SEMINAR PAPER

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The application of clinical simulation in crisis management training

在危機處理培訓中臨床仿真的應用

Since it was first introduced more than 30 years ago, clinical simulation has become a popular tool for medical training, particularly in crisis management. The modern high-fidelity patient simulator consists of a whole-body mannequin with integrated electronic patient monitoring; it is controlled by computers capable of simulating numerous clinical scenarios and patient characteristics, and reacting to various interventions appropriately. Simulator training is theoretically superior to conventional training in management of rare crisis situations, as it allows unlimited practice in a safe yet familiar environment. Training in clinical skills can be developed, together with competency in crisis management behaviours such as leadership and communication skills. Although there is evidence demonstrating the popularity, reliability, and validity of simulator training, its superiority over conventional training has not been proven, and research in this area is required.

自30多年前首次引入臨床仿真以來，它已成為醫學培訓的普遍工具，在危機管理中更是如此。現代高仿真病人模擬器由整個人體模型結合電子病人監測組成，它由電腦控制，該電腦能模擬眾多臨床狀態和病人特性，並對各種療法作出適當反應。理論上，對於罕見的病例，模擬器培訓比常規培訓優越，因為它可以在安全而又熟悉的環境中無限制地進行練習。這種培訓可以開發臨床技能，並增強危機管理中的應對能力，如領導和溝通能力。雖然現時已有證據證明模擬器培訓的普及、可靠及有效性，惟它較之於常規方法的優越性尚未被驗證。因此這方面的研究仍需進行。

Key words:
Anesthesia;
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Introduction

In the field of medicine and medical education, technology plays an increasingly important role in clinical skills development and training. Simulation technology has been well established in the aviation industry and the military. In the aviation industry, in-flight simulation training provides an opportunity for the trainee pilot to be in ‘life-like’ situations, and has been shown to improve the skills of pilots.[1] Military training also commonly makes use of simulation technology, where war games and military manoeuvres are executed and then reviewed. In recent years, this technology has devolved to medicine, and provides new opportunities and new experiences in medical training.

The development of clinical simulation in medical training

Simulators have been used in anaesthesiology training for over 30 years.[2] The SIM 1 system, which was introduced in the 1960s, incorporated a simulator system that partially mimicked the patient and the anaesthesiologist’s workstation. However, technology at that time did not allow SIM 1 to provide any integrated electronic or invasive monitoring, and the system only recognised six drugs in its simulation programme. Since that time, advances in technology have led to the development of more sophisticated simulation systems, which provide a highly complex model of human physiology and pharmacology that responds to drugs and other interventions like a human patient. Some of these systems are available as computer simulation programmes with multimedia features that include computer graphics and real-time audio capability.[3]

More elaborate systems are available as high-fidelity 'hands-on' simulators, which comprehensively recreate the environment of the operating room—including the manual and cognitive tasks of anaesthesia administration to a whole-body mannequin, integrated electronic patient monitoring, and real-time responses to medical intervention.[4] The computer software running the simulator is now able to recognise over 30 drugs and simulate over 50 clinical scenarios, and to control the responses of the simulator, which may vary according to the scenarios and interventions. A high-fidelity simulator mannequin has an anatomically correct airway, and can breathe spontaneously or be connected to an anaesthesia machine for mechanical ventilation, with all the expected ventilatory parameters. Complex physiological models representing the circulatory system generate palpable carotid and radial pulses and central venous pressure, as well as intra-arterial pressure waveforms. Breath and heart sounds—normal or abnormal, electrocardiogram tracing, SpO_2, and data from a pulmonary arterial catheter (eg cardiac output) are also available.

The momentous progress in simulation hardware and software technology coincided with the development of novel methods of training in medical skills, particularly management of medical emergencies and crises. In the early 1990s, it was recognised that there was no systematic anaesthesiological training in handling critical situations, so that the anaesthesiologist might lack the ability to manage resources effectively during a crisis despite sound medical and technical knowledge. A training programme was introduced to remedy this deficiency, focusing not only on clinical skill, but also on behaviours during crisis management that emphasise teamwork and coordination of resources.[5] Training in these behaviours, which has been well studied in aviation and is now standard in training commercial pilots, was adopted into anaesthesia crisis management training (Box). This type of crisis management training is now widely conducted in a realistic full-scale simulation environment using high-fidelity patient simulators (Fig 1).[6,7]

The use of simulation technology for skill training in other areas of medicine has also gained wide acceptance. Laparoscopic surgical simulators assist surgeons in acquiring laparoscopic surgical skills in a standardised and controlled environment.[8] The technology today allows surgeons to practise virtual surgery in simulated conditions without risk to the patients. In internal medicine and cardiology training, the Harvey simulator developed by the University of Miami School of Medicine realistically simulates over 25 cardiac conditions in a life-sized mannequin, providing realistic physical findings.[9] Simulation technology is also widely used in emergency medicine resident training, and in trauma care skills training in paramedics, nurses, medical students, and residents.[10,11]

The key behaviour principles in anaesthesia crisis resource management[5]

- Anticipation and planning
- Communication
- Leadership and assertiveness
- Use of all available resources
- Distribution of workload and mobilisation of help
- Re-evaluation of situations
- Use of all available information and cross-checking of redundant data

Fig 1. Full-scale clinical simulation environment at the Institute of Clinical Simulation
The Institute of Clinical Simulation is jointly managed by the Hong Kong College of Anaesthesiologists and the North District Hospital. Trainees are seen participating in the management of an anaesthetic crisis scenario

Clinical simulation has enjoyed widespread and enthusiastic acceptance since it was first introduced. This popularity can be explained by the many theoretical advantages of applying simulations in clinical crisis management training (see below).

