Development of 8K-UHD 3D Display for Advanced Digital Surgical Imaging

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ABSTRACT

We have developed a prototype of 55-inch 8K ultra-high definition (UHD) three-dimensional (3D) display using a polarization filter for advanced digital surgical imaging with the new camera system with 8K-UHD resolution (7680 x 4320 pixels), which is 16 times as much as that of high-definition (HD; 1920 x 1080 pixels).

1 INTRODUCTION

We started medical applications of an 8K UHD imaging technology since 2009, based on UHD camera technology for broadcast field[1-4]. After 8K UHD laparoscopic animal experiment in 2013 and 8K UHD laparoscopic cholecystectomy surgery in 2014[5] using a prototype 8K UHD camera of over 2 kg. For microscopic surgery, we tried preliminary evaluation in eye surgery using a prototype 8K UHD camera mounted on a camera port of standard surgical microscope in 2014[6]. These trials were progressed as a part of activities of Medical Innovation Consortium. Furthermore, since clinical needs for three-dimensional (3D) camera and monitoring system were high in endoscopic and microscopic surgery, we started development of prototype of the 8K-UHD 3D display from 2016 based on a 55-inch IPS LCD (Panasonic Liquid Crystal Display Co., Ltd., Himeji, Japan)[7].

In this paper we report collaboration between 8K-UHD medical camera technology and 8K-UHD 3D display for near-future advanced digital surgical imaging

2 Methods

2.1 8K UHD rigid endoscope system

Kairos Co. Ltd succeeded the reduction of the 8K-UHD camera weight to 370 g which can truly be practicable in the medical field and finally commercialized as a medical device by Kairos Co., Ltd in 2017 in Japan[8].

An 8K UHD endoscopic system comprises an 8K UHD endoscope, light source, camera control unit (CCU), 8K UHD recorder, interface converter, and 8K UHD liquid crystal display (LCD) as shown in Fig. 1. The 8K UHD endoscope consists of an 8K UHD camera head, lens adapter, and rigid endoscope. The CCU has a signal processing board with various functions, such as calibration of the color balance and gain in real time, digital zooming (1.0-4.0x), gamma curve compensation, and resolution enhancement of the 8K UHD endoscopic images. Surgeons can observe thin blood vessels, thin membrane structures, important nerve fibers and the boundary between tumor and normal tissues which have been hard to see clearly. Moreover, with a digital zooming function the endoscope can be positioned to stay high up close to the abdominal wall, presenting a bird's eye view of the operative field to prevent the surgical instruments and endoscope from interfering with each other, allowing the surgeon more space to perform surgical maneuvers.

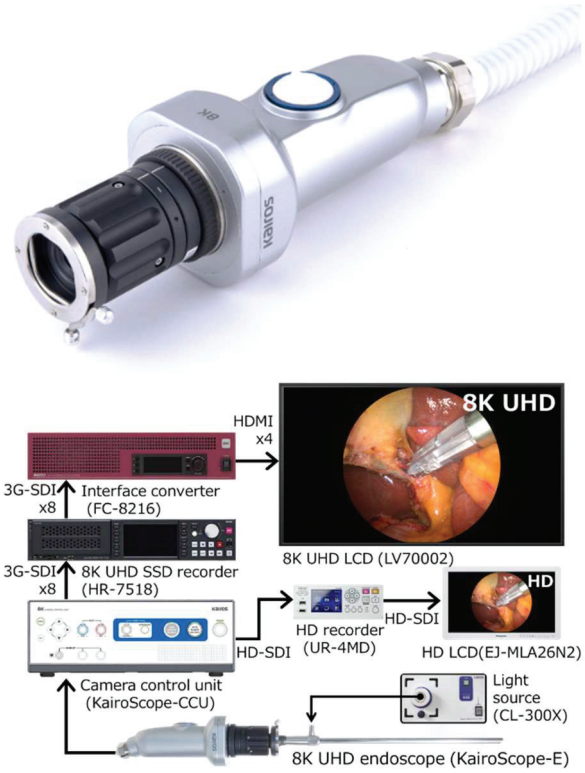

Fig. 1 System configuration example of the 8K-UHD rigid endoscopic system. Above figure shows an 8K-UHD camera head. Below figure shows a standard connection configuration from the 8K-UHD endoscope to 8K-UHD display[8].

2.2 8K-UHD microsurgery system for eye surgery

Our new 8K UHD camera, developed for endoscopic surgery at first, was enabled to be attached to a camera port of a commercialized ophthalmology microscope (Carl Zeiss, Zeiss Lumera T, Oberkochen, Germany). A 70-inch 8K-UHD 2D display (LV-70002; Sharp Corporation, Osaka, Japan) was placed in front of a surgeon. Fig. 2 shows the operating room site using an 8K-UHD microscopic camera for ophthalmic surgery to a pig eyes in 2018.

Fig. 2 The latest 8K UHD microscopic camera test for ophthalmic surgery using a pig eye in the operating room in 2018.

2.3 Prototype of the 8K-UHD 3D display

Fig. 3 shows our prototype of 55-inch 8K-UHD 3D IPS-LCD panel with a line-by-line circular polarization filter (Xpol®, Arisawa Manufacturing Co., Ltd., Niigata, Japan). We developed an 8K-UHD 3D display based on this panel and an 8K-UHD 2D monitor (DM-3815, ASTRODESIGN, Inc., Tokyo, Japan), Viewing-distance is about 1.2~1.5 m in operating room because of its vertical viewing-angle is +/-4 degrees with 3D glasses[7].

