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Technical note

From stereoscopic recording to virtual reality headsets: Designing a new way to learn surgery

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A B S T R A C T

Objective. – To improve surgical practice, there are several different approaches to simulation. Due to wearable technologies, recording 3D movies is now easy. The development of a virtual reality headset allows imagining a different way of watching these videos: using dedicated software to increase interactivity in a 3D immersive experience. The objective was to record 3D movies via a main surgeon's perspective, to watch files using virtual reality headsets and to validate pedagogic interest.
Material and methods. – Surgical procedures were recorded using a system combining two side-by-side cameras placed on a helmet. We added two LEDs just below the cameras to enhance luminosity. Two files were obtained in mp4 format and edited using dedicated software to create 3D movies. Files obtained were then played using a virtual reality headset. Surgeons who tried the immersive experience completed a questionnaire to evaluate the interest of this procedure for surgical learning.
Results. – Twenty surgical procedures were recorded. The movies capture a scene which is extended 180° horizontally and 90° vertically. The immersive experience created by the device conveys a genuine feeling of being in the operating room and seeing the procedure first-hand through the eyes of the main surgeon. All surgeons indicated that they believe in pedagogical interest of this method.
Conclusions. – We succeeded in recording the main surgeon's point of view in 3D and watch it on a virtual reality headset. This new approach enhances the understanding of surgery; most of the surgeons appreciated its pedagogic value. This method could be an effective learning tool in the future.

1. Introduction

Simulations must be developed in order to improve learning and ensure safer surgical practice [1]. There are several different approaches to simulation. In medicine, we can use role-play or a high-fidelity patient simulator; in surgical practice, human cadavers, animals, low-fidelity synthetic simulators and, more recently, virtual reality (VR), are available for use [2]. With the development of robotics, such as the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA), students can train in a variety of ways. Moreover, simulations enhance visualization due to their stereoscopic approach [3] and allow for training specific to endoscopic surgery. In the neurosurgical field, the NeuroTouch (NAJD Metrics) simulator has been designed to provide haptic feedback [4].

The above-mentioned novel tools, nevertheless, have some limitations. First, they cannot be applied to all types of surgical procedures. Second, they concentrate on skill, e.g., with respect to hand movements, but not on knowledge of the different steps involved in a surgical procedure. Furthermore, the tools cannot be applied in order that knowledge of the duration of a surgical procedure is acquired. Presently, to learn about surgical procedures in a step-by-step manner outside of the operating room, technical notes or videos are reviewed in two dimensions [5]. A method of three-dimensional (3D) recording has been recently developed but the need to wear specific glasses has limited its use [6].

New tools are currently being developed, including VR headsets (designed initially by Oculus; Irvine, CA). These headsets allow for total 3D immersion using stereoscopic views of a scene (i.e., two screens, one for each eye). Moreover, head tracking permits the observer not only to visualize the scene but also to view what happens in the area around the central view. VR allows us to design software that increases interactivity, permitting students to be active rather than just passively watching the videos. In this article, we introduce our first study that aimed at improving surgical learning.

Objectives were to test feasibility to record main surgeon point of view in 3D in various neurosurgical procedures; then to use VR

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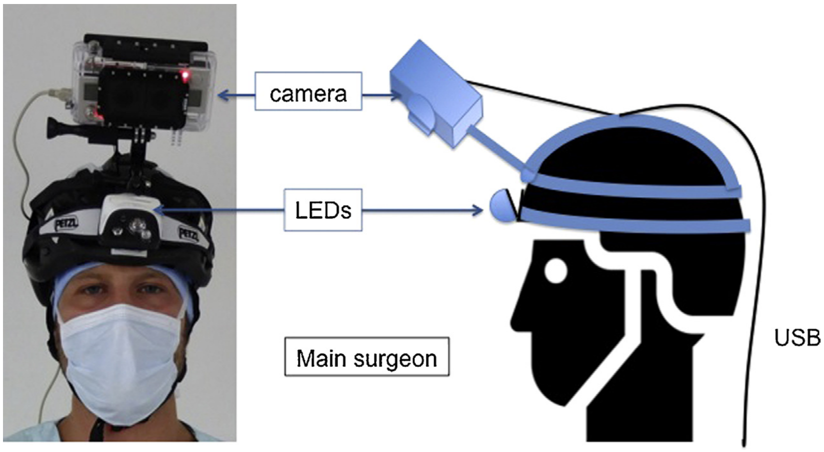

Fig. 1. Front view (photo) and lateral view (picture) of recording device: one stereoscopic camera (two cameras side-by-side) and two LEDs are placed on a helmet. The helmet is on head of main surgeon. Cameras are inclined to record surgeon point of view.

headsets to watch files obtained; finally, to have feedback from surgeons about this VR application.

