Acta Orthop. Belg., 2006, **72**, 659-663

REVIEW ARTICLE

Virtual Reality – A 'play station' of the future
A review of virtual reality and orthopaedics

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Virtual reality has been used in planning and executing various surgical procedures. Technical competence is the bedrock of surgery and virtual reality is the modern tool to assess and improve this competence. These methods are more cost effective and safe. Orthopaedic surgery is based on imaging and hence, can be strongly influenced by the concept of virtual reality. High performance computing has a potential for revolutionary innovation in practice of medicine. Fusion of real and virtual information can produce images that can help plan and undertake various surgical procedures.

Keywords : virtual reality ; orthopaedics ; computers and orthopaedic training.

INTRODUCTION

Virtual reality is a three dimensional computer generated world in which a person can interact as if he were a part of that imaginary world. The person is immersed in this virtual world with the help of a head mounted display and virtual tools. The head mounted display is a helmet fitted with paired wide-angle television screens that sit in front of the eyes and stereophonic speakers placed over the ears, so a person wearing the helmet can only see and hear what the computer generates. The virtual tool or hand is an input device that acts as a joystick and appears as a hand in the "virtual world". One can move in this virtual world by pointing in a direction for travel and picking up and manipulating objects by making a grasping motion with the tools. This concept of virtual reality has been used extensively in orthopaedic surgery for :

1. Training in orthopaedic surgery,
2. Virtual reality assisted orthopaedic procedures : diagnosis, preoperative and intraoperative planning and actual surgery.

Role of virtual reality in orthopaedic training

Planes do crash ! Fortunately most of the time this happens in the simulator. For over four decades, the aviation industry has recognized that the way to train pilots to react appropriately to critical emergencies, which occur infrequently, is to expose them to those emergencies in a simulated virtual reality environment. Not only is it less

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No benefits or funds were received in support of this study

expensive than crashing real planes, but also it permits complete control over the environment and provides the means to collect relevant data for subsequent educational feedback. In addition this is a safe method that helps to save time and equipment. Ultimately, it is used for credentialing pilots to fly commercial airliners after they have spent initial hours of 'flying' in the simulator making perfect take offs and landings.

Technology in the form of computer graphics and haptic feedback technologies initially designed for a computer game has found its way into simulators of various kinds of minimally invasive procedures. The 'weakest link' with the present technology is that there is a lack of surgeons who can provide specific medical and surgical knowledge to computer programmers to enable them to develop realistic simulations (*13*). Simulators have been developed for training in knee arthroscopy and shoulder arthroscopy in England (University of Hull – VE-KATS) (*20*), Exeter virtual worlds project – University of Exeter (*9*), Warwick, Imperial and Sheffield Haptic Knee Arthroscopy Training System (WISHKATS) (*15*), Munich Knee-Germany (*16*), China (*6*), Japan (*14*) and America (*3*).

The simulator has to be constructed in a way that enables the images, sensory input and interactivity to convince the surgeon that the illusion in front of him is real. All simulators are driven by capabilities of soft and hardware. For a realistic simulation five areas need to be addressed :

1. Object properties- Organs must deform when handled. Real time deformation has been simulated using finite element analysis (FEA) (*5*).
2. Good image quality. The biggest challenging factors at present are computing power to generate high level computer graphics and video display (*18*).
3. Interactivity. Surgeons hand and surgical instruments must interact realistically with the organs.
4. The surgeon must feel sensory input – force, feedback, tactility and pressure. Tactility has been developed using force feedback hardware device (*5*).
5. Reactivity. Organs must have reaction to manipulation or cutting such as bleeding, etc.

Virtual reality provides the first opportunity to combine 3-D visual imagery with interactivity at a level that would permit realistic visualisation of complex anatomic dissection or performance of surgical procedures. It can make learning surgical anatomy easier by allowing the student to explore the interrelations of various organ systems in perspectives not available through other standard teaching techniques (*22*). Anatomic visualisation has made it possible to perform 'virtual dissection' of human body and uses it as a tool to train surgical trainees. One of these virtual anatomy endeavours is www.primalpictures.com, which is an online resource for medical students, doctors and healthcare industry (*21*). The Chinese have adopted the visible human project and Chinese visible human data set to construct virtual models (*24, 25*).

The surgical simulator can be used in surgical residency training and research. A trainee can practice asynchronously without the trainer until perfect before performing it on a patient (*13*). A researcher can attempt new surgical procedures repeatedly before the first attempts on an animal model so fewer animals are needed for research. Teaching surgical skills becomes easier as the risks are fewer. This can also reduce the risk of contracting blood borne infections (HIV and hepatitis) that can be high in the trainees due to an increased risk of needle stick injuries and risk of legal complication as a result of malpractice litigation.

In the present changing environment of training in the UK with reduced working hours for the trainees (European working time directive) and decreased hospitalisation of the patients (day care procedures are mostly done in Diagnostic and Treatment centres) there is erosion of the traditional training system in surgery that was based on didactic lessons and apprentice like lessons. We have moved into an era of structured training with 'competency- based' training to be evaluated by the PMETB (Post Graduate Medical Education and Training Board). Operation theatre is sometimes not an ideal place to train as there can be pressures like time constraints, patient condition and anaesthesia considerations that impinge upon the teaching of the trainee. In view of the change in training in the UK, the simulator allows learning to occur in a purely educational environment so that the learner is not distracted by clinical service concerns. Evidence suggests that virtual reality simulation techniques offer a cost effective alternative to traditional training methods (*5*). It is important to validate whether we can transfer skills from a simulation based education system to clinical practice and for this we need to plan high quality randomised controlled studies in the future, as evidence of this at present in literature is very scant.

