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Original Article

Remote neuro-endovascular consultation using a secure telemedicine system: A feasibility study

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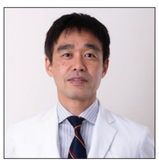

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ABSTRACT

Background: Telemedicine has been rapidly implemented under COVID-19 conditions, to assess the ability to use an audio-visual telemedicine system for neuro-endovascular remote consultation.

Methods: The system consists of a live streaming function for angiography and an operating room (OR) camera using a smartphone application (JOIN; Allm Inc, Tokyo, Japan) in conjunction with verbal communication using the Zoom app. The system allows us to display multiple angiographic images in addition to streaming video from the 4K camera recording the operator's procedure and from the 4K camera showing the OR view on the monitor of any smart device.

Results: The operator was able to speak with the senior supervisor through a bone conduction headphone and to talk to assistants or radiology technicians without any hearing difficulties. The remote supervisor was able to check the streaming images, which had almost the same imaging quality as real digital subtraction angiogram (DSA) monitors, and he could advise the handling of devices and preparation through the 4K video camera systems. The DSA image delay was within 2 s.

Conclusion: A remote consultation system with real-time audio-visual capability may play an important role in acute stroke management and maintain the quality of patient care under COVID-19 conditions.

Keywords: Education, Endovascular, Remote, Stroke, Telemedicine

INTRODUCTION

Telemedicine has been quickly applied under COVID-19 conditions. Several studies have shown that telemedicine is effective in the management of stroke care.[3-5,8,9] Under COVID-19 conditions, hospital regulations sometimes prohibit technical support from senior neuroendovascular specialists outside the hospital. In addition, the rapid expansion of acute ischemic stroke therapy imposes further work tasks on experienced neuro-endovascular specialists. Young physicians who need expert opinion or supervision for complex neurovascular treatments sometimes experience difficulty analyzing the treatment strategies or selecting the optimal devices. Therefore, a more direct "audio-visual" communication system is required for real-time consultation.

We recently established a telemedicine system that allows further remote support, including real-time imaging and verbal communication, for neuro-endovascular therapy. We report our initial clinical experience in acute stroke treatment and scheduled unruptured aneurysm embolization using a remote neuro-endovascular support system.

MATERIALS AND METHODS

This system was developed at the university and was used for case consultation at an affiliated hospital. The study protocol was reviewed and approved by the ethics committee and the research review board at the affiliated hospital. All patients were provided informed consent, and each site had obtained Institutional Review Board approval and signed consent forms. The participants and any identifiable individuals consented to the publication of their image.

The system consists of 1) a live streaming function for angiography and cameras and 2) a verbal communication function [Figure 1]. We use medical software, which complies with medical information guidelines (Ministry of Health, Labor and Welfare "Guidelines for Safety Management of Medical Information Systems" 2021/1), for the live streaming function (JOIN; Allm Inc, Tokyo, Japan). Because angiography devices and cameras in operation contain medical information, streaming from angiography is delivered to the system cloud through the encoder, a JOIN Gateway server (JGW). Steaming from the camera is delivered to the cloud through the JGW. The system users can access the closed cloud system through smartphones or tablets to see live streams from angiography. The system has a viewing function that allows the senior supervisor to view the images he or she wants to see, with multiple images simultaneously presented side by side. We use "Zoom" as the verbal communication program. We allow only the system user to access the Zoom event by linking it with the JOIN App. The endovascular surgeon wears a bone conduction headphone system connected with smartphones, tablets, or PCs. The endovascular surgeon sets up "Zoom" through "JOIN." The remote doctor sets up "Zoom" through "JOIN" with smartphones, tablets, or PCs. Then, they can start communication. The systems introduced in each hospital are shown in [Table 1].

