Virtual reality simulation: a paradigm shift for therapy and medical education

Virtual reality refers to a computer-generated environment designed to simulate a person's physical presence in a digital space. Compared to conventional two-dimensional computer-generated images on flat screens, virtual reality uses head-mounted displays which situate the user in a fully immersive, three-dimensional world. The objects are perceived as life-size, and head movement facilitates a 360° field of view. Headset-based virtual reality technology was introduced in the early 1990s and the subsequent 20 years have seen enormous advances in the quality of computer-generated images to improve realism, and now the advent of virtual reality for captivating gaming, entertainment and social experiences.

The recent introduction of commercially available and low-cost motion tracking into virtual reality headsets has further enhanced the opportunities for truly interactive virtual experiences. Tracking the head and hands enables a user to move within a virtual space, and to perform motor tasks on virtual objects. Clinicians have seized this opportunity to improve patient care, and are working with programmers to apply virtual reality technology in hospitals and universities. Alongside augmented reality, where holograms are projected on top of the real world within the viewer's field of view, virtual reality is revolutionizing how patients are treated (therapeutic virtual reality) and clinicians are trained to perform procedures (virtual reality simulation).

Virtual reality therapy

In creating three-dimensional environments which distract or engage patients, the therapeutic value of virtual reality has been validated in reducing anxiety during medical procedures (Indovina et al, 2018), and in reducing acute pain (Gold et al, 2006). Its use in burns patients is well evidenced: Schmitt and colleagues (2011) demonstrated that interactive virtual reality – with patients throwing virtual snowballs at snowmen – reduced acute pain by up to 44% in paediatric patients undergoing burn management. A study on adolescents showed similar results, with virtual reality therapy reducing acute pain by 24%, compared to 13% in the cohort which had a calming two-dimensional experience (Jeffs et al, 2014).

In the fields of neuropsychiatry and rehabilitation, virtual reality has been an effective adjunct to conventional interventions such as cognitive behaviour therapy or physical therapy, to treat motor deficits after stroke (Laver et al, 2017). For patients who had suffered a stroke, virtual reality rehabilitation games increased engagement and time spent in therapy by providing an accessible bedside platform to perform guided physiotherapy without supervision (Warland et al, 2018). Many studies have demonstrated how virtual reality therapy can improve motor function, postural balance or chronic neglect; others have highlighted how the technology can be a diagnostic tool to identify spatial neglect (Ogourtsova et al, 2017). These insights may have enormous implications for how, when and where therapy is administered in settings including cardiovascular, orthopaedic and neurological rehabilitation within and outside the hospital.

Virtual reality simulators

Working hours restrictions, increasing litigation and workforce shortages have created significant challenges for clinicians training in interventional specialties such as surgery, radiology and anaesthesia (Khan et al, 2017). Cadavers remain the gold standard for simulating a procedure, particularly in surgery. They offer high realism, haptic feedback (the sense of touch), and the opportunity to use real instruments and tools. However, they are expensive, not always accessible and offer no objective feedback of skill. In keyhole surgery, simulators have combined computer-generated images on flat screens with controllers representing laparoscopic or arthroscopic tools. These simulators are highly effective in training surgeons to perform for example knee arthroscopy or cholecystectomy, and have improved patient outcomes by reducing errors and increasing efficiency (Seymour et al, 2002), while neuroradiologists can now train to perform thrombectomy on an endovascular simulator, with patient-specific models using real catheters and guidewires (Liebig et al, 2018).

For open surgery, the addition of motion-tracked controllers to virtual reality headsets has provided a significant new function – the user's hands can freely manipulate virtual objects. This has created fresh opportunities for simulating open surgery (by which the majority of procedures are performed worldwide) (Rose et al, 2015).

Several academic institutions and industrial collaborators are developing virtual reality simulators for common orthopaedic procedures, such as hip and knee arthroplasty, trauma procedures such as femoral and tibial intramedullary nailing, and neurosurgical procedures, such as disc decompression and spinal fixation. By practicing in virtual reality, trainees can receive immediate, quantitative, objective feedback using metrics of surgical skill. They can learn the procedural steps and how to use equipment, and integrate psychomotor and cognitive skills, before a cadaveric or in vivo learning experience.

For more advanced learners, virtual reality surgery can help identify potential pitfalls and apply clinical pearls or solutions. This flexible training model enables surgeons to repeatedly practice complex procedures in a safe environment, with less reliance on conventional apprenticeship. An early publication in this zone by Harrington et al (2018) demonstrated how learners can

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evaluate a patient and develop decision-making skills in fully immersive virtual reality trauma scenarios, related to Advanced Trauma Life Support guidelines. Multiplayer virtual reality, in which a learner can assess a patient, perform a procedure or interact with other health-care professionals to communicate and plan a patient's treatment, is on the horizon.

Conclusions

Recent developments in virtual reality technology have made it affordable, scalable and accessible. In health care, virtual reality is currently well validated for neuropsychological assessments and therapy, cognitive, optical and physical rehabilitation, and pain management. The next decade will see its widespread adoption in these spheres, as well as its growth for applications in medical telecommunication, procedural training and planning, and in empowering the multidisciplinary team to train together. **BJHM**

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KEY POINTS

- Virtual reality has therapeutic use in treating patients.
- Virtual reality in surgery is mainly used for training and keyhole surgery.
- Virtual reality is a technology that is cheap, validated and commercially available for wider adoption into medical practice.