Virtual reality assisted Orthopaedic procedures

Imaging has developed significantly in the last decade. These faithful high-resolution images in 3D and 4D have made it possible to create a real experience rather than simulation of reality. Three dimensional images allow surgeons to virtually enter the images and see the detailed anatomy. This also allows the surgeon to make accurate measurements along with controlling an interventional process. These images help to make a detailed diagnosis of the problem and then give an opportunity to plan the surgery and do a rehearsal of the procedure before it is actually carried out in the operation theatre (*2*). Virtual reality assisted procedures can be as diverse in the field of Orthopaedics as :

1. Passive use in the form of surgical navigators displaying the surgeons' tools with in patients images including MRI, CT, Ultrasound or radiographs.
2. Surgical simulators create preoperative surgical rehearsal possible by mixing the data from patients' images and performing surgical tactic in a virtual environment.
3. The imaging data can be combined with intraoperative data obtained with ultrasound or electromagnetic sensors using bony landmarks and virtual tools that the manufacturer calibrates. The surgeon can communicate with this virtual environment with a touch screen, voice recognition system or a virtual keyboard. This virtual reality can be used semi passively by the surgeon doing the operation or can be used actively by a robotic arm doing the operation (*7*).

Virtual-reality-assisted interventional procedures help to bring to the operation theatre pre-surgical planning data. It also helps to combine actual patient and intraoperative data. This helps to optimise the effectiveness of the procedure, minimises patient morbidity and reduces healthcare costs. The rate of evolution and acceptance of these 3-D biomedical-imaging systems increasingly will be dependent on effective software packages and user interfaces. Virtual reality assisted surgical planning is being used in various surgical specialities including complex plastic, neurosurgical and orthopaedic procedures. It has been used to plan surgeries like separation of conjoined twins. Virtual reality helps the surgeons to interactively visualise the 3D data of CT and MRI images with hands free manipulation of virtual display. The surgeon can then scale, orient and position prescanned body imaging on line in real time from any desired perspective. The clinical goal is dynamic fusions of 3D body scan data with actual patient in the operation theatre. The customised interface permits on line access to preoperative plan and to update measurement and analysis based on real time data (*17*).

In the constantly growing world of computer assisted surgery using the principles of virtual reality passively or actively, various procedures that are being done like :

1. Hip surgery for insertion of cups and implantation of stems actively or passively. Instability is one of the most challenging complications of total hip arthroplasty especially in revision hip surgery and use of virtual radiograph system using preoperative CT scan and radiographs has been used to plan surgeries in patients with recurrent dislocations (*19*).
2. Computer-assisted surgical-navigation machines are generating virtual images to guide surgeons through complicated knee procedures, like robot assisted knee replacement and tunnels for ACL and PCL reconstruction. Human motion has been captured with 3D images and used to observe knee behaviour during gait cycle (*23*). The 3D images are then used to plan the osteotomy as most complications with osteotomies stem from inappropriate cuts e.g. 20% for high tibial

osteotomies. Collaborative project looking at computer/robotic assistance for osteotomy and joint replacement of knee joints is underway at Hull University, UK (*20*). These osteotomy simulators can also be used to train junior doctors (*8*).

3. Spinal surgery is one of the orthopaedic subspecialties in which computer assisted virtual reality has been used for CT and fluoroscopy based trans pedicular screw placement, vertebroplasty, kyphoplasty and spinal osteotomies and fusions (*10*).
4. Trauma surgery is also one of the beneficiaries of the computer assisted orthopaedic surgery. SimVis have developed an X-ray vision system with a passive manipulator arm employing a novel phantom based image/anatomy registration technique. This technique has been developed for distal interlocking of intramedullary nails and guide wire placement for dynamic hip and cannulated hip screws (*12*). The Computer Assisted Orthopaedic Surgical System (CAOSS) (*12*) has been developed at University of Hull for distal locking of intramedullary nails. FRACS (Fracture computer aided surgery) for closed intramedullary nailing of long bones is a computer integrated orthopaedic system developed in Israel that uses virtual reality display of three dimensional bone models created from preoperative tomography and tracked intraoperatively in real time (*11*). Computer assisted orthopaedic surgery has been used for minimally invasive pelvic screw fixation.
5. Virtual reality has been used for tumour surgery in Orthopaedics involving the spine and the pelvis. VIRTOPS or 'virtual operation planning in orthopaedic surgery' is a German system used for preoperative planning and simulation of hip operations. This system helps to simulate endoprosthetic reconstruction of hip joint with hemipelvis replacement and supports the designs of adaptable modular prosthesis (*4*).
6. Virtual reality has been used for planning and simulation-involving planning of complex deformities, assessment of implant accuracy and implant migration. Virtual reality is useful for audit and doing research that earlier required animals and had issues with ethical approval (*7*).
7. Virtual reality has been used for rehabilitation of orthopaedic patients with hand, elbow, knee, ankle impairments and spinal injuries (*1*).

CONCLUSION

Virtual reality is truly one of the greatest developments in surgery in the recent times that has empowered us to develop high precision minimally invasive surgery. We as surgeons need to understand that virtual reality adds a scientific slant to the 'art of surgery'. Virtual reality is an interphase of 'human-machine partnership'. Many surgeons are concerned that technology might replace the skill and judgement of a surgeon. In 'virtual reality' the idea is to combine human experience, adaptability and critical analysis with machines untiring and reproducible geometrical accuracy. Virtual reality is our play station of the future where we surgeons, trainees and scientists of the next generation would play and enjoy this wonderful game of orthopaedics.

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