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My Thoughts / My Surgical Practice

Immersive Virtual Reality in surgery and medical education: Diving into the future

Over the last years, the quick advancement and widespread diffusion of Immersive Virtual Reality (IVR), prompted by the gaming and entertainment industry, has led to great interest in its possible applications in medical education and surgery. In particular, IVR is a technology based on specialized hardware platforms capable of generating a completely virtual world the user can dive into. This "immersion" is typically achieved using head-mounted displays and haptic devices, so that the user can block out the surroundings and interact with the virtual objects in the simulated environment.[1] In terms of experience provided, the available systems are heterogenous. Many simulators allow the three-dimensional visualization of anatomical virtual models, which can be reconstructed from the patient's radiological imaging and manipulated through zoom, pan and rotation functions or "ghosting" individual components. More complex setups simulate also the surgical instruments, usually recreating settings of endoscopy or laparoscopy. Using these tools, the user can perform from basic tasks, like pattern cutting, up to whole procedures, such as virtual cholecystectomy or appendectomy. IVR can even replicate the fully equipped operating room, including staff and furniture, but it is currently rare because of the low degree of attainable realism. As an alternative, video sequences of real operating room recorded with 360° cameras can be used to recreate the virtual environment.[2]

An increasing number of institutions have implemented solutions to evaluate the role of IVR as a safe and effective training tool.[3] Regarding the undergraduate medical curriculum, the benefits of IVR in didactics are still a matter of debate, but cumulative evidence to date suggests that it may improve the acquisition of knowledge in Anatomy, integrating and enhancing the traditional learning methods. Indeed, the immersion in the virtual scene allows multiple viewpoints, even those impossible through cadaveric dissection, and strengthens the comprehension of spatial relationships between organs. The high engagement and involvement in the learning process provided by IVR seem also to increase the retention of the acquired notions. Moreover, since the virtual models can be generated directly from the patient's radiological imaging, they can provide safe exposure to patient-specific anatomical variability, another aspect of key importance for future surgeons.[4] Conversely, caution is needed not to overload the user with an excessive amount of information, since highly complex scenarios may increase the mental workload and the demand for visuospatial problem-solving strategies, slowing the learning process. The implementation of easier-to-use interactions, as through haptic controllers or hand gestures to feel virtual objects via force feedback and to give the sense of being located in the virtual space, is also essential to maximize the learning benefits from IVR.

The application of this technology in surgery looks even more promising. IVR can provide users with a realistic environment to train and get used to specific surgical procedures, shortening the learning curve, avoiding unnecessary risks and minimizing the need for animals for educational purposes. This approach could be beneficial for both the training of inexperienced surgeons and the practice of experienced personnel.

The use of increasingly accurate models, allowing to identify the main features of the anatomical structures of interest, and the simulation of the surgical environment are expected to promote the transfer of technical and non-technical skills from the virtual to the real operating theatre. Considering the major concerns about the readiness of surgical trainees after completion of residency[5] and that the performance level required of surgeons is rising under the medicolegal pressure,[6] IVR could represent a safe and effective answer to the growing demand for training and professional skills. To simulate a wide range of procedures or even just to "warm-up" with exercises in the IVR can help surgeons to improve their psychomotor abilities and gain more proficiency. The close-up knowledge of patient-specific anatomy, with its frequent and manifold variations, the exposure to relevant surgical techniques and the opportunity to rehearsal before operating are likely to translate into better operative strategy and better clinical outcomes, such as shorter procedure time or reduced bleeding.

Interestingly, it was showed that the closer approximation to realistic hands-on experience imposes a significantly higher cognitive workload than standard methods. In fact, IVR can recreate stressful and involving conditions able to affect the user's performance.[7] At first, this may seem contradictory and even a disadvantage, but it can bring added value compared to traditional training sessions on mannequins, which may lack the appropriate situational stress.

At present literature is very limited, but the results about the application of IVR in surgical practice so far are overall positive. Remarkably, in a work published by Parkhomenko et al.,[8] the use of IVR induced the surgeons to alter their approach in 40% of cases. This finding is not surprising considering that 3D representation of the patient's anatomy coupled with the possibility to spatially explore the surgical scene from multiple points of view is more intuitive and less mentally demanding than the 2D vision provided by traditional cross-sectional imaging like computed tomography or magnetic resonance imaging.

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However, some problems need to be solved in the design and development of suitable IVR tools in medicine. Provided the importance of realism in the immersive experience, it must be underlined that the gap between the virtual environment and the real-life clinical scenario, i.e. the operating room, is still a challenge that IVR simulation must face. For instance, haptic devices are not yet capable to provide adequate sensory feedback,[9] but also head-mounted displays and other IVR setups are not yet fully optimized for the creation of "really realistic" virtual scenes. Unrefined methodology and small sample size of the studies so far, as well as the lack of external validation of the developed IVR simulators, are other issues requiring to be addressed in the future. Specifically, with the implementation of ever close to reality virtual environments, prospective randomized studies involving adequate cohorts are warranted to assess not just the user's satisfaction but the concrete benefits of IVR systems in comparison with traditional methods or other novel tools (e.g. augmented virtual reality). Finally, the evaluation of the side-effects related to the use of IVR, including the long-term impact of this technology on the user, must be investigated with a view to its implementation in medical education and surgical practice.

Therefore, despite the exciting potential to provide an easier learning experience and support in surgical training or preoperative planning, the application of IVR technology in the field of surgery is still at an early stage. However, the preliminary findings and the unceasing advances of computing power and digital rendering are good omens for the role IVR will play in the future of medicine.

Declaration of competing interest

The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

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