The Royal Academy of Engineering

Simulation and medical training

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Biomedical engineering creates new medical technologies and systems that can greatly improve patient care and quality of life. The UK Focus for Biomedical Engineering is the Academy's forum for this increasingly important area of engineering in which the UK is taking a lead.

Introduction

Simulation has been used extensively in training and education for many high-risk industries including aviation, nuclear power, military and rail. Repeated exposure to simulated crises and events has meant that, for example, airline crews are well prepared to face a rare disaster when it happens in real life.

The use of simulation and simulators in medicine to train and educate healthcare professionals has gained attention in recent years and many simulation centres have now been set up in the UK. These offer a similar concept to that which the high-risk industries use, with training for medical emergencies using sophisticated manikins in realistic medical settings, and task trainers teaching, for example, practical surgical skills.

Many potential accidents in medicine are due to human error and communication problems. Simulators can help by training teams to function optimally using human factor style teaching.

Simulation can also be a practical solution to several current educational issues. These include the challenges faced by educational institutions in securing clinical placements, the decrease in the social acceptance of trainees learning on patients, and the dramatic decrease in training time available to junior doctors due to the reduction of hours through the European working time directive.

The technology

Training using simulation for healthcare professionals takes place in many settings. They include:

- purpose built simulation centres which contain sophisticated manikins
- clinical skills laboratories, which contain surgical skills trainers
- hospital wards and clinical areas such as intensive therapy units (ITUs), which will have portable manikins
- specialist teaching rooms, for virtual reality training
- specialist teaching rooms containing manikins.

Purpose-built simulation centres have designated rooms for different types of training. Simulated operations and team training can be carried out in the operating room. This is made as close as possible to a modern operating room, with real equipment such as ventilators, defibrillators, patient monitors, trolleys and drip stands. A control room is next to the operating room, with a one-way viewing window, where the manikin is controlled and where the simulation training is viewed and video recorded. Tutors in the control room communicate with key people in the clinical rooms using radio headsets. Audio-visual facilities are located in the control room, and any of the simulation rooms can be recorded. The operating room can be configured to be a different type of clinical room, such as an ITU.

A de-briefing conference room is essential to the simulation process. This can be connected to the simulation room by a one-way viewing window or viewed using the audio-visual facilities. There is normally a multi-bedded ward, provided with monitors, ventilators and similar equipment to that provided in the real situation.

Both the operating room and the multi-bedded wards have manikin-based simulators in them, making this type of centre unique. These simulators can be at many levels of complexity with those driven by mathematical models being the most complex. These model-based systems attempt to faithfully represent the anatomy and physiology of a human being, and are capable of functioning on their own. Non-model driven systems are less complex and are operated by the tutor or operator.

Mathematical models simulate patient physiology and pharmacology and provide responses in real time to whatever treatment has been given. The models rely on software to predict the manikin's responses and have great flexibility for changing parameters. A typical human patient simulator contains three groups of models: cardiovascular (heart systems), respiratory (lung systems), and distribution and pharmacology (drug systems).

The manikins can talk, breathe on their own or be ventilated. They have pulses, blood pressure and heart waveforms. They can respond to intravenous simulated drugs given by special coded syringes containing saline or entered by the operator's console. The eyes blink and the pupils react. The most advanced manikins take in real anaesthetic gases from a machine, or oxygen from normal air and breathe out exhaled anaesthetic gases or carbon dioxide.

All the mechanical functions in the manikin are controlled from the mathematical models in the system to give a high degree of realism. All the signals from the manikin (for example heart waveforms) are monitored by normal hospital monitors.

At a less advanced level, surgical skills laboratories contain many devices to teach and provide objective evaluations of trainee surgeons' technical abilities. The simulation devices range from the simple plastic devices that teach medical students how to stitch wounds, to complex sophisticated devices that combine mechanical models with computer stations. Both can be used to teach basic skills and surgical tasks through repetitive supervised challenges, and will enable detection and analysis of surgical errors and near-miss incidents without risk to patients. These simulators include an endoscopic sinus surgery simulator for procedural training, and the Minimally Invasive Surgical Trainer-Virtual Reality (MIST-VR) system for basic surgical skills training. Measurements include time-to-completion of tasks, number of errors, economy of motion, and the tracking of the movement of the trainees' limbs.

Hybrid training is where surgical trainers are combined in either manikins or strapped to actors, but in a realistic environment, so that team training using human factors and crisis events can be practised during "real surgery".

Simulation task and team training can be provided in a complete virtual world which contains virtual patients, virtual medical devices within a very realistic 3D clinical environment. Advanced computer models mean that the virtual patients behave very realistically, although there is no actual physical hands-on experience.

The engineering contribution

There are many aspects to training and education using simulation, and it involves many different professions, including psychologists (for the study and teaching of human factors and non-technical skills), educationalists (researching how staff learn), medical staff (for teaching and training), and professional engineers.

Engineers are vital to the development of simulation. They design the environments, and are involved with provision of clinical equipment and equipment management. Engineers design the manikins, and future challenges include developing manikins with improved physical properties, such as skin feel and skin colour change with physiological state. Challenges also include better mathematical modelling, so that manikins respond to treatment and drugs more realistically.

Other areas where engineers' input is vital include:

- Measuring the effects of training, in both technical skills and non-technical skills, by designing special sensors
- Equipment design and testing, including how the equipment interfaces with humans in the simulation environment
- Designing the audio-visual and Information Technology (IT) part of facilities
- Design and development of the surgical simulators and all the sensors associated with that
- Design and development of software and mathematical models with virtual reality
- Teaching and designing of research experiments.

Future work

Most of the sophisticated manikins are manufactured and designed in the US or in mainland Europe, although there has been collaboration on some design components with the UK. The majority of surgical simulators are also manufactured outside the UK, although there is some UK presence in the simpler surgical simulator market.

However, there is a large academic and NHS contribution to the development of physiological models, the development of surgical simulators and computer programs, and the development of parts for manikins. Some centres in the UK are world-leading in their innovation in simulation training. Simulation training can help in reducing costs and helps address the challenges faced by educational institutions, including securing clinical placements, the decrease in social acceptance of trainees learning on patients and the dramatic decrease in training time being available to junior doctors.

Simulation and simulators are now a vital part of our healthcare system. They make training and education much more efficient and improve patient care and safety. The simulation environments with their sophisticated equipment can help teach practical skills (for example surgical and anaesthetic skills) and teach teams of staff how to work well and communicate effectively together. Engineering and engineers have a vital, underpinning role in supporting and developing simulation.

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