2. Material and methods

2.1. Surgical recording

Patients were informed of the study procedures, and consent to record the surgery was obtained. The surgical procedures were recorded using a system combining two side-by-side cameras (GoPro, San Mateo, CA). The distance between the two lenses corresponded to the mean distance between two eyes (6 cm). The two cameras were connected to synchronize different commands. The system was placed on a helmet to improve surgical comfort and avoid any problems caused by the weight of the original recording device on the forehead of the surgeon. The device was linked via a USB port to an external battery situated in the back pocket of the surgeon. We added two LEDs just below the cameras to enhance luminosity (Fig. 1). The first LED was an ambient light, used instead of scialytic lamps. The other LED was a focal lamp allowing for a deeper operative field, thereby ensuring optimal luminosity in the region of interest.

Cameras were inclined approximately 45° from the horizontal plane to ensure the same field of view as that of the surgeon. The view was checked using a WiFi connection between the camera device and a smartphone. The surgeon placed an object in the central field of vision of the camera device, with the position of the cameras then checked by watching a streamed recording of the view on the smartphone.

Recording was controlled using the WiFi command packaged with the initial device. For the first recording, we assisted the surgeon by maintaining control of the command.

If preferred by the surgeon, access to the recording button could be achieved by placing the command in a sterile pocket on the operating table. We began recording after the checklist was completed and prior to the incision.

Three senior surgeons used the device to record the different surgical procedures. We tested this recording method on various surgeries to determine if it was applicable to a different context and position.

2.2. Virtual reality headset

After the surgery was performed, two files were obtained in a mp4 format, one for each eye. The two files were then edited using professional software Adobe Premiere Pro CC (Adobe Systems, San Jose, CA) to create 3D movies presented side by side. Accuracy, luminosity and contrast were then checked. Different sequences were cut to create new files corresponding to the different steps of the surgical procedure.

The new files were then played using a VR headset (the prototype Rift DK2 [Oculus VR, Irvine, CA] was used initially; the Gear VR Innovator [Samsung, Seoul, South Korea], designed to be used with the S6 Edge [Samsung] device, is now employed). At the outset, we at first used a VR player, MaxVR (Supersinfulsilicon software, St Edmonton, AB) that permitted the use of an appropriate virtual screen. However, a computer engineer subsequently designed a mobile software called Surgevry (Revinax, Montpellier, France) that uses a special template for each surgical procedure permits the observation of procedures and creates a movie specially designed for the type of surgery that has been recorded. In the central field of view, a screen corresponding to the immersive video can be seen. In the upper field of view, different stages of the surgical procedure are divided into chapters according to time. In lateral fields of view, data can be added to explain surgery. For example (Fig. 2), in the left field of view, X rays, computed tomography (CT) or magnetic resonance imaging (MRI) scans can be integrated and visualized; in the right field of view, anatomical chart or 3D reconstruction can be seen.

2.3. Validation from surgeons

In order to obtain a representative sample of the surgical population, thirty other surgeons (mainly neurosurgeons, different generations, from residents to seniors, with an academic function or not) tried the VR headset (Gear VR). They watched one of the surgical procedures that we have recorded with the method described (external ventricular drainage) during 10 minutes. After this brief experience, they were asked to fill out a form to determine the interest of using this new method (Table 1). We identified, in the first questions, the surgical experience or degree of the different surgeons (specialty, university status). Second part of questionnaire was to obtain their initial impression using this device: nausea, stressful, surprising, interesting, captivating; then, did they think this method could have any pedagogical interest and to quantify it (1 to 5). Third part focused on the way they would use it (to learn from it, to teach with it), if they though that this device will be part of the learning procedure in the future, and if they would use it. Possible answers were “certainly not”, “probably not”, “maybe”, “probably”, “certainly”. Fourth part was to know their feelings about their own past and the way they used to learn: if this device has been available during their studies, did they think

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Table 1
Survey answers. A total of 30 surgeons answered the questionnaire: 15 neurosurgeons, 6 orthopedists, 3 plastic surgeons, 2 ENT, 2 digestive surgeons, 1 urologist and 1 vascular surgeon.

Question asked N (%)	Certainly	Probably	Maybe	Probably not	Certainly not
Would you use it to learn?	13 (43,3)	10 (33,3)	5 (16,7)	1 (3,3)	1 (3,3)
Would you use it to teach?	15 (50)	11 (36,7)	3 (10)	–	1 (3,3)
This will be a part of training	14 (46,7)	16 (53,3)	–	–	–
Would you want this?	20 (66,7)	8 (26,7)	1 (3,3)	–	1 (3,3)
Would have understood faster?	9 (30)	17 (56,7)	3(10)	–	1 (3,3)
Would have learned faster?	7 (23,3)	16 (53,3)	6 (20)	1 (3,3)	–
Would have mastered skills faster?	5 (16,7)	17 (56,7)	7 (23,3)	1 (3,3)	–
Would have extended knowledge?	6 (20)	14 (46,7)	8 (26,7)	1 (3,3)	1 (3,3)
Would have exceeded limits?	5 (16,7)	9 (30)	9 (30)	6 (20)	1 (3,3)

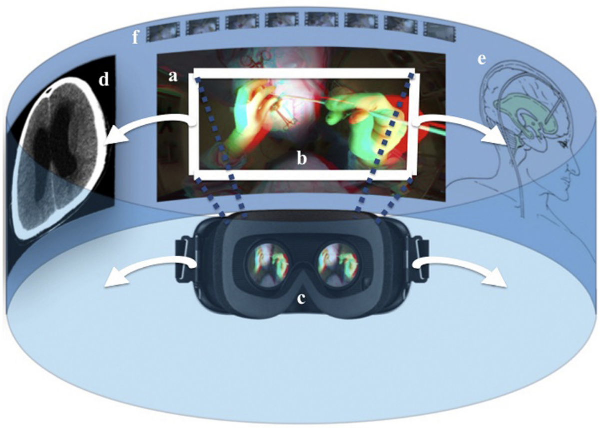

Fig. 2. Illustration of the vision allowed by dedicated VR software. Example of extraventricular drainage (EVD) placement. VR 3D screen is in the central part (a). Field of view (b) through lenses of VR headset (c) is represented by a white square. Moving head to the left allow to move field of view to the left and to explore CT-scan (d), to the right, observer will find anatomical chart (e). Looking upside, observer can choose different chapters (f) corresponding to different surgical steps (Video 1 illustrates this learning environment).

they would have been able to understand, to learn, to acquire skills faster. Moreover, did they think they would have extended surgical knowledge, and if they would have exceeded their own limits.

3. Results

3.1. *Surgical recording*

We succeeded in recording twenty consecutive neurosurgical procedures in total, as follows: cranial (two scaphocephalies and one skull fracture); craniofacial (one trigonocephaly and one forehead reconstruction); brain (two ventriculoperitoneal shunts, one occipital metastasis, one frontotemporal meningioma, one chronic subdural hematoma, one external ventricular drainage); spine (one epidural abscess, one cervical diskectomy, one lumbar percutaneous screw fixation, five posterior reduction and fixation of thoracolumbar fractures).

The original recording device began to cause pain on the forehead approximately 1 hour after starting the procedure; the new prototype device prevented pain and permitted progressive dispensability of the helmet. At first, it was necessary to load the battery after 1 hour of recording, using permanent WiFi. WiFi streaming was used to confirm that a good view had been obtained, and the link to external battery permitted recording during the entire procedure (approximately 3 hours of surgery).

Scialytic lamps carry a risk of overexposition, particularly on white surfaces (e.g., skull, gloves) and metallic tools used during surgery. Using LEDs permitted the use of ambient light although, when the region of interest was in a deeper position, darkness was preferred so that a second LED was added to focus the light and aid visualization of every detail.