Clinical simulation and theories of training and learning

Traditionally, postgraduate medical training and education has been carried out in three major forms. Firstly, there is self-learning from reading textbooks and journals. Secondly, didactic teaching is given in the form of lectures and tutorials. The third and probably most important method is apprenticeship. This involves 'on-the-job' training where trainees are exposed to clinical content in the hospital ward, out-patient clinic, operating theatre, or laboratory where they are posted. While this is a time-tested and generally well-accepted training system, it has important limitations, some of which may be overcome with the use of clinical simulation as a supplementary training tool.

The limitations of self-learning by reading and didactic teaching are well known. Depending on the quality of the trainers, the format of presentations may often be dull and mundane, and trainees as well as trainers become bored easily. The information presented to trainees in these types of learning sessions may also be poorly retained. Trainees commonly tend to use less satisfactory learning styles such as superficial learning where they only attempt to memorise the information presented to them, and 'strategic' learning where they try to learn what is likely to appear in their examinations. Training in crisis management through self-learning and didactic teaching is inadequate. Management of a medical crisis is complex and time-critical, and requires the operator to be in the primary control loop of the system. The complexity of these high-performance tasks[12] makes it almost impossible for trainees to learn simply by self-reading and from didactic teaching. Furthermore, the behavioural skills in managing the crisis situation are not easily acquired through conventional methods of learning.[13] Coordination and distribution of resources, which are critical aspects of the management of a life-threatening event, are skills that are often learned from experience. Managing a simulated crisis situation provides exposure to a 'life-like' experience.

The method based on apprenticeship also has many limitations in the training of crisis management. Firstly, clinical emergencies and crises occur infrequently and irregularly. Therefore, the opportunity for learning about crisis management in the real world is incidental and sporadic, and the exposure of trainees to rare crisis situations by the end of their training periods is likely to be inadequate. Furthermore, during crisis situations, supervisors or senior colleagues usually take charge in managing the situation. The trainers involved are so busy managing the patient during and after the crisis that there is often little time for teaching or debriefing of the crisis management process; trainees are simply expected to 'learn from the experience'. However, experience and learning are two different processes: experience only becomes effective learning with reflection and review of clinical performance, as highlighted in learning models such as Kolb's learning cycle (Fig 2).[14]

Most of these limitations can be overcome by including clinical simulation in crisis management training. The strongest merit of adopting clinical simulation in teaching crisis management is the possibility of allowing the trainees to have unlimited practice in managing many different crises, no matter how rare they may be in real life. The well-known learning equation, or 'learning curve', has been tested for quite some time.[15] It may be represented mathematically as $T=BN^{-a}$, where T is the time required to perform the task, B is the performance time on the first trial, a is the learning rate, and N is the trial number. Thus with practice, trainees are expected to respond more quickly and with greater accuracy to a crisis situation. The other merit is the possibility of exposing trainees to different versions of a crisis, which can be provided for by programming at different levels of complexity and pace.

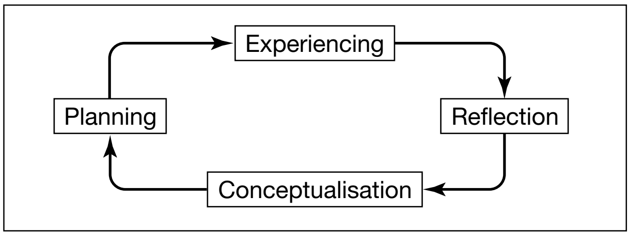

Fig 2. Kolb's learning cycle[14]

Translating experience into learning can be tackled during the process of a well-conducted simulation training session. Reflection on the experience gained in a simulation session is much more reliable and structured than in a real-life crisis situation. Debriefing sessions are routine and form the most important part of a simulation training session. During the debriefing session following each simulation scenario, the participants view videotapes and critique their own performance with the assistance of a trained instructor. While the general principles of crisis management behaviours are emphasised during these sessions, medical and technical issues related to the scenario are also discussed.

There are many other advantages of using clinical simulation in crisis management training. Trainees usually find simulation sessions less boring than traditional learning. Indeed, many participants enjoy a surge of adrenaline and the ensuing excitement during clinical simulation. They are more likely to appreciate the relevance of the training to their daily practice, and are thus able to achieve a deeper level of understