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Questionnaire survey of virtual reality experiences of digestive surgery at a rural academic institute: A pilot study for pre-surgical education

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ABSTRACT

We developed a prototype VR platform, VECTORS L&M (VLM), aiming to enhance the understanding of digestive surgery for students, interns, and young surgeons by limiting costs. Its efficacy was assessed via questionnaires before implementation in surgical education. The VLM provides nine-minute VR views of surgeries, from both 180- and 360-degree angles. It was created with L.A.B. Co., Ltd. and incorporates surgery videos from biliary malignancy patients. Following VLM development, a survey was conducted among surgeons who had experienced it. Twenty-eight participants (32% of observers) responded to the survey. A majority (81%) reported positive experiences with the VR content and showed interest in VR video production, though some reported sickness. Most respondents were experienced surgeons, and nearly all believed VR was important for medical education with a mean score of 4.14 on a scale of up to 5. VR was preferred over 3D printed models due to its application versatility. Participants expressed the desire for future VR improvements, such as increased mobility, cloud connectivity, cost reduction, and better resolution. The VLM platform, coupled with this innovative teaching approach, offers experiential learning in intraabdominal surgery, effectively enriching the knowledge of students and surgeons ahead of surgical education and training.

Keywords: Surgical education, medical staff, internship doctors, digestive surgery, virtual reality

Video links: https://turkjsurg.com/video/UCD-6202-v1.mp4
https://turkjsurg.com/video/UCD-6202-v2.mp4

INTRODUCTION

The field of operative simulation systems using the latest computerized technology has witnessed significant advancements in the past two decades (1-5). Notably, the use of three-dimensional (3D) angiographic images from contrast-enhanced computed tomography (CT) has revolutionized surgical simulation and navigation, greatly enhancing the safety of surgical procedures such as the SYNAPSE VINCENT (Fujifilm Medical Co., Ltd., Tokyo, Japan), which enables surgeons to simulate the anatomy before surgery, proving invaluable for both training and experienced surgeons in preoperative simulation (5,6). These systems have gained widespread commercial popularity and convenience, leveraging high-resolution radiological images and advanced workstations.

Recently, extended or cross-reality (XR) technology, such as virtual reality (VR) and augmented reality, has found applications in the field of surgery. For instance, the Holoeyes MD system (Holoeyes Inc., Tokyo, Japan) uses 3D holograms to enhance the surgeon's understanding of surgical anatomy before and during operations (7,8). Recently, there has been a growing application of XR technology during the peri-Coronavirus disease 2019 era (9,10). While various VR systems have been adopted in the field of cardiovascular or orthopedic surgery worldwide, the development of VR for digestive surgery or operating nursing has been limited. Furthermore, the existing VR systems and contents in Japan still require high costs. Nonetheless, we

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still believe that XR, including VR, can significantly enhance the understanding of operative procedures for medical students and young trainees entering the surgical field. Evidence of educational or training usefulness for digestive organ surgery has not been fully elucidated. Therefore, it is essential to examine the significance of this technological advancement in the field of general surgery, from medical students to experienced surgeons. To develop a VR platform for digestive surgery education with reasonable costs, we collaborated with a rural company to produce the VR prototype content depicting the operating atmosphere and procedures. As a preliminary step, we conducted a surgical evaluation using a questionnaire among 28 surgeons at a rural academic institute, aiming to establish a practical and affordable VR educational platform in digestive surgery.