Main limitation for the acquisition is the time of preparation, to clean the device, to wear it, and to calibrate the recording view. There is a learning curve that permits to go faster. We are still working to get it more ergonomic for surgeons. First prototype cost was approximately 1,000 US dollars, and may be more expensive to increase comfort during surgery. Another limitation is the kind of surgery: for the moment it is not possible to zoom. In this way, details of cervical diskectomy can be difficult to visualize. Head-tracking is performed by mobile phone, next generation will be able to calculate a displacement on z-axis, allowing student to zoom in the screen. Currently, this method can be used for open technique, but for endoscopy or microsurgery, special equipment is required: 3D cameras. File obtained directly by USB connection is still side by side, but as it is used for colored glasses, there is a treatment applied (blue and red images). It is not relevant for virtual reality: the surgeon has to be connected to each camera in order to have two separated files without post-treatment. We are working on this new technical challenge in order to correct this problem.

3.2. *Virtual reality headset*

The movies capture a scene extended 180° horizontally and 90° vertically; the main surgeon has a central point of view. The lateral fields of view are able to show residents and nurses, the upper field of view shows the anesthesiologist, and the view below the central field shows the hands of the first surgeon.

The immersive experience created by the device conveys a genuine feeling of being in the operating room and seeing the procedure first-hand through the eyes of the main surgeon.

The main limitation of the method is motion sickness, i.e., vertigo and nausea due to rapid head movement by the main surgeon. During the first step when we used the prototype called DK2, it was unbearable for two surgeons who tried it (one of them previously had vestibular neuritis). However, calibration can address both of these problems. Additionally, improved recording and post-treatment, and use of the new VR headset produce a better image and superior movement stability: less motion sickness has been reported with the new device.

3.3. *Surgeon validation*

Thirty surgeons filled out the form (Table 1): 30% were residents, 30% were young surgeons, 40% were advanced practitioners, (half with a university status). The experience conveys good feelings: fascinated in 50% of the cases, interested in 25%. The worst feeling was nausea concerning one surgeon. Everyone agreed regarding pedagogical value of this tool (mean quote 4/5).

Concerning their use of this device, to learn: 43% answers certainly, 33% probably; to teach: 50% answers certainly, 36.7% probably. They all thought that this device will be part of the

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learning method in the future, and 67% would certainly like it, 27% probably. Concerning the way they would have learned if this device has been proposed during their studies, 57% thought they would probably have understood faster, 27% would certainly have learned faster and 60% replied probably, and 57% thought that they would have probably mastered skills sooner. Moreover, 50% thought that they would have certainly extended their surgical knowledge, and 30% that it would probably have permitted to extend their limits (17% certainly).

The main limitation was added in free commentary by a surgeon. The surgeon knows it would be part of the future but is reticent about the use of these technologies. He argues that these new tools prevent practitioners from thinking, and that there is a risk of losing the ability to work without external help.

4. Discussion

4.1. Surgery and video

Movies on surgery became available following advances in cinematography [7]. Medical movies using X rays have been developed to study different aspects of movement focusing on the limbs and joints. The first surgical video was recorded during the first half of the 20th century. At that time, there was a lot of skepticism regarding the pedagogic value of movies. Clinical examinations relevant to the discussion of new types of syndromes were also shown. Medical movies have been used progressively more widely for public health purposes, to provide medical explanations and promote disease prevention programs thereby underlining the pedagogic power of movies.

During the latter half of the 20th century [8], British universities developed a large database of different types of medical movies, for study purposes.

At the beginning of the 21st century, it became clear that watching medical movies represented an effective way of learning about surgical techniques [9]; thus, surgeons should be encouraged to develop movie databases for use in their schools or for publication in journals [10].

Specialties that have developed, and routinely use, intraoperative recordings are primarily those involving endoscopic or microscopic surgery [11]. Previously, monitors were connected to a videotape recorder. Today, it is easier to record and save movies on a personal computer [12]. Surgeons employ endoscopic cameras to record open surgery because they can be used in a sterile manner. Another strategy involves placing the camera inside scialytic lamps. However, the problem remains of visualizing all of the details of the surgery because a hand or tool can obscure the region of interest. Even if miniaturization of the recording material permits focus on the operative region, it remains difficult to experience the procedure from the surgeon's point of view. Moreover, collaboration with another person is required to achieve the best perspective. The development of wearable technologies allows us to record procedures from a subjective point of view, i.e., that of the main surgeon.

The first example of this new technology being used by surgeons was with the Google lens (Menlo Park, CA,) [13], which comprises of a camera attached to glasses. We preferred to use another device, namely the stereoscopic camera: recording with two adjacent cameras allows us not only to obtain a subjective point of view, i.e., that of the main surgeon, but also the point of view from each eye. Movies obtained this way can be instantly viewed in 3D.

