Neurochirurgie 65 (2019) 152–157

Disponible en ligne sur ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com

Original article

# Toward the development of 3-dimensional virtual reality video tutorials in the French neurosurgical residency program. Example of the combined petrosal approach in the French College of Neurosurgery

F. Bernard[a,b,*], C. Gallet[a,b], H.-D. Fournier[a,b], L. Laccoureye[c], P.-H. Roche[d], Lucas Troude[d]

[a] Department of neurosurgery, CHU d'Angers, 49100 Angers, France
[b] Laboratory of anatomy, 49100 Angers, France
[c] Department of ENT, CHU d'Angers, 49100 Angers, France
[d] Department of neurosurgery, hôpital Nord, CHU, AP–HM, 13015 Marseille, France

ARTICLE INFO

*Article history:*
Received 4 November 2018
Received in revised form 25 March 2019
Accepted 29 April 2019
Available online 21 May 2019

*Keywords:*
Pedagogy
Neurosurgery
Anatomy
3D
Virtual reality headset
Simulation
Skills

ABSTRACT

*Background.* – The present study developed 3D video tutorials with commentaries, using virtual reality headsets (VRH). VRHs allow 3D visualization of complex anatomy from the surgeon's point of view. Students can view the surgery repeatedly without missing the essential steps, simultaneously receiving advice from a group of experts in the field.
*Methods.* – A single-center prospective study assessed surgical teaching using 3D video tutorials designed for French neurosurgery and ENT residents participating in the neuro-otology lateral skull-base workshop of the French College of Neurosurgery. At the end of the session, students filled out an evaluation form with 5-point Likert scale to assess the teaching and the positive and negative points of this teaching tool.
*Results.* – Twenty-two residents in neurosurgery ($n = 17$, 81.0%) and ENT ($n = 5$) were included. Eighteen felt that the 3D video enhanced their understanding of the surgical approach (81.8%). Fifteen (68.2%) thought the video provided good 3D visualization of anatomical structures and 20 that it enabled better understanding of anatomical relationships (90.9%). Most students had positive feelings about ease of use and their experience of the 3D video tutorial ($n = 14$, 63.6%). Twenty (90.9%) enjoyed using the video. Twelve (54.5%) considered that the cadaver dissection workshop was more instructive.
*Conclusions.* – 3D video via a virtual reality headset is an innovative teaching tool, approved by the students themselves. A future study should evaluate its long-term contribution, so as to determine its role in specialized neurosurgery and ENT diploma courses.


## 1. Abbreviations

| | |
|---|---|
| ENT | ear, nose and throat specialist |
| VRH | virtual reality headset |

## 2. Introduction

Since 2004, a skull-base course for residents has been run in the anatomy laboratory of our teaching hospital to teach the otoneurosurgical anatomy and surgical approaches of the lateral skull-base (combined petrosectomy). Students have lectures, study scientific and anatomical prerequisites for one day, and then perform dissection of complex skull-base approaches such as combined petrosectomy on cadavers under the supervision of senior surgeons. During these years, new technologies have been developed, notably in the entertainment and gaming domains, such as broadcast video platforms, 3D cinema and virtual reality. All residents and fellows are familiar with these new technologies, which have become part of everyday life. As previously studied, the recent development of digital technologies offers new perspectives for medicine,

* Corresponding author at: Laboratory of anatomy, faculté de médecine, 49100 Angers, France.
*E-mail addresses:* bernardflorian.bf@gmail.com (F. Bernard), gallet@gmail.com (C. Gallet), hd-fournier@chu-angers.fr (H.-D. Fournier), Lalaccourreye@chu-angers.fr (L. Laccoureye), proche@ap-hm.fr (P.-H. Roche), lucas.troude@hotmail.fr (L. Troude).