The system allows us to display AP, lateral view; native AP, lateral view; reference AP, lateral view; and workstation images, in addition to the 4K operator's procedure streaming video camera and the 4K operating room (OR) view video camera on the monitor of any smart devices. A total of eight images can be displayed simultaneously on the iPad (Apple Inc., Cupertino, CA, USA) [Figure 2]. The remote supervisor can select one of the images on the touch screen of the iPad or smartphone to magnify the images. All communication between the endovascular surgeon and remote supervisor can be conducted through bone conduction headphones (endovascular surgeons). In this study, two independent observers checked the data transmission delay time at the angiography suite and remote supervisor's office when a scheduled unruptured aneurysm procedure was conducted. The speed delay was verified by the digital subtraction angiogram (DSA) and the quality of the camera image that the doctor confirmed to be clinically available. Then, we recorded images from both DSA and camera monitoring in the hospital and that out of the hospital in parallel and measured the delay speed with a stopwatch.

RESULTS

The operator was able to speak with the senior supervisor through a bone conduction headphone and to talk to assistants or radiology technicians without any hearing difficulties [Figure 3a]. The remote supervisor could check

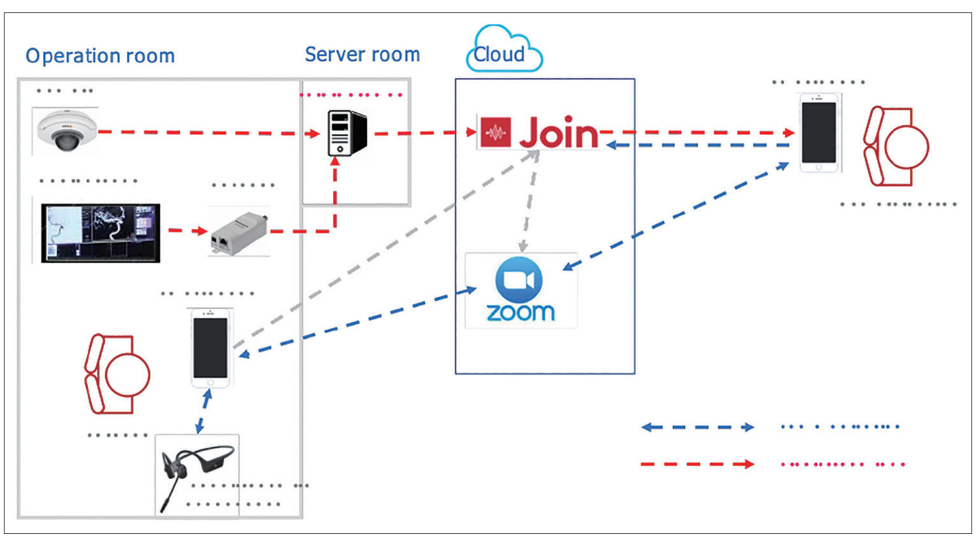

Figure 1: System configuration.

streaming images with almost the same imaging quality as real DSA monitors, and he advised the handling of devices and preparation through 4K video camera systems.

We used 4G Long Term Evolution (LTE) and internet WiFi as the network infrastructure. However, the hospital with the interventional specialist could not use 4G LTE because the radio waves did not reach the OR where we conducted the measurements. The range of delay speed was approximately 1–2 s [Table 2]. In the affiliated hospital (Kanagawa prefecture), we could use both 4G LTE and internet WiFi. There was no difference in delay speed between the two methods. The range of delay speed was also approximately 1–2 s.

Illustrative case 1

A 73-year-old patient who had an unruptured intracranial IC ophthalmic aneurysm was scheduled for stent-assisted coiling at the affiliated hospital (Kanagawa Prefecture). Under general anesthesia, the guiding system was advanced into the right internal carotid artery (ICA), and the microcatheter was placed in the aneurysm sac. The operator and consultant, who were located at the hospital with the interventional specialist (Tokyo), discussed the treatment strategy by viewing the same 3D workstation before the procedure. The distance between the 2 institutions was 30 miles. The consultant used 2 display systems and advised placing the microcatheter tip at the center of the aneurysm, and subsequently, a low profile visualized intraluminal support stent (Microvention/Termo, Tokyo, Japan) was placed. The consultant detected slight proximal stent corning before the operator realized it because of the high magnification of the image on the iPad (Apple Inc.). All procedures were safety conducted in the same manner as those under conventional supervision. There were no communication errors or image deteriorations during the procedures [Video 1].