MATERIALS and METHODS

Participants

The VR contents presented in this study were experienced by surgeons who attended the 59th Kyushu Associations of Surgery, Pediatric Surgery, and Endocrine Surgery held in Miyazaki City, Miyazaki on March 10 and 11, 2023. The VR system used in this study, called the Virtual Educational Communication Tool for Operating Room in Surgery by L.A.B. Co., Ltd. (https://livecity.co.jp/LAB/index.php) and Miyazaki University (VECTORS L&M), was exhibited, and a total of 87 participants had the opportunity to try the prototype contents of VECTORS L&M. Eventually, 28 (32%) of 87 participants responded to our questionnaire. We followed the guidelines in the Declaration of Helsinki, which provides ethical principles for research involving human participants, including studies that use identifiable human material and information. The institutional ethics committee has approved our study protocol (C-0149, Date; 14.03.2023 and O-1116-2, Date: 08.05.2023). Informed consent was obtained from each participant using the opt-out method, where a declaration was presented on the website of the Clinical Research Support Center, University of Miyazaki Hospital, allowing participants to decline participation within one month.

VR Tool and Production of Surgical Contents

1. List of equipment used for photographing the operating field

The cameras used were the LUMIX GH5S (Panasonic, Osaka, Japan) and Insta360Pro2 (Insta360, Shenzhen, Guangdong, China). The storage medium was Blackmagic Video Assist 7” 12G HDR (Blackmagic Design, Melbourne, Australia). The crane for fixing the camera was SWIFT JIB 50 (Heiwa Seiki Industry Co., Ltd., Saitama, Japan).

2. Flow of setting imaging conditions at the operating field

The means for installing cameras were described as follows: During the process of installing the camera, ensuring safety (without contamination) and non-interference were considered absolute conditions. Based on these conditions, it was judged that the installation of a tripod was not adequate, and installation with a crane was proposed, and a test was conducted several times. As a result, we preliminarily confirmed that the system was safe and that the equipment did not obstruct the practitioner, and then we decided to introduce the final setting.

During the test shooting of the video, it was found that the luminosity of the operative field became a significant issue. The surgical shadow-less light used in the surgical field was positioned at a higher altitude than anticipated, and the video image was overexposed. Attempts were made to address this by adjusting the sensitivity of the International Organization for Standardization (ISO) and the shutter speed. However, when the luminous intensity was adjusted to match the operating field, the surrounding areas became excessively dark, posing a potential issue for future tests. The test footage was examined, and efforts were made to correct the video, but the overexposed and excessively dark portions of the footage could not be adequately adjusted. As a result, since it is difficult to respond with conventional MP4 file recording, we proposed to save it as a raw file and then edit it to selectively adjust the luminosity. Eventually, through further adjustments and additional fixes, it was determined that the basic problem was resolved, and the shooting conditions were established based on the results of the test shooting under the aforementioned conditions.

3. Production shooting: Equipment used and condition setting

The camera settings of the LUMIX GH5S were ISO 320, shutter speed 4000, anamorphic 3.3K, and 59.94 fps. In the first half, high-definition multimedia interface raw data was obtained by an output to video assist and shoot. The raw data settings showed the best quality settings, which were recorded on a 2TB solid-state drive. In the second half, we switched to vlog settings inside the camera, which was a secure digital memory card. By using Insta360 Pro2, the entire 360-degree inside operating room video with 8K and 29.97 fps was photographed from the wall. The quality level was determined to be high and was recorded on a 2TB solid-state drive.

4. Editing work regarding equipment and processes used for editing

The data captured using the Insta360 Pro2 camera was processed and converted into a 360-degree video using the Insta360 Stitcher software. Subsequently, at the Da Vinci Solve Studio at L.A.B. Co., Ltd. (Miyazaki, Japan), the raw and log data obtained from the LUMIX camera were subjected to color correction. Additionally, the video footage shot at the operating field using the Insta360 Pro2 camera underwent color correction as well. Eventually, Adobe Premiere Pro was used to

Figure 1. Wearing a VR headset by the author.

VR: Virtual reality.

convert the LUMIX footage into VR video format and edit it to include only the relevant parts for the evaluation by the main researcher's panel.

5. Watching VR videos

For the viewing of VR video, the DPVR® Pro (Shanghai, China), a 4K compatible headset licensed by L.A.B. Co., Ltd., was applied (Figure 1).