https://doi.org/10.1016/j.neuchi.2019.04.004
0028-3770/

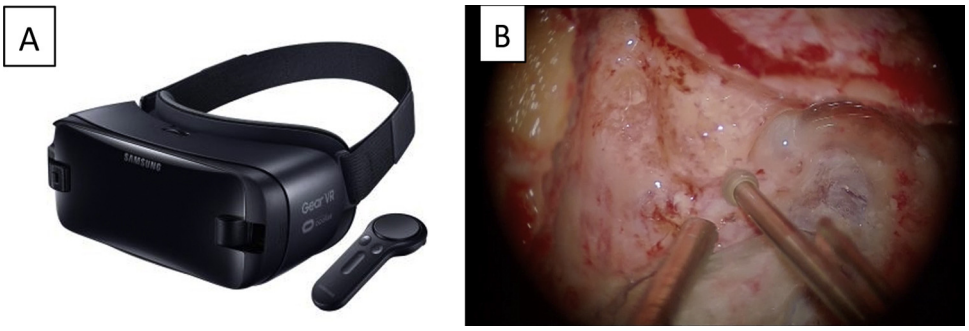


**Fig. 1.** A. Samsung gear virtual reality (VR) headset. B. 3-dimensional intraoperative view of the translabyrinthine approach with the virtual reality headsets or 3D television.

regarding clinical follow-up [1], awake brain surgery [2] and teaching [3]. 3D videos viewed on smartphones open up new possibilities for digital anatomy and surgery courses for students.

To learn a surgical approach, residents need to assist a senior surgeon several times. The repetition allows them to increase their mental representation of the surgery [4–6]. They can then learn in anatomy labs and perform stepwise surgery, helped by a senior. This teaching method is good, and decades of neurosurgeons have been successfully trained in all approaches in this manner. However, it has limitations, requiring a mentor, a university reference center for rare surgical techniques, several workshops, and the fees incurred. . . Moreover, the increasing number of students admitted to French neurosurgical residency programs raises issues of training in rare procedures, with too many interns for too few surgeries. The present study reports on the development of a commented 3D video displayed via virtual reality headsets (VRH) as a surgical tutorial. The aim is to allow students to see the surgery, with anatomy in 3D, from the surgeon's point of view, as many times as they need, pausing as needed, and with comments and advice from an expert group (senior authors).

The main objective of this study, conducted by the French College of Neurosurgery, was to present a project of surgical neuroanatomy teaching through a 3D video tutorial accessible via a VRH. The secondary objective was to evaluate this teaching method.

## 3. Methods

A single-center prospective study was made of surgical teaching using 3D video tutorials via VRHs.

### 3.1. Study population

Every year, the anatomy lab of the Angers university hospital runs a workshop on anatomical and surgical approaches in the lateral skull-base. The present study population comprised fourth and fifth year French neurosurgery and ENT residents participating in this workshop. The teachers were ENT and neurologic surgeons from Angers and Marseille (France).

### 3.2. 3D surgical video

A 3D video with commentary was developed to demonstrate the operative technique and surgical nuances of combined petrosectomy, showing useful anatomic landmarks for safe petrosectomy drilling, pearls for cranial nerve preservation and exposure of Meckel's cave. It could be seen on 3D television, or on a VRH, which improves 3D immersion (Fig. 1). The video had to be visualizable on several platforms (2D, 3D, VRH, 3D TV) and freely accessible (Fig. 2A). A teaching committee provided anatomical and surgical content meeting the requirements of the two specialties (ENT and neurosurgery). The surgical technique video was later accepted for publication in *Operative Neurosurgery* [3], and is available at https://academic.oup.com/ons/advance-article/doi/10.1093/ons/opy228/5106134.

We also developed 3D video capture, 3D legend and studio sound recording tools, to produce a 3D video adapted to several platforms (Fig. 2A).

### 3.3. Overview of teaching

We integrated the 3D video in the neuro-otology lateral skull-base workshop of the French College of Neurosurgery in May 2018. Two-day sessions were supervised by ENT, neurosurgery and anatomy teachers trained in skull-base surgery techniques.

Following theoretical teaching, a seminar with VRHs was organized using the elements of the previous workshop in a 3D presentation of the various organ structures and their anatomical relationships. The 30-minute course enabled each student to visualize, in 3D, the structures that they would then dissect in two 4-hour sessions (Fig. 2).

### 3.4. Evaluation of teaching

At the end of the 3D surgical anatomy session in May 2018, the students filled out an assessment form based on a 5-point Likert scale ("strongly disagree", "rather agree", "don't know", "somewhat agree" and "strongly agree") to assess the teaching and the positive and negative points of the teaching tool (Table 1). The questionnaire included several closed questions and some open questions, as in other pedagogical studies [5,7,8]. Participation was voluntary and unpaid. Responses were collected as single-choice questions or free text. Data analysis was conducted on SPSS software (version 17.0). Descriptive statistics were reported as numbers and percentages.

## 4. Results

The capacity of the skull-base workshop was limited to 22 participants. In 2018, there were 37 applicants, versus 21 in 2004, so that the teaching committee had to reject 16 applications.

Residents who participated were from neurosurgery ($n = 17$, 81.0%) and ENT specialties ($n = 5$). All reported no prior experience of learning via video tutorials. All knew how to visualize a 3D video using a VRH. When asked whether they expected to spend time using 3D digital teaching in their careers, one-third ($n = 6$, 28.6%) replied yes, one half ($n = 10$, 47.6%) said this would rather concern future students, and the other 5 did not have any opinion.

Questions Q1 to Q5 concerned surgery and anatomic visualization (Table 2). Eighteen students felt that teaching using the 3D video improved their understanding of combined petrosectomy (81.8%; Q1), and of the surgical steps ($n = 18$, 81.8%; Q2). Fifteen