Table 1: Systems introduced in each hospital.

	Hospital with interventional specialist (Supervisor)	Affiliated hospital (Endovascular surgeon)
Camera	Sony, Tokyo, Japan	Axis Communication, Lund, Sweden
Angiography	Siemens, Erlangen Germany	Canon, Tokyo, Japan
Encoder	STRASSE, Tokyo, Japan	Carina System, Kobe, Japan
Bone conduction headphone	AfterShokz, Texas, Austin	AfterShokz, Texas, Austin

Illustrative case 2

An 80-year-old female who presented with hemiparesis was transferred to the affiliated hospital. Her NIHSS scale was 13. CT and imaging work-up demonstrated left ICA occlusion [Figures 3b and c]. The junior staff neurosurgeon called a senior specialist who was already on-call at home for emergency procedures [Figures 3d and e]. Senior specialists conducted remote supervision from their homes to save time. During the procedure, junior staff could discuss the procedural strategy with senior staff. Using the same setup, the clot was successfully removed from the ICA and middle cerebral artery segments without any procedural complications.

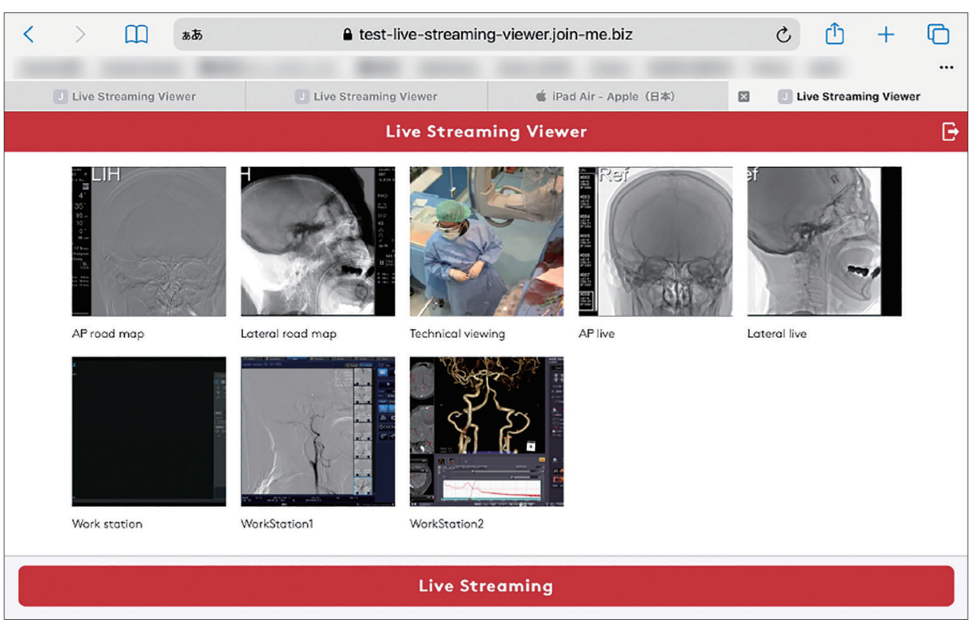

Figure 2: Live streaming display on iPad. Eight images can be displayed at the same time. By selecting the screen, images can be freely enlarged or reduced on the iPad.

