Medical Applications of 8K Technology

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Video technology is an aspect of broadcasting that has been applied to various industries as a means of visualization. In particular, various life-saving advances have been made in the medical field through the prompt application of the latest video technology. Here, we introduce the efforts made by NHK Engineering System Inc. (NES)[1][2] to apply 8K technology developed by NHK to the medical field.

1. Development of an 8K camera and filming of surgery

Medical applications of 8K began with the filming of various surgical procedures in 8K. During each year from 2010 to 2014, we filmed heart surgery operations using 4K/8K cameras so that live video can be transmitted to other venues and presented at large-scale conferences attended by many medical professionals (organized by Tokyo Heart Lab).

In 2014, as part of an 8K technology demonstration experiment by the Ministry of Internal Affairs and Communications, we obtained 8K video of operations being performed in the fields of cardiac surgery, esophageal surgery, and liver/gall bladder/pancreas surgery at the University of Tokyo Hospital. These were presented at conferences related to each field within the hospital in order to elicit the opinions of medical professionals on the usefulness and issues of 8K images.

In 2014, we also obtained 8K video of an off-pump coronary artery bypass procedure performed by Dr. Atsushi Amano of Juntendo University Hospital. Dr. Amano is a cardiac surgeon who performs highly difficult coronary artery bypass surgery while the heart is beating and without the use of an artificial heart (i.e., off-pump). In the 8K video, it is even possible to see subtle deformations of the vessel walls while the blood vessels are being sewn together with fine thread. This highlighted the usefulness of 8K video in medical applications, with viewers remarking that it was possible to grasp the amount of force applied to the thread, and that this sort of video is extremely useful for passing on the skills of skilled physicians [2].

In February 2015, an 8K camera was attached to a surgical microscope to film a neurosurgical operation performed by Dr. Arakawa of Kyoto University School of Medicine (Fig. 1). Here, the lead surgeon and his assistant performed the surgery while looking through a microscope, and the same operative site was filmed from different optical paths. It may eventually capture microscope images with an 8K camera so that surgery can be performed while viewing a large 8K monitor.

Figure 1: A neurosurgical procedure performed under a microscope (2015)

These demonstrations not only confirmed the usefulness of 8K in the medical field, but also helped us to accumulate know-how and clarify the requirements for cameras and other equipment for such purposes. It was also suggested that 8K could be used for education by filming and storing video footage of surgeries performed by prominent surgeons.

2. Experimental demonstration of 8K telemedicine

For some time, hopes have been pinned on the use of telemedicine as a way of addressing the uneven regional distribution of medical experts and regional disparities in advanced medical care. If the use of 8K technology makes it possible to perform diagnoses that have been difficult to make with conventional technology, then it could bring about rapid progress in telemedicine. In 2016, a telemedicine demonstration experiment in which video was captured, transmitted and displayed using 8K technology was conducted by the Ministry of Internal Affairs and Communications to verify the applicability of 8K to telemedicine and the medical efficacy of this technology.

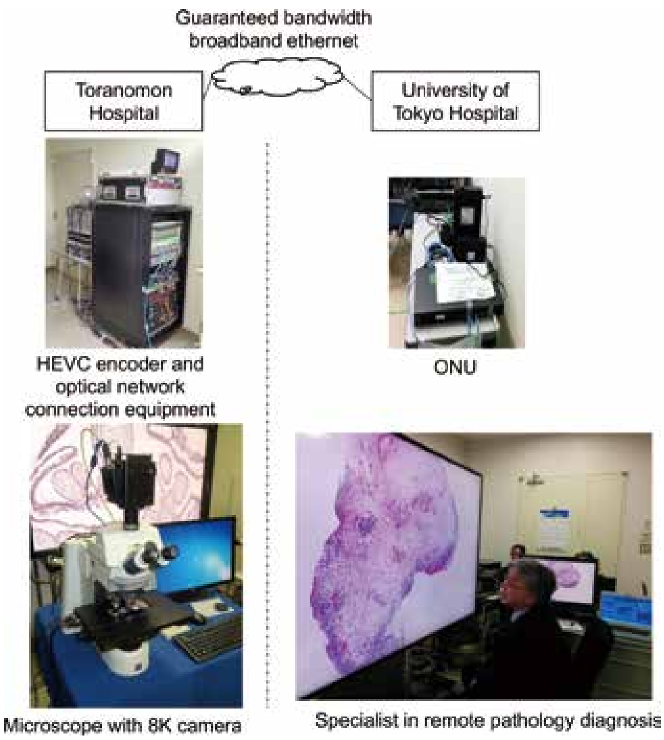
(1) Remote pathological diagnosis

Pathological diagnosis involves examining thin sections of organ parts, etc. under a microscope to check for the presence of cancer cells, bacteria, or lesions. In the case of cancer surgery, rapid pathological diagnosis is performed while surgery is in progress to confirm whether a tumor has been completely removed, and that the surfaces left after excision do not contain any cancer cells. However, since pathologists are not available at every hospital that performs cancer surgery, there is a need for the implementation of high-precision remote pathological diagnosis.