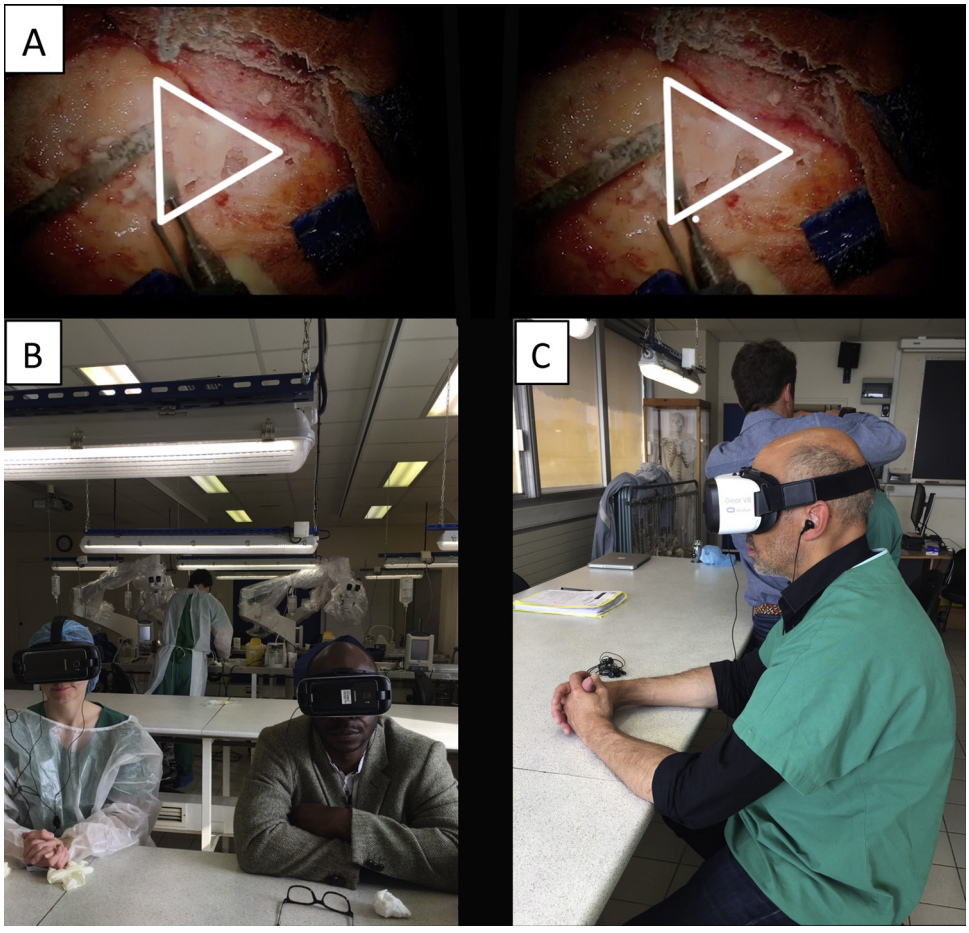


**Fig. 2.** A. Development of a 3D legend by stereoscopic overlapping. Visualization of the video by the students (B) and the faculty (C) during the 2018 neurosurgery workshop of the French Society of Neurosurgery.

**Table 1**
Evaluation criteria for the 3D video by students using a Likert scale.

| | |
|---|---|
| Q1 | The 3D video helped me better understand the topic |
| Q2 | The 3D video helped me better understand the surgical stages of petrosectomy |
| Q3 | The video provided good 3D visualization of anatomical structures |
| Q4 | The 3D video helped me better understand the anatomical relationships |
| Q5 | The 3D video helped me improve my mental representation of the surgical approach |
| Q6 | 3D visualization with a virtual reality headset is easy to use |
| Q7 | I enjoyed using the video |
| Q8 | I learned more using 3D video than from the lecture |
| Q9 | I learned more with the help of the 3D video than during the practical dissection work in the anatomy laboratory |
| Q10 | I preferred the virtual visualizations to cadaver dissections |
| Q11 | Digital tools help me learn and understand surgical anatomy |
| Q12 | 3D video tutorials should be incorporated in routine teaching |

(68.2%; Q3) thought that the video provided good 3D visualization of anatomical structures, and 20 that it improved understanding of anatomic relationships in acquiring a mental representation of the surgical approach (90.9%; Q4). Twenty respondents thought the 3D video also improved their mental representation of the surgical approach (90.9%; Q5).

Questions Q6 and Q7 assessed the students' 3D VRH experience. Students had positive feelings about ease of use and their experience of the 3D tutorial ($n = 14$, 63.6%; Q6), and enjoyed using the VRH ($n = 20$, 90.9%; Q7).

Questions Q8 to Q12 concerned the role of the tutorial in the overall workshop program. Fifteen students (68.2%; Q8) had mixed feeling about whether the 3D video was more informative than the preceding lecture. Twelve considered that the cadaver dissection workshop was more instructive (54.5%; Q9). Thirteen (59.1%; Q10) preferred cadaver dissection to the 3D video. However, most students ($n = 15$, 68.2%; Q11) believed that the 3D video was a good educational tool, and a useful part of the surgical neuro-anatomy course. Sixteen students thought that 3D tutorial videos should be included in routine neurosurgical teaching (72.7%; Q12). Positive and negative points are presented in Table 3.

## 5. Discussion

For young senior residents and teachers, surgical teaching needs to help visualize the anatomy of the operated region in 3 dimensions with advice from senior surgeons. Two observations emerged from setting up this teaching and discussion with students:

- this teaching is necessary for training students as much as for the future of neurosurgery;
- there is a definite need on the part of students who may otherwise have trouble assimilating 3D anatomy and want to revise before starting the actual surgery.

**Table 2**
Results of the evaluation of the 3D video by the students.

| | Not agree at all (%) | Rather disagree (%) | Don't know (%) | Somewhat agree (%) | Totally agree (%) | Positive responses (%) |
|---|---|---|---|---|---|---|
| Q1 | 0 | 0 | 18.20 | 54.50 | 27.30 | 81.80 |
| Q2 | 0 | 18.20 | 0 | 59.10 | 22.70 | 81.80 |
| Q3 | 0 | 0 | 31.80 | 45.50 | 22.70 | 68.20 |
| Q4 | 0 | 0 | 9.10 | 36.40 | 54.50 | 90.90 |
| Q5 | 0.0 | 0.0 | 9.1 | 40.9 | 50.0 | 90.9 |
| Q6 | 9.1 | 27.3 | 0.0 | 45.5 | 18.2 | 63.6 |
| Q7 | 0.0 | 9.1 | 0.0 | 22.7 | 68.2 | 90.9 |
| Q8 | 0.0 | 22.7 | 9.1 | 36.4 | 31.8 | 68.2 |
| Q9 | 22.7 | 22.7 | 9.1 | 31.8 | 13.6 | 45.5 |
| Q10 | 22.7 | 36.4 | 0.0 | 31.8 | 9.1 | 40.9 |
| Q11 | 0.0 | 0.0 | 31.8 | 50.0 | 18.2 | 68.2 |
| Q12 | 0.0 | 13.6 | 13.6 | 31.8 | 40.9 | 72.7 |

**Table 3**
Summary of student feedback on the positive and negative points of the 3D video.

| |
|---|
| Positive points |
| Ease of use |
| Open access |
| Immersive approach |
| Ability to repeat the course |
| Certification of content |
| Ability to get tips and tricks other than in a reference center |
| Good complement to traditional teaching approaches |
| 3D visualization of anatomical structures and their relationships with adjacent structures |
| Visualization of the procedure from the surgeon's point of view |
| Ability to go back during the video |
| It does not require an anatomical specimen |
| Negative points |
| Cost (for the student or the university) |
| Accessibility |

### 5.1. A teaching need

Each year we receive more workshop applications than places are available, forcing us to reject some applicants. From 2004 (21 applications) to 2018 (37 applications), the number of students interested in the workshop has increased, while the number of dissection tables available has not changed (11 anatomical specimens and fully equipped microsurgical dissection tables). The number of applications has increased in spite of the rising price of the workshop (currently more than 200 euros, not counting transport and accommodation).

As the number of neurosurgical residents keeps growing every year, at its 2018 Grenoble national congress the French College of Neurosurgery advocated developing video teaching supports, such as tutorials or lectures; and in 2019 a Congress session is dedicated to "Innovative new educational projects".

### 5.2. A need for new learning tools

3D animations and video games are now a part of a student's everyday life, and their use in teaching is increasingly interesting. The technology can be really useful for students who do not yet master the basics of brain and skull anatomy. With 3D digital supports, organs can be "turned around" and located in context, starting with simple images and getting progressively more complex, to show organs in motion with precision adapted to the level of skills that the student is supposed to master. This step of visualization is crucial before integrating the principles of a surgical approach [5,7,9]. With VRHs, all of these views can be shown from the surgeon's intraoperative point of view, according to the patient's position [4]. The present results showed that 3D video is effective in training for anatomy and surgical steps.

In addition to solid theoretical knowledge of anatomy, mastery of surgical procedures is the cornerstone of clinical expertise in neurosurgery. Teaching surgical skills is one of the most important and exhilarating tasks for a university hospital surgeon [11]. Teaching programs all aim at the acquisition of professional skills: i.e., the "individual's capacity to effectively resolve various problems encountered in their domain of practice" [10]. Clinical skill, in neurosurgery as in other surgical specialties, is multidimensional. It needs cognitive capacity to assimilate relevant clinical data and resolve problems, clinical reasoning, empathy in the patient/surgeon relation and, as mentioned above, technical psychomotor skills [11]. Most of this surgical technique is learned in the operative room in real operations during surgical residency. There are three necessary stages: demonstration, repeated practice, and immediate feedback [12]. The first stage (demonstration) progressively yields to the next ones (practice and feedback). This kind of teaching is obviously dependent on day-to-day mentoring, and students need to be taught by their senior surgeons to develop and acquire technical skills for surgical procedures. This kind of "buddy-system" is center-dependent, in terms of habits, specialties and the inevitable affective aspect of the senior-student relationship [13]. Furthermore, surgical disciplines tend to be hyper-specialized (oncology, skull-base, functional surgery, spine, pediatric, etc.), with numerous new techniques and instruments, both complementary and alternative to conventional procedures, multiplying the teaching burden. This increasing orientation toward centers of excellence and hyper-specialization is a trend that is widespread among surgical teams. The specific care needs of local populations and the frequent medical under-staffing of university teams accentuate this complexity. The present study considered that 3D video courses could be an interesting tool in surgical education, and the young surgeons who were interviewed agreed.