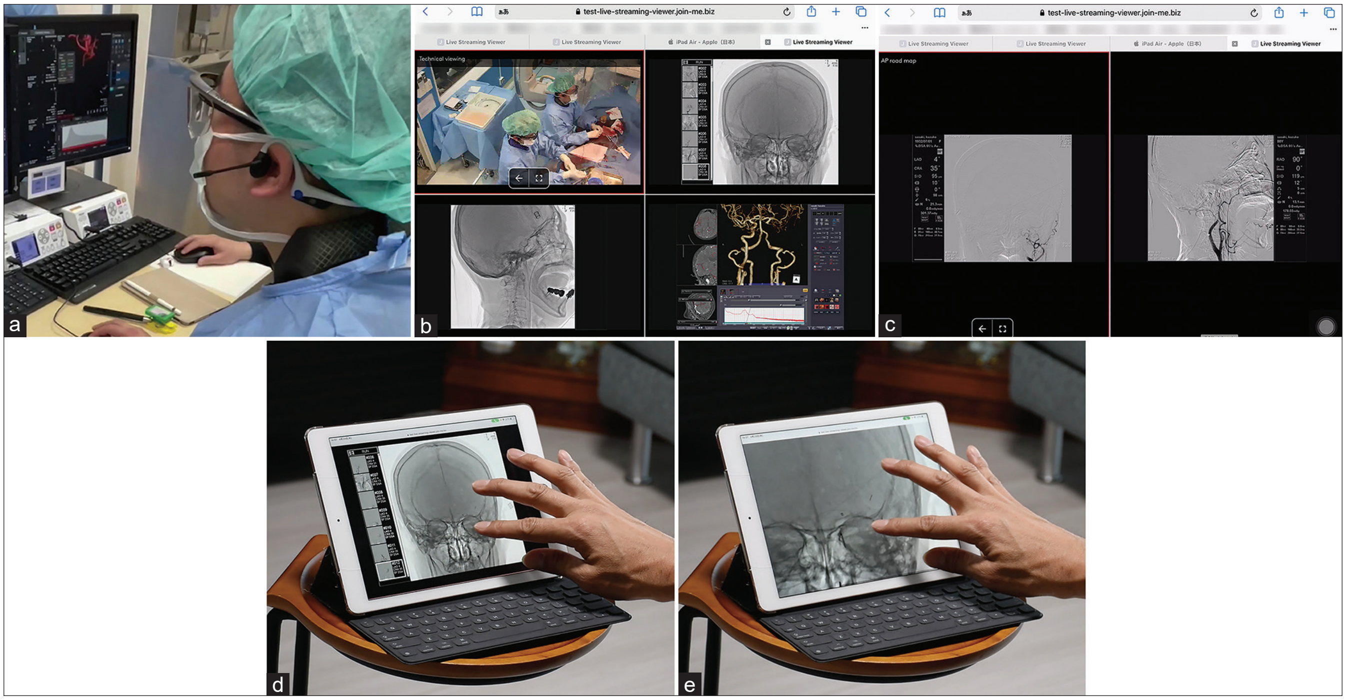

Figure 3: Acute ischemic stroke supervised at home. Acute ischemic stroke due to the left middle cerebral artery occlusion. Thrombectomy with a stent retriever was performed by neuroendovascular trainees. The operator was able to speak with the senior supervisor through a bone conduction headphone and to talk to assistants or radiology technicians without any hearing difficulties (a). Live streaming images of split monitors on the iPad (b). By selecting areas on images, left ICA occlusion was made clearly visible on the screen (c). The supervisor at home could freely change the size of the image by pinching in and pinching out. The senior physician could supervise the procedure while at home (d and e).

Table 2: Speed delay between the source and devices in each hospital.

Place	Source	Internet access	Internet speed (Download)	Devices	Speed delay
Affiliated hospital (Endovascular surgeon)	DSA	WiFi	26 Mbps	iPad	1.9 s
		4G LTE	14 Mbps	iPhone	1.9 s
	Camera	WiFi	13 Mbps	PC	1.2 s
		4G LTE	14 Mbps	iPhone	1.2 s
Hospital with interventional specialist (Supervisor)	DSA	WiFi	33 Mbps	iPhone	1.4 s
		4G LTE	NA	iPhone	
	Camera	WiFi	33 Mbps	iPhone	1.2 s
		4G LTE	NA	iPhone	

s: Seconds, DSA: Digital subtraction angiogram, Mbps: Megabits per second, LTE: Long-term evolution