In this experiment, a microscope equipped with an 8K camera was installed in a hypothetical hospital with no pathologist, and the 8K images were transmitted over broadband Ethernet to a specialist hospital where they could be observed by a pathologist for diagnosis. The video signals were encoded using the HEVC (H.265) compression standard. Figure 2 shows an overview of the experiment.

The results of this experiment showed that 8K remote diagnosis is not inferior to direct diagnosis (103 out of 104 correct answers). The 8K remote diagnosis system is also ideal for displaying large areas of prepared specimens at once on a single high-definition screen so that the pathologist can approach the screen to get a close-up view of areas of interest in much the same way as would be achieved by switching the objective lens of a microscope. This new system is expected to be effective at improving diagnostic accuracy and reducing the burden on the medical examiner.

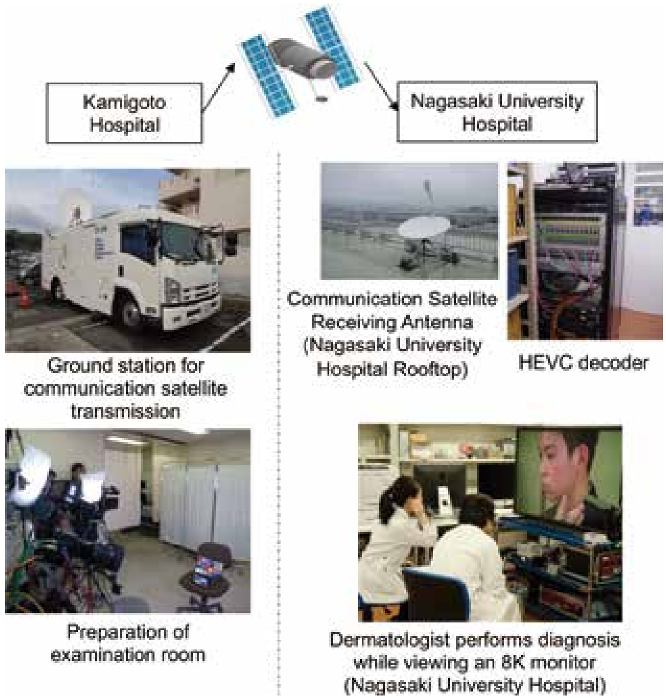
■ Figure 2: 8K remote pathological diagnosis demonstration experiment (2016)



(2) Telemedicine Support

To demonstrate the use of 8K technology in supporting telemedicine, we chose the field of dermatology, where visual information is considered to be of particular importance. Using a satellite link, we connected a remote island hospital in Nagasaki Prefecture, which has no full-time dermatologist, to a university hospital where a dermatologist was able to provide experimental telemedicine support. 8K images of the affected areas of patients were transmitted to the dermatologist, who was able to view them while interviewing the patients and giving instructions to the doctor on the remote island to enable to acquisition of information necessary for diagnosis. An outline of the experiment is shown in Fig. 3. By comparing the results of diagnoses made by dermatologists in person with those made by remote diagnosis, we found that the rate of agreement between these results was much higher than achieved using conventional video systems such as HD. The dermatologists who participated in the experiment commented that the ability to observe minute lesions made it possible to recognize signs of malignancy and refer patients for more thorough examinations at an earlier stage. On the other hand, it became clear that there is a need for imaging equipment that is smaller, more sensitive, and as easy to use as consumer-oriented cameras.

■ Figure 3: 8K telemedicine support demonstration (2016)



3. Research and development of an 8K rigid endoscopic (laparoscopic) surgical system

A rigid endoscope is a non-flexible endoscope that basically consists of lenses built into a metal pipe, unlike a soft endoscope (which is called a gastric camera). A camera is usually attached to the eyepiece so that surgery can be performed while viewing the images displayed on a monitor. A laparoscope is a rigid endoscope that is used to observe the interior of the abdominal cavity. Most rigid endoscopes use 2K cameras, but 4K endoscopes are also commercially available. To develop an 8K rigid endoscope system, it is necessary to develop a compact and high-performance 8K camera and high-performance rigid endoscope lenses that match the high-resolution performance of 8K.

In December 2015, in collaboration with the National Cancer Center Hospital and Olympus Corporation, NHK Engineering System Inc. (NES) successfully filmed the intra-abdominal cavities of animals by using an 8K camera in combination with a 4K rigid endoscope. Despite only using 4K apparatus, on seeing the 8K images for the first time, the medical professionals were surprised to find that the images were clear enough to demonstrate the benefits that can be expected from 8K technology.