Fig. 3 Sample of 8K-UHD 3D surgical image (CG) with line by line format.

2.4 Prototype of the 8K-UHD 3D converter

Kairos Co. Ltd., developed a prototype of 8K-UHD 3D converter based on the previously reported technology of the 3D converter for endoscopic surgical HD image[9]. From a monocular 8K-UHD camera 2D image, simulated parallax right-eye and left-eye images are generated. These images are output to 8K-UHD 3D display with line-by-line circular polarization filter for observers with 3D grasses (Fig. 4).

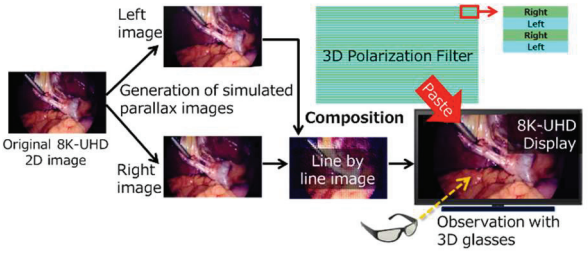

Fig. 4 8K-UHD 3D converting flow from a monocular 8K-UHD camera 2D image to a line-by-line format virtual binocular 3D image.

3 RESULTS

3.1 Demonstration of 8K-UHD 3D static images

In medical exhibition in Japan, we demonstrated 8K-UHD 3D static images, which was generated by right and left 8K-UHD recorded images on the prototype of 8K-UHD 3D display (Fig. 5). Visitors in our exhibition booth gave their comments that "pixels cannot be seen at all in this display.", "it seems to be natural 3D, different from conventional 3D display", and “real things are like in front of me." and so on.

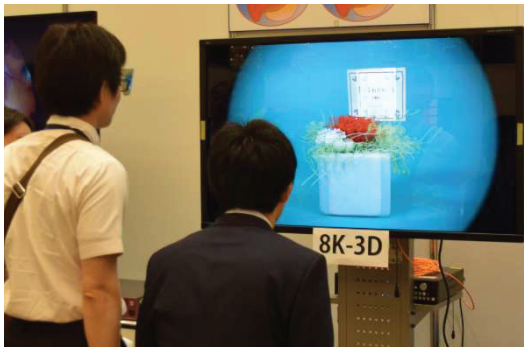

Fig. 5 Exhibition of the prototype of 8K-UHD 3D LCD in 2017

3.2 8K-UHD 3D monitoring in eye surgery

We tried to show surgeons some 8K-UHD 3D videos of clinical eye surgery after recording of their cataract surgery, glaucoma surgery and vitreous surgery in operating room in 2018 (Fig. 6). 8K-UHD 3D videos were converted from monocular 8K-UHD camera videos in real time with parameters adjustment such as parallax, convergence angle and magnification ratio. Using the 55-inch 8K-UHD 3D IPS LCD and 3D glasses, surgeons said that these 8K-UHD 3D images were more natural than conventional binocular HD 3D image. However, 8K-UHD 3D image quality depended on the brightness detected by 8K-UHD monocular camera through optical lenses of surgical microscope.

Fig. 6 Observation of 8K-UHD 3D converted eye surgery images with 3D glasses.

3.3 8K-UHD endoscopic 3D video demonstration

We tried to show medical professionals 8K-UHD 3D endoscopic videos converted from recorded 8K-UHD 2D videos in The 31st Annual Meeting of the Japan Society for Endoscopic Surgery (JSES 2018) (Fig. 7). Some surgeons who had already experienced just 8K-UHD "2D" endoscopic surgery were surprised at 8K-UHD 3D images they didn't see during their endoscopic surgery.

Fig. 7 Observation of 8K-UHD 3D converted laparoscopic surgery video with 3D glasses.

4 DISCUSSION

We have developed a prototype of 55-inch 8K-UHD 3D display using a circular polarization filter for advanced endoscopic and microscopic imaging with the new medical camera system with 8K-UHD resolution. The combination of 8K-UHD 3D display and 8K-UHD medical camera has a possibility to realize realistic surgical images just like surgeons are seeing them with the naked eye.

On the other hand, the 8K-UHD 3D display requires to resolve a technical issue about narrower vertical viewing-angle than one of a conventional 3D display with HD to 4K-UHD resolution. In addition, we have to improve the perfection of prototype of 8K-UHD 3D converter for a monocular 8K-UHD 2D camera with parameters tuning.

We believe that 8K-UHD 3D imaging system is very likely to lead to major changes in the future of medical practice, not only in typical video endoscopic surgery but also in ocular-free heads-up surgery in microscopic surgery for safer and successful microsurgery by multi-eyes observation and reducing surgeons' stiff shoulders/neck, backache, and eye strain.

In conclusion, image quality of our prototype of the 8K-UHD 3D display is sufficiently high and might be practically useful, however, improvement of vertical viewing-angle is urgent issue for use in operating room. We strongly wish mass production model of 8K-UHD 3D medical display for our advanced digital surgical imaging.

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