We did not encounter the same limitations reported by Lee et al. [14], as regards the use of a head-mounted set, because we designed a prototype to ensure surgeon comfort. Recording tests are now permitted using WiFi so that the device is not touched during surgery, and recording can be started using a simple command. With an external battery, recording is also possible using the entire capacity of memory cards.

4.2. Surgical movies and learning

Surgery students are more likely to study using videos than by reading technical notes [15]. From a teaching perspective, creating a movie permits the sharing of knowledge. Movie editing can represent a first step in the learning process [16] and movies can be used in training programs [17]. Another way in which these videos could be used is as trainee evaluation tools [18,19] because they have been shown to be an effective and reliable means of assessment.

In studies comparing two-dimensional (2D) and 3D movies, evidence of an improvement in learning using the latter is equivocal [20,21]. There are two facets of 3D movies that require further development. First, to date, 3D movies have been projected on to a plane screen. This provides a sensation of depth but the viewer does not feel to be a part of the action, i.e., there are no projections from the screen such that it is experienced as similar to looking through a window. The development of the VR headset has conferred to viewers to sense being a central part of the action, an effect referred to as immersion. This represents the first advantage of watching a video using a virtual headset. Moreover, the goal of VR is not to just watch a movie in a passive manner but to provide a better overall experience. An entire virtual world can be constructed encompassing the surgical scene [22]. Additional information about patients can be also obtained, including CT or MRI results and anatomical data; students can also interact with virtual nurses. Thus, by using augmented reality in a virtual world, students can interact with tools used by surgeons and better understand the surgical procedure.

Next step is an objective validation of this method to learn. A new prospective study will be designed using two groups: one group will acquire surgical skills via a formal course taught in a classical way and the other group will acquire these same skills through a VR headset.

4.3. Virtual reality and learning

VR allows learning to unfold in a different way. Designing a virtual learning environment permits the explanation of difficult concepts in a simple manner. Mikropoulos and Natsis (2011) published a 10-year review of VR and pedagogy research [23]. The theoretical model used by the included studies was constructivist and most of them were empirical and demonstrative with no real assessment of the benefits for students. From these analyses, Dalgarno and Lee (2010) defined three major characteristics necessary to build an effective 3D virtual environment [24]: the illusion of three dimensions, smooth temporal and physical changes and a high level of interactivity. These authors began by discussing technical affordances and reported benefits from pedagogy. It is not just the illusion of 3D that is important but genuine 3D involving images recorded from each eye. In this instance, new technology allows for real immersion, characterized by a sense of "presence". However, in itself the new tool is insufficient: Fowler emphasizes that a 3D virtual environment must also be designed to promote learning [25]. He presented a three-stage framework for learning, which involves explanations, constructions and discussion [26], and proposed that different theories concerning VR and pedagogy be combined to create the most effective virtual learning environment. Advances in new technology would be gained by combining these theories to create the best possible tool.

In the surgical field, the results of studies evaluating the benefits of virtual reality-based simulation are most encouraging [27]. VR is a new tool which will allow a greater input from trainees and reduced time spent in the operating room. It could also ensure

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patient safety when a surgical procedure is practiced for the first time.

The challenge is to allow each surgeon to have access to an immersive database. The goal is that everyone could participate, and in this way, disseminate skills.

5. Conclusion

New technologies allow us to think about new ways to transmit skills. We can recreate the environment recorded thanks to immersive VR. In this way, sentiments can be closer to those expressed in real life, adding an emotional value.

Recording surgical procedures through the eyes of the main surgeon can provide students with a direct and optimal view: with a VR headset, students can now obtain this first-person viewpoint. Using the methods and concepts involved in virtual learning environments enhances the pedagogic value of these videos.

With these novel technologies, we can create a new way via which to record, watch, and learn. Keeping in mind that it is a new tool, but would absolutely not replaced experience without technologies. We have shown that surgeons are interested in this project. We now need to continue further and demonstrate learning benefits provided by this useful new method.

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Disclosure of interest

M.R. and J.-V. T. own shares in Revinax SAS; Maxime Ros works with Jean-Vincent Trives as co-founders of Revinax. The article presents first step of Revinax project. This is now a company aiming to develop the method presented in this paper. The author N.L. declares that he has no competing interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.neuchi.2016.08.004.

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