In addition to clearer images, the medical professionals also expressed their hopes for the following benefits:

(1) With existing laparoscopes, it is often necessary to bring the tip of the laparoscope very close to internal organs for a closer look at the affected area, and as a result, the laparoscope is liable to get in the way of the surgical implements. With 8K resolution, it would be possible to obtain a detailed view of the affected area by observing the operation area from an overhead position and using electronic zoom when a close-up view is needed, thereby resulting in fewer blind spots and less interference between the surgical instruments and the laparoscope.

(2) With an 8K system, it is relatively easy to identify nerves that are difficult to see with conventional laparoscopy. This is expected to be effective for preserving autonomic nervous system functions in operations such as colorectal cancer surgery.

■ **Figure 4: 8K endoscopic camera system Top: Model #1 (2017), Bottom: Model #2 (2020)**

■ **Figure 5: Clinical trial of the 8K endoscopy system**

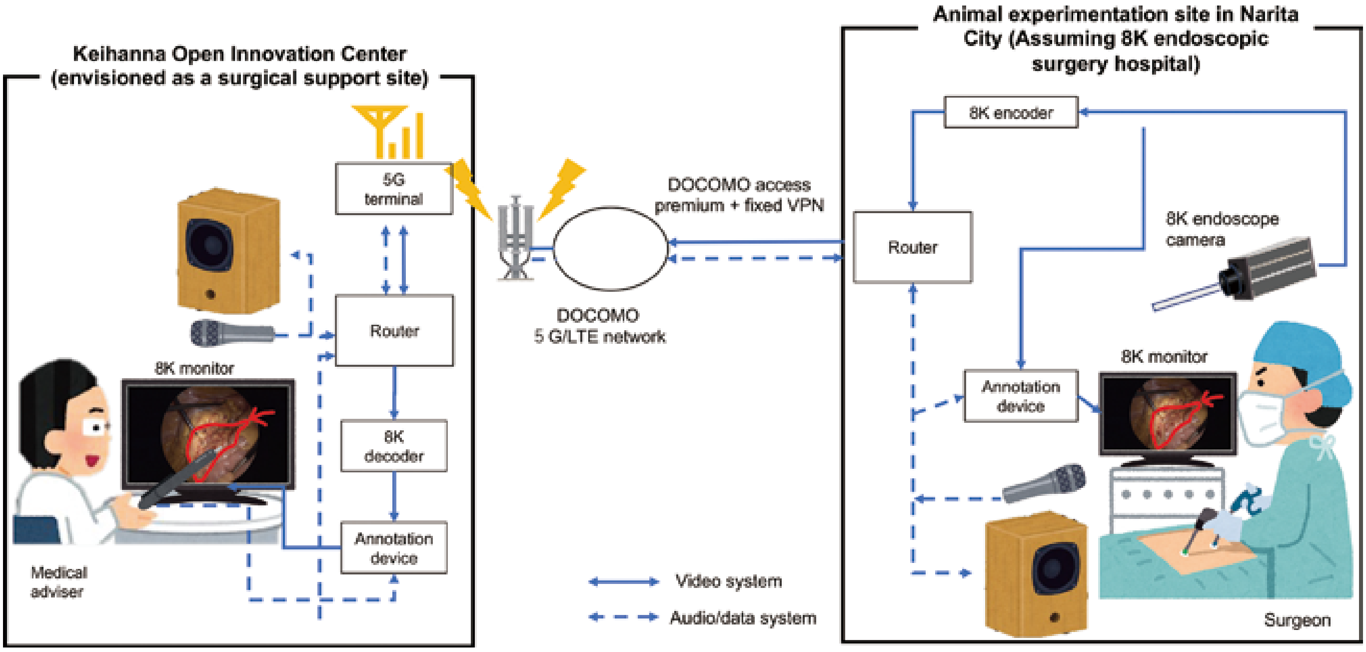
A research group that includes the National Cancer Center, Olympus and NES was entrusted by the Japan Agency for Medical Research and Development (AMED) to conduct research and development related to 8K laparoscopic surgery systems over the two periods of FY2016–8 and FY2019–21.

In the first period, we worked on the development of a compact, high sensitivity 8K camera and an electronic zoom device, and we performed animal experiments to verify the performance of the 8K system combined with a prototype 8K laparoscope made by Olympus. This 8K laparoscopic camera is shown in the upper part of Fig. 4. The camera is a modified broadcast camera using a 1.7-inch imaging device[4], and the camera head connected to the laparoscope weighs 720 g. In addition to this camera, we also implemented functions including an electronic zoom function (magnification 1.0–4.0×) that scales up a section of the 8K image. From March 2018 to March 2019, we conducted clinical trials of this system in 25 cases to verify the effectiveness of the 8K endoscopy system (see Fig. 5). The results showed that the amount of blood loss during operations was reduced to about half that of conventional laparoscopic surgery, while the camera, although smaller, was still large and made it difficult to change the operation area during surgery [5].