Patient selection

During an actual surgical procedure, a patient diagnosed with extrahepatic cholangiocarcinoma and scheduled for a pancreaticoduodenectomy was selected. A written informed consent with signature was obtained by this patient to record VR videos and for the secondary use of those videos in educational study. The operative video was captured from the skin incision to the intraabdominal procedures for one hour. To capture the perspective of the main operator, a 180-degree-angled video camera was positioned near the right shoulder, replicating the visual angle of a typical third assistant. Video of the delivery of operative forceps between the scrub nurse and the doctors was focused. The other side of the view from the first assistant operator was taken by the 180-degree camera as well (Figure 2, Supplement Video 1). The 360-degree camera was set at the entrance of the operating room, and the video of zoom-in and zoom-out focusing operators was arranged (Figure 3, Supplement Video 2). The time of the edited video from the 180- and 360-degree cameras was 15 and four minutes, respectively. Participants watched both videos and answered questions.

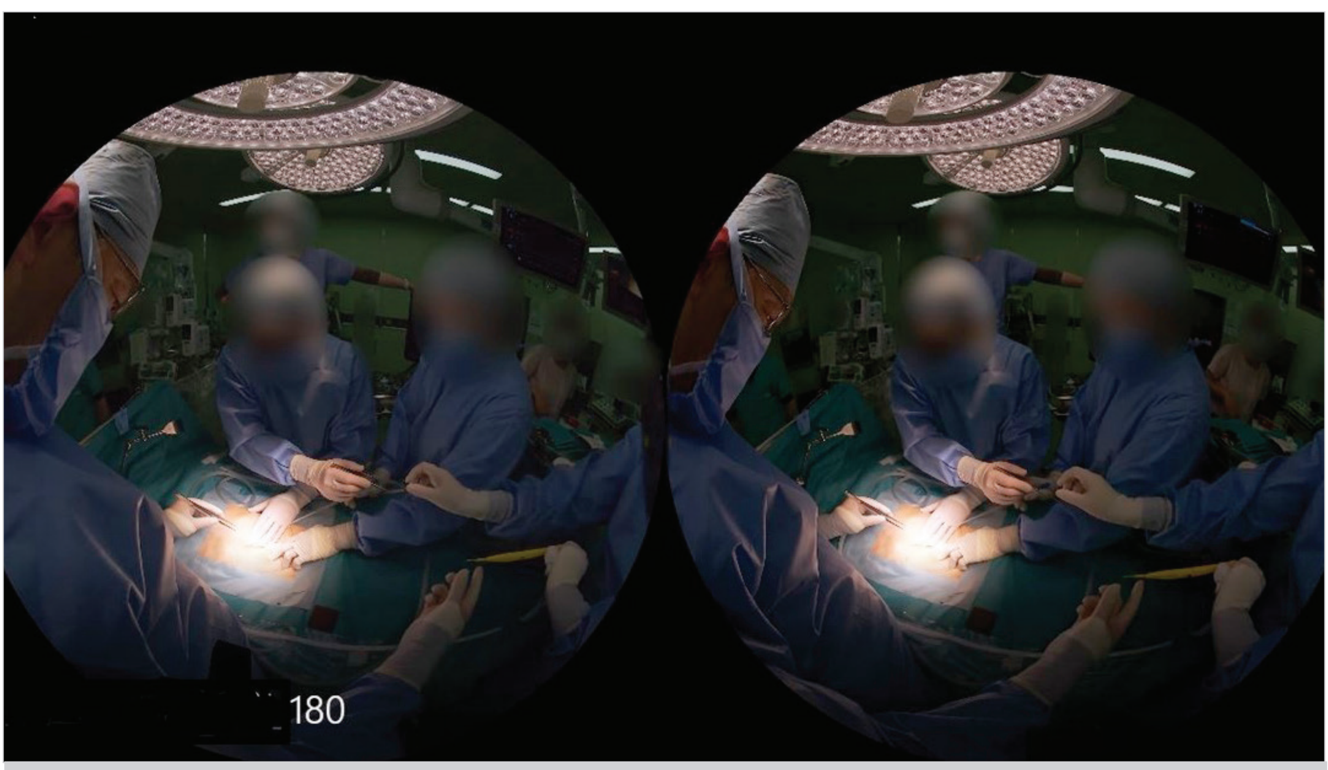

Figure 2. A broad perspective 180-degree VR image from the third assistant surgeon between the first operator and instrument nurse. The video of 180-degree visual points for VR video by the participant was attached in Supplemental Video 1.