DISCUSSION

Telemedicine is a rapidly growing component of the global health-care system under the circumstances of COVID-19.[11] Especially in stroke medical care, the benefits of telemedicine are remarkably demonstrated because urgent treatment is required. At the same time, it is necessary to protect medical staff from infection. We have developed a telemedicine network system using medical software that complies with medical information guidelines. JOIN[10] is a communication application for smartphones and tablet devices that operate over current high-speed networks (LTE, 4G, 5G). This is cloud-based remote radiology related to smart device "chat" consultation applications, first approved as a medical device by the Ministry of Health, Labor and Welfare. Medical professionals such as doctors, nurses, and radiologists can share patient medical information and still/streaming images in Digital Imaging and Communications in Medicine format on high-resolution screens of smart devices. The JOIN system was initially developed for interdoctor telemedicine systems in the field of neurosurgical disorders and was first approved as a commercial medical app in Japan.[8,10] We have

Video 1: Video of the illustrative case 1.

improved this system and developed a telemedicine system that enables two-way communication between audio and video in real time.

Because of a shortage of experienced neuroendovascular specialists, emergency stroke care for stroke intervention is limited. Young neurosurgeons who have just completed fellowships are sometimes dispatched from university hospitals to affiliated local hospitals to cover regional medical services. They need expert supervision when complex stroke patients are transferred to their hospital. However, since the beginning of the COVID-19 pandemic, there have been unprecedented limitations in the movement of people. In such situations, remote consultation systems with real-time audio-visual capability are extremely useful for safe procedures. In this report, we demonstrated the usefulness of a remote supervision system for young physicians. This system has several potentials, such as a two-way education system. Skilled physicians can demonstrate their technique for residents, trainees, or junior attending's for teaching purposes under restrictions of patient privacy and security. Resident education or device training has also been restricted by hospital infection control. Using this system, trainees can learn the endovascular cutting-edge technique using their own monitoring system, such as the iPad. A similar system was reported by Orru *et al*.[6] for endovascular proctoring purposes in the United States and Canada. In their system, images were controlled by the operator site, not the proctor site. Bechstein *et al*.[1,2] also reported endovascular proctoring achieved by using a specialized live camera system. After COVID also believes that this system must be utilized. Due to the influence of COVID, people are accustomed to teleconferencing, telemedicine, etc. This practice will continue with After COVID. In stroke practice, a significant strength of the system is that neuroendovascular specialists do not have to be always on standby in or near the hospital. Excessively speaking, even if you are abroad, it is a great advantage to receive treatment advice in real-time as if you were in the operation room. A feature of our system is that telemedicine is possible using an iPad or iPhone, and the size can be changed with a finger while maintaining the high resolution of the image.

One limitation of this system is the requirement for a secure encoder system that connects the hospital DSA/streaming video network. The system anonymizes private patient data, such as the patient's name or ID. Only the patient's age and case number are displayed. This system transmits images in an unidentified HIPAA-compliant manner and complies with national guidelines.[7]

Despite such Japanese HIPPA compliance[7] clearing the cloud system, illegal recording should be strongly restricted for patient privacy. However, there are several things to note in the patient protection and legal areas when operating this system. At first, the patient's face, etc., may be shared in remote areas. By adjusting the position of the camera, the patient's privacy is protective. It is desirable to devise such as blurring the screen, but it is technically advanced and may affect the communication speed. The second point is the surrounding environment when viewing images in remote locations. If other people are in a situation where they can see the screen, it is possible for an unspecified number of people to see the image. Regarding these, it is necessary to make rules for remote surgery support.

CONCLUSION

Under COVID-19 conditions, a remote consultation system with real-time audio-visual capability may play an important role in acute stroke management while maintaining the quality of patient care.

Ethics approval statements

The study protocol was reviewed and approved by the ethics committee and the research review board at the affiliated hospital. All patients were provided informed consent, and each site had obtained Institutional Review Board approval and signed consent forms. The participants and any identifiable individuals consented to the publication of their image.

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Authors' contributions

All authors have met the four criteria for authorship, as described by the journal.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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