4. Development and validation of an 8K rigid endoscopic surgery system for remote surgery assistance [6]

These clinical trials showed that although the 8K endoscopic surgery system is effective, further downsizing of the camera is also required. Based on these findings, we were commissioned by AMED to research and develop a remote surgery-assisted endoscopic surgery system for three years from FY2019 to FY2021. Recently, endoscopic surgery has become increasingly commonplace due to its low patient burden, but because it requires advanced skills, there are sometimes insufficient specialist surgeons in certain areas. We have developed an endoscopic surgery system for remote surgery assistance as a candidate technology for alleviating regional disparities in the availability of endoscopic surgeons. This system transmits endoscopic video images obtained during surgery to a remote specialist, who is able to monitor the progress of the surgery and offer advice to the surgeon in the operating theater while observing the endoscopic surgery in progress. This makes it possible to provide support to inexperienced surgeons and assistants. The purpose of the 8K endoscope is to make it possible for specialists to provide accurate

■ **Figure 6: System configuration of the remote surgery support experiment using live 8K live video transmission**



■ **Figure 7: Experimental animal surgery performed with remote surgical support**
Left: A specialist doctor provides verbal and written instructions via an 8K monitor (Kyoto Prefecture); Right: The surgeon proceeds with the surgery in accordance with the specialist doctor's instructions (Chiba Prefecture)

surgical support based on high-definition, highly realistic intra-abdominal images sent from remote locations.

NES developed this system after clarifying the above system requirements, and confirmed its medical effectiveness in animal experiments.

Prior to the development of the system, evaluation experiments were conducted with medical professionals to determine the bandwidth required for compression coding of 8K endoscope images and the acceptable lag time of transmitted images. As a result, it was found that a transmission bandwidth of at least 70 Mbps or thereabouts is required, with a video transmission lag time of no more than 1.3 seconds. The video coding method is H.265.

For the 8K camera that forms the core of the system, we developed an endoscope camera using a compact 8K medical camera that was jointly developed by NES and Ikegami Tsushinki (Figure 4, bottom). The camera weighs 210 g, which is less than a third of the weight of the #1 model. We also developed a camera control unit (CCU) with electronic zoom and autofocus functions. This camera is light enough to be used with a commercially available scope holder, making it easily adaptable to surgical applications. We also developed a system including an 8K video encoding and transmission device and a drawing and display device (annotation device) that can be used to write support information on the 8K screen and send it back to the operating theater, which is a necessary feature for supporting remote surgical operations.

5. Experiment verification of the remote operation support system[6]

To verify the effectiveness of this system, we conducted an animal experiment in which an inexperienced endoscopic surgeon and a surgical assistant were provided with guidance by a specialist physician who was able to view the 8K endoscopic images at a remote location. We compared the time taken to complete the surgery and the quality of operations performed with and without remote guidance. Figure 6 shows the system configuration used in this experiment. The experiment was conducted by connecting an animal experimentation site in Narita City, Chiba Prefecture, with the Keihanna Open Innovation Center, Kyoto Prefecture, via a wired network and 5G network so that 8K endoscopic images, bidirectional audio and on-screen instructions could be conveyed between the two sites. Figure 7 shows the setup at each end of this connection. The 8K video was transmitted at a bit rate of 80 Mbps, and the transmission lag from the endoscopic camera to the 8K display device at the remote site was approximately 600 ms.

Our experimental results show that two inexperienced surgeons were able to perform the same procedure in less time with remote guidance than without. We also evaluated the quality of surgery with and without support, based on the endoscopic images, and found that operations achieved better quality with remote guidance than without.

6. Future prospects

We have introduced activities on medical applications of 8K technology conducted by NES. High-definition imaging technology has always attracted attention in the medical field, and applications in this field have always been promoted. However, this trend is becoming particularly strong in the 8K era. In addition, "contactless" and "remote" technologies have become particularly important in the wake of the coronavirus pandemic over the last couple of years, and 5G is also expected to become an important part of the communications infrastructure. The combination of two cutting-edge technologies, 8K and 5G, is likely to become increasingly important in the medical field.

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Cover Art

View of Mount Haruna in the Snow, from Famous Views of 60 Provinces

Utagawa Hiroshige (1797-1858)

Source: National Diet Library, NDL Image Bank (https://rnavi.ndl.go.jp/imagebank/)