VR: Virtual reality.

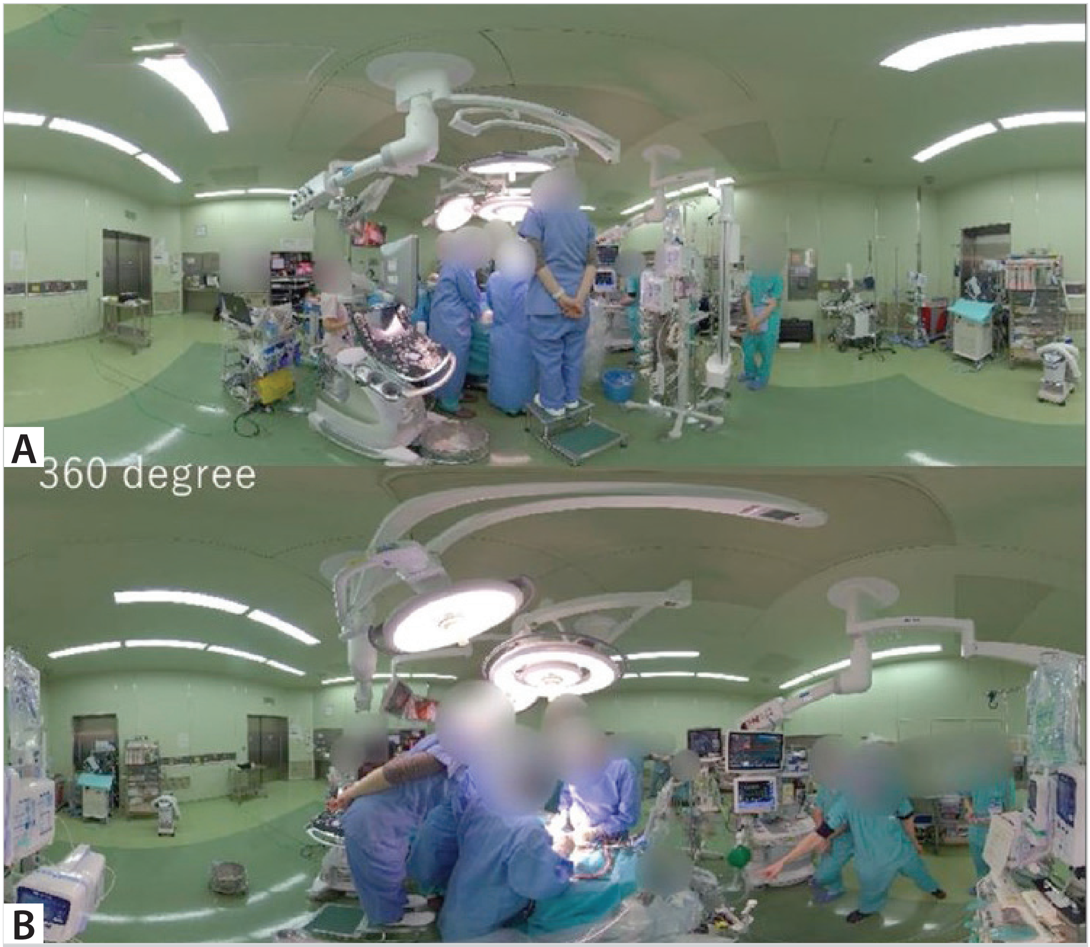

Figure 3. A broad perspective 360-degree VR image around the operating field in the operating room. The video of 360-degree visual points for VR video by the participant was attached in Supplemental Video 2.