For these young surgeons, using the VR headset was straightforward (63.6% positive responses), requiring little explanation and procuring maximum enjoyment, with 90.9% of students satisfied.

### 5.3. Organization of the French residency program

Neurosurgical training in France is delivered by the French Neurosurgical College at national level. At inter-regional level, universities are in charge of this teaching, which leads to a diploma in specialized studies [14]. During the 5-year internship, trainee neurosurgeons attend at least 3 workshops organized by the French Neurosurgery Society and/or European courses previously approved by the regional coordinator.

As Pr. J.J. Moreau et al. point out [15], the third cycle of medical training is organized by region and inter-regionally, at considerable distances. Due to the variable number of students in neurosurgery, it is difficult to develop and harmonize training in new surgical

techniques. To prepare the future for clinical practice workshops that will meet the requirements of educational institutions, and the needs of society, it is necessary to standardize the current training of neurosurgeons. The new information and communication technologies provide a good way to respond to the need to deliver these courses to a restricted number of students. To this end, we developed a training method that is complementary to existing ones, with a 3D video tutorial on the key-points of a surgical approach. This provides a complement to the diagrams of operative steps found in surgery textbooks.

During the last few years, the College of Neurosurgery has developed a new training project. The first step consisted in a study of the needs of students and teachers by group discussions and an anonymous questionnaire. Then, new objectives were defined for 3rd cycle training: (1) increasing the number of inter-regional courses; (2) modifying the format of teaching; (3) using attractive and adapted methods to smooth over differences between regions, and combat non-attendance (either intentional or due to duties); (4) establishing an self-assessment system; and (5) contributing to training in neurosurgical practice [15]. The 3D video tutorial responds to 4 of these 5 objectives defined by the teachers' College (1–3 and 5).

### 5.4. Limitations and perspectives

There are several limitations to the present study. Sample size was small, although residents were recruited from several hospital sites and represented two specialties. However, we do not believe this limited the generalization of findings, because results are not expected to vary according to students' geographical provenance. However, this study was specifically centered on the French training in neurosurgery, while this new technology is also likely to impact other trainees.

Demonstrating the advantage of a purely visual method over traditional learning is challenging and it needs further study. Given that the goal of our intervention was sustained improvement in teaching, future objectives should include broadening the use of digital 3D video tutorials and assessing long-term benefit. Further validation of the pedagogical efficacy of the method should include comparing results with 2D video tutorials, assessing residents' technical and theoretical skills, and repeated assessment over time to see whether 3D shows benefit over 2D, followed by analysis of performance criteria in terms of task accomplishment.

The present study evaluated the contribution of 3D video in a rare and complex surgical approach (combined petrosectomy) that requires solid anatomical knowledge. This approach, at the crossroads of two specialties, needs orientation of view and understanding of operative steps. These skills are less instinctive in petrosectomy than in routine procedures. Nevertheless, we think that, at the outset of residency, 3D video may provide a "virtual buddy", explaining surgical gestures that are considered easy by experienced surgeons. 3D video surgical tutorials could be integrated in a multimodal approach with simulation and other educational techniques. As 54.5% of the students clearly said, training with 3D video obviously cannot replace cadaver dissection courses. It therefore appears necessary to integrate this training program in a complementary way. Ideally, video tutorials would be rather a means to answer students' questions, like tutoring. The place of this kind of tutoring in the residency program has to be defined by the teaching committee of the French College of Neurosurgery.

The teaching of neuro-anatomy and surgical approaches is central in the 3rd cycle of neurosurgery studies. The French Neurosurgical College plans to evaluate the impact of the present VRH 3D video teaching method on students' long-term knowledge in subsequent years. The further aim is to improve teaching and lesson quality, and to generate an exchange between students and teachers about their expectations and perceptions.

