktop system and the connection time, we used AppNetworkCounter v1.51, which was created by Nir Sofer and is available on the Internet.

RESULTS

Some of the results are shown in Table 2.

Table 2. Diagnostic accuracy and time required for diagnosis.

	Organ	Accuracy (Note-PC)		Accuracy (Smartphone)		TAT (Note-PC)	TAT (Smartphone)
Intra-operative diagnosis	Breast (cut end)	20/20	100%	20/20	100%	Pathologist 254 sec Technician 382sec	Pathologist 409 sec Technician 521sec
	Breast (lymph nodes)	12/12	100%	11/12	92%		
	Stomach (cut end)	5/5	100%	5/5	100%		
	Esophagus (cut end)	4/4	100%	4/4	100%		
	Pancreas (cut end)	3/3	100%	3/3	100%		
	Brain	3/3	100%	3/3	100%		
	Ureter	3/3	100%	3/3	100%		
			100%		98%		

Operability

When the diagnosis was made using RDP, there was almost no delay due to the decrease in communication speed, and there was no decrease in the resolution of the image to be examined.

However, when a screen with an aspect ratio of 16:10 was received by the iPhone XS (screen aspect ratio of 19:9), the image was not displayed on the entire screen, and it was necessary to repeat scaling.

Diagnostic accuracy

When the sending side was operated by a pathologist and data were downloaded at the remote site using a laptop computer, the diagnostic agreement rate was 100%; similarly, when a smartphone was used, the diagnostic agreement rate was 100%.

When the sending end was operated by a clinical technologist and the remote data were downloaded onto a laptop computer, the agreement rate was 100%, and when a smartphone was used, the agreement rate was 98%.

Cases with a discordant diagnosis were sentinel node biopsy samples submitted at the time of mastectomy, which is required for the diagnosis of Isolated tumor cells (ITC). The sample should have been positive for ITC but was mistakenly determined to be negative due to inadequate enlargement of the metastases at the time of diagnosis.

Time required for diagnosis

The average time required for diagnosis was 254 s when the sending side was operated by a pathologist and data were received on the remote side by a laptop computer, and 382 s when a smartphone was used. When the sending side was operated by a clinical technologist and the remote side was operated using a laptop computer, the time required for diagnosis was 409 and 521 s when a smartphone was used.

Communication file size

The average communication file size required for diagnosis was 653 MB when information and imaging data were obtained and sent by a pathologist and the remote data were received using a notebook computer, and 728 MB when a smartphone was used. When the sending end was operated by a clinical technologist and the remote end used a laptop computer for diagnosis, the communication file size was 779 MB and when a smartphone was used, it was 901 MB.

DISCUSSION

Ensuring the accuracy of pathological diagnosis, and not only a rapid intraoperative diagnosis is essential for the promotion of advanced and safe medical care. However, in Japan, there is a shortage of pathologists available, and even central hospitals responsible for cancer treatment do not have full-time pathologists. It takes considerable time and effort to train a skilled pathologist and thus it is difficult to rapidly increase their availability. Thus, it is necessary for pathologists currently active in the field to resort to remote strategies for determining diagnoses to address the poor regional distribution of pathology services.

To date, there have been numerous reports on the application of remote diagnostic techniques for pathology assessment. In particular, since the 2010s, remote diagnosis using WSI data from virtual slide scanners has become popular, and many reports are showing that pathology diagnosis using WSI is comparable to that of using conventional microscopy with a microscope and glass slide. Some reports have shown that remote diagnosis is possible by converting specimens for rapid intraoperative diagnosis into WSI.

However, it is currently difficult to introduce a virtual slide scanner into clinical practice due to its cost. Furthermore, from the point of view of hospital management, the introduction of a virtual slide scanner for rapid intraoperative diagnosis is not feasible in medical institutions that also have difficulty hiring pathologists or that have not yet established a pathology department. Therefore, we have devised the following remote-based diagnosis system to address these difficulties.

We devised a scheme that allows a rapid intraoperative diagnosis using a microscope, a CCD camera, and an ordinary personal computer, which does not require an expensive virtual slide scanner. The results suggest that the accuracy of the diagnosis is comparable to that of on-site diagnosis. This system costs less than US$14,000, even if all microscopes and other equipment are newly purchased. In reality, the system can be built even more inexpensively, since it is expected that many hospitals already have microscopes installed. In this study, smartphones and notebook PCs were used on the receiver end to download imaging data, although a tablet can also be used, to adapt the system to the context of each medical institution.

In this study, the time required for RDP diagnosis was longer. This was especially true for diagnosis using a smartphone with small screen size. However, the present diagnostic method is not intended to diagnose a large number of specimens daily, but rather at a frequency of once or twice weekly; thus, the length of time required for diagnosis may be acceptable. Additionally, the time disadvantage of the diagnosis is unavoidable, as the diagnosis is made while providing instructions on the operation of the microscope by telephone.

The diagnostic method using RDP does not require time to scan specimens with a virtual slide scanner. Considering that intraoperative rapid diagnostic specimens are often not sufficiently dry for encapsulation and may not be immediately scanned by the virtual slide scanner, the time disadvantage can be offset to some extent.

In recent years, network speeds for mobile communications have been increasing. The 5G network, which is expected to spread globally in the future, will enable screen displays with less time lag. The 5G network also has the advantage of low latency, and the development of an adapter that can be attached to existing microscopes will enable stage and revolver operations. This is also possible by developing an adapter that can be attached to existing microscopes.

In this study, whether the operator on the transmitting side was able to recognize the lesion site on the specimen was also considered an important point in determining the correct diagnosis rate. In the discordant cases in this study, the ITC lesion in the sentinel node was not recognized by the sending clinical technologist, resulting in a false diagnosis. Therefore, the need for a certain level of pathological diagnostic skill of the operator on the sending side is considered an issue for the successful outcome of this approach.

The RDP-based method used in this study raised concerns about the large volumes of cellular data required for each diagnosis. About the use of a smartphone, the average file volume was more than 900 MB. However, in recent years, there has been fierce price competition in terms of communication costs, with some fee structures now available that allow 100 GB of communication data in a 5G environment at a cost of less than US$35/month in Japan.

Telepathology, including rapid intraoperative diagnosis, is expected to become increasingly important in the future. The technical issues and cost of hardware, such as virtual slide scanners, are expected to improve over time. Although it will be challenging for remote intraoperative rapid diagnosis using RDP to eventually become mainstream, it could play a specific role during the transition period until the use of virtual slide scanners becomes commonplace.

CONCLUSION

The RDP system proposed in this study consisting of a remote desktop and a microscope camera represents a diagnostic method that can find clinical applications for rapid intraoperative diagnoses by pathologists.

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AUTHOR CONTRIBUTIONS

M.C. and Y.A. were in charge of designing, conducting, summarizing, and discussing the results of the study.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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