VR: Virtual reality.

Questionnaire

The survey questionnaire consisted of three questions regarding VR imaging by the production company L.A.B. Co., Ltd., and seven questions regarding surgical issues using VR imaging by the Department of Surgery, University of Miyazaki Faculty of Medicine. The first three queries were about the production company, and questions four to 10 corresponded to surgical researchers, which included the following:

1) Please watch this operative video and tell us your honest impressions;

2) Are you interested in VR video production? [Scored with a scale ranging between 1 (not at all) and 5 (very interested)];

3) Please let us know if you have any ideas on the use of VR images;

4) Occupation;

5) Have you tried other or original surgical simulation systems or educational contents that utilize VR?

6) Which of the following types of VR content are you most interested in? (Multiple choices: simulation of the doctor, surgical anatomy visualization, patient education, student education, trainee or major medical education, virtual medical training, etc.);

7) How important do you think VR content is for medical education and training? [Scored with a scale ranging between 1 (not important at all) and 5 (very important)];

8) Which is more useful, a 3D printing product or VR content?

9) What kind of improvements do you expect for future VR content and information technology (IT) innovations to make in surgical education and skills?

10) and were there any technical issues or challenges encountered while using VR content? For statistics, continuous variables were expressed as mean ± standard deviation (SD). The results of 28 people participating in the study may not give a statistically significance due to the small size of the target audience.

RESULTS

Questionnaire About the Production company

1. Honest impressions on the operative video: The description rate was 21 (75%), and the blank answer was seven out of 28 participants. A good reputation was found in 17 of 21 (81%) participants. Virtual realism seemed to be evaluated by nine participants, including their opinion of VR sickness. Three participants reported no satisfaction with the quality of VR.

2. Interest in VR video production: About 82% of the participants felt interested in the present VR imaging quality. The median and mean scores were 4 and 4.14, respectively.

3. Ideas on the use of VR images: Answers for the recent surgical application were observed in three participants at the present level of VR images. A combined visual and hand simulation was expected in two.

Questionnaire About the Surgical Researchers

4. Occupation: Eighteen participants (64%) were expert surgeons, comprising three with expertise in thoracic surgery, one in vascular surgery, four in hepatobiliary and pancreatic surgery, and ten in digestive tract surgery. The number of intern doctors or resident surgeons was eight (29%), and the number of surgical educational instructors (surgeons) was two (7%).

5. Exposure to other or original surgical simulation systems or educational contents that utilize VR: Five surgeons used commercial-based 3D imaging analysis system for computed tomography.

6. Most interesting VR content: Twenty-five answers were expectations for the usual operating simulation using VR, XR, or augmented reality like holograms or projection mapping procedures. Except for the present VR system, several educational VR contents were required.

7. Opinion on VR content in medical education and training: Twenty-six participants (93%) thought that VR content was important for medical education or training. The median and mean scores were 4 and 4.32, respectively.

8. More useful between a 3D printing product and VR content: By comparing questions, the usefulness of VR content was required for some reasons, mainly variously applicable.

9. Expected improvements in future VR content and IT innovations to be made in surgical education and skills: Various opinions or expectations for future development regarding IT solutions were required. Among them, more usefulness or light mobility during operation or internet cloud connection and lower cost (mainly contents or system fees) were predominant.

10. Technical issues or challenges while using VR content: Five steps of zoom-in functions or light modulation were controlled by using a headset apparatus with VECTORS L&M contents. However, some participants required more development of resolution or light adjustment by the zoom-in function.