## 6. Conclusion

3D video viewable with a VRH appears to be an innovative teaching tool, enabling anatomic structures to be seen in 3 dimensions, accompanied by expert advice at each step of the procedure. A future study will be necessary to evaluate this tutorial method and define more precisely its role in the neurosurgery residency program.

## Authors' contributions

Author contributions to the study and manuscript preparation were as follows. Study design: FB, PHR, HDF. Acquisition of data: FB, CG, LT, HDF, PHR. Analysis and interpretation of data: all authors. Drafting the article: FB, CG, LT, PHR, LL. Critically revising the article: all authors. Study supervision: PHR, HDF, LT.

## Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. For this type of study (retrospective study), formal consent is not required.

## Funding

There was no study funding.

## Disclosure of interest

The authors declare that they have no competing interest.

## Acknowledgements

We are indebted to Mathias Rostagno (sound engineer) and Cyril Royer (video editor, Angers Medical School) for their technical help.

## References

[1] Bernard F, Lemée J-M, Lucas O, Menei P. Postoperative quality-of-life assessment in patients with spine metastases treated with long-segment pedicle-screw fixation. J Neurosurg Spine 2017;26:725–35, http://dx.doi.org/10.3171/2016.9.SPINE16597.
[2] Bernard F, Lemée J-M, Aubin G, Ter Minassian A, Menei P. Using a virtual reality social network during awake craniotomy to map social cognition: prospective trial. J Med Internet Res 2018;20:e10332 [doi:10.2196/10332].
[3] Bernard F, Troude L, Laccourreye L, Roche P-H, Fournier H-D. Stereoscopic surgical video with virtual reality headset: 3D combined petrosectomy. Oper Neurosurg Hagerstown Md 2018;16:638–9.
[4] Ros M, Trives J-V, Lonjon N. From stereoscopic recording to virtual reality headsets: Designing a new way to learn surgery. Neurochirurgie 2017;63:1–5, http://dx.doi.org/10.1016/j.neuchi.2016.08.004.
[5] Bairamian D, Liu S, Eftekhar B. Virtual reality angiogram vs. 3-dimensional printed angiogram as an educational tool – a comparative study. Neurosurgery 2019, http://dx.doi.org/10.1093/neuros/nyz003.
[6] Bernardo A. Virtual reality and simulation in neurosurgical training. World Neurosurg 2017;106:1015–29, http://dx.doi.org/10.1016/j.wneu.2017.06.140.
[7] de Boer IR, Wesselink PR, Vervoorn JM. Student performance and appreciation using 3D vs. 2D vision in a virtual learning environment. Eur J Dent Educ 2016;20:142–7, http://dx.doi.org/10.1111/eje.12152.
[8] Gaur DD. Laparoscopic operative retroperitoneoscopy: use of a new device. J Urol 1992;148:1137–9.
[9] Heath MD, Cohen-Gadol AA. Intraoperative stereoscopic 3D video imaging: pushing the boundaries of surgical visualisation and applications for neurosurgical education. Br J Neurosurg 2012;26:662–7, http://dx.doi.org/10.3109/02688697.2012.672057.

[10] Jean P, Delorme P, Des Marchais JE. Apprendre à enseigner les sciences de la santé : guide de formation pratique : cahier 1 [-cahier 5]. Faculté de Médecine des Universités de Montréal et de Sherbrooke; 1993.
[11] Norman GR. Defining competence: a methodological review. Assess Clin Competence N Y NY Springer 1985;1:15–35.
[12] Reznick RK. Teaching and testing technical skills. Am J Surg 1993;165:358–61, http://dx.doi.org/10.1016/S0002-9610(05)80843-8.
[13] The surgical clerkship: characteristics of the effective teacher - Sloan - 1996 - Medical Education - Wiley Online Library n.d. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2923.1996.tb00712.x. [accessed July 5, 2018].
[14] Organisation de l'enseignement de la neurochirurgie en France. n.d.:12.
[15] Moreau JJ, Moubacher MH, Proust F, Marchand L, Dauger F. Modèle d'enseignement inter-régional par visioconférence. Neurochirurgie 2003;49:464–9.