DISCUSSION

Current understanding suggests that VR technology is increasingly being integrated into surgical practice for various applications, such as surgical planning, training, and intraoperative guidance, as described above (2,7-13). However, a thorough exploration of the potential advantages, disadvantages, and limitations of VR in surgery is necessary. One presumed advantage is improved training. VR provides a safe and repeatable platform for surgical training, which helps reduce the learning curve associated with complex surgical procedures (13,14). It can simulate a wide array of scenarios a surgeon may encounter, thereby providing invaluable experience. Currently, preoperative planning is essential, and surgeons often use 3D imaging to visualize the anatomy of patients before surgery (1-5).

VR can enhance comprehension of the unique anatomy and pathology of the patient and aid in decision-making. XR technology may be useful for patient orientation or education (9,10). Among these technologies, VR can be primarily used to educate patients about their conditions and the surgical procedures they will undergo, potentially reducing their anxiety and improving their understanding (11-14). XR technology could possibly decrease operative time because practicing on a virtual model of the anatomy of the patient can potentially reduce the duration of the actual surgical procedure, leading to better outcomes and less time under anesthesia for the patient. Nevertheless, these emerging technologies require validation with the latest resources to keep pace with advancements (11-15).

Regarding VR content creation, the production of high-quality videos is crucial, and therefore, technical support from specialized VR companies is often sought. It is important to note that commercial IT or DX medical solutions can be costly, which could pose a barrier to widespread use (15). For example, a renowned company in Japan charges 20 million yen (1.54.000 USD) for basic VR cloud costs, along with an annual contract fee (not publicly disclosed but required in practice). Additional fees apply if custom content is created. However, some institutes have implemented low-cost VR systems (11). Despite these costs, companies with a strong concept can create high-resolution VR content, similar to what is used in tourism, which is not solely limited by technical costs.

We initially conducted market research in Japan, and our product required several meetings and sessions in the operating room to finalize the video-taking scenario, which cost us 8.00.000 yen, or approximately 6.200 USD. This cost was significantly lower than that of commercial products. We have produced two types of content: 1) a 180-degree wide video showing the perspective of an assistant operator, and 2) a 360-degree wide video inside the operating room. Additionally, we are currently working on creating content for a robotic surgical workshop and primary damage control surgery at the emergency room (not published yet). The current image resolution of our content is state-of-the-art 8K (8000 pixels) full-high vision. The first author of the study served as the primary operator and provided voice-over explanations for the content. Importantly, no adverse events occurred during the operation. It took us seven days of editing to complete this prototype VR content, which was then used in a questionnaire-based prospective trial at a surgical congress.

In response to a query from the product company, approximately 61% of the participants responded positively to the VR content. However, some participants experienced technical issues, which can be attributed to their familiarity with the latest generation of VR games. Previous reports have indicated that hologram or computer graphics-based operative simulations have been well received (5-14). These simulations can be altered or synthesized using the latest graphics software. However, it is important to note that real images used for virtual experiences might be influenced by background lighting or movement. Interestingly, from the perspective of surgeons, only 18% of the participants reported using surgical simulation systems, suggesting a potential interest in VR or computerized images. Around 64% of the participants expressed interest in using VR for confirming surgical anatomy or simulating operations, while the remaining participants were interested in training or education. Most participants recognized VR content as a valuable surgical tool, aligning with the acceptance of 3D operation simulation systems in the last decade. Previously, 3D printing materials created from Digital Imaging and Communication in Medicine data have been used for surgical simulation or donor organ preparation in liver transplantation (16). However, these materials have not been widely adopted or developed due to high individual costs despite our attempt to create a hepatectomy sample (17). Additionally, producing these materials required a specialized technician, a ventilated room to eliminate organic matter produced during the printing process, and access to suitable materials for each organ. The disposal of these materials also posed challenges. Contrastingly, digital imaging could potentially resolve these issues, with the exception of the lack of tactile sensation. Consequently, only a small number of participants still required 3D-printed samples. The ideal solution may lie in combining the latest technology to replace traditional anatomical models (18).

Disadvantages and limitations of VR in surgical practice include high cost associated with individual contracts and the significant initial investment required for VR equipment and software. Regular updates and maintenance can further increase the overall cost, as described above. Additionally, while VR provides a learning platform, there is a learning curve associated with becoming proficient in using VR technology. Currently, there are no widely accepted standards or certification processes for VR surgical training programs, which could lead to inconsistencies in training quality. This lack of standardization might suggest instability in such systems. Therefore, the utility of VR and other XR systems will be progressively demonstrated as IT develops.

At our institution, we have plans to incorporate this VR system into the clinical practice of medical students and gather evidence on its efficacy as a VR platform. However, some users may experience physical discomfort or symptoms such as nausea, dizziness, or eyestrain, commonly referred to as VR sickness (19,20). In our current study, one participant reported experiencing such symptoms. Since personal characteristics were not obtained through this questionnaire, this issue will be further evaluated in the next phase involving medical students. For experienced surgeons, despite the rapid advancement of VR technology, it still cannot fully replicate the tactile feedback experienced during actual surgery. This technological limitation could potentially reduce the effectiveness of VR as a training tool for experienced surgeons. For patients scheduled for surgery, the issues to be resolved are more complex compared to medical or co-medical staff. Data privacy is a significant concern due to ethical considerations in VR simulations (21).

CONCLUSION

Our original VR platform, VECTORS L&M, which provides the perspective of surgeons and medical practitioners, has generated high expectations as a clinical and educational tool, even in its prototype stage. We have the vision to continue the development of this unique surgical education platform, making it more affordable and integrating its tools into practical training, research, and internships in surgical medicine. We also plan to advance the assessment of understanding before and after the VR experience for the participants and utilize this tool for the improvement of clinical skills and the recruitment of surgeons.

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Bölgesel bir akademik enstitüde sindirim cerrahisinin sanal gerçeklik deneyimlerinin anket çalışması: Cerrahi öncesi eğitim için bir pilot çalışma

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ÖZET

Maliyetleri sınırlayarak öğrenciler, stajyerler ve genç cerrahlar için sindirim cerrahisi anlayışını geliştirmeyi amaçlayan bir prototip VR platformu olan VECTORS L&M'yi (VLM) geliştirdik. Cerrahi eğitimde uygulanmadan önce etkinliği anketlerle değerlendirildi. VLM, ameliyatların hem 180 hem de 360 derecelik açılardan dokuz dakikalık VR görünümlerini sağlamaktadır. L.A.B Co., Ltd ile oluşturulmuştur ve biliyer malignite hastalarının ameliyat videolarını içermektedir. VLM gelişimini takiben, bunu deneyimleyen cerrahlar arasında bir anket yapıldı. Yirmi sekiz katılımcı (gözlemcilerin %32'si) ankete yanıt vermiştir. Çoğunluk (%81) VR içeriğiyle ilgili olumlu deneyimler bildirdi ve VR video prodüksiyonuna ilgi gösterse de bazıları rahatsızlık hislerini bildirdi. Katılımcıların çoğu deneyimli cerrahlardı ve neredeyse hepsi VR'nin tıp eğitimi için önemli olduğuna inanıyordu ve ortalama 4,14 puan 5'e kadar çıktı. VR, uygulama çok yönlülüğü nedeniyle 3D baskılı modellere göre tercih edildi. Katılımcılar, artan mobilite, bulut bağlantısı, maliyet azaltma ve daha iyi çözünürlük gibi gelecekteki VR iyileştirmeleri için arzularını dile getirdiler. VLM platformu, bu yenilikçi öğretim yaklaşımı ile birleştiğinde karın içi cerrahide deneyimsel öğrenme sunarak cerrahi eğitim ve öğretimden önce öğrencilerin ve cerrahların bilgilerini etkili bir şekilde zenginleştirmektedir.

Anahtar Kelimeler: Cerrahi eğitim, sağlık personeli, stajyer doktorlar, sindirim cerrahisi, sanal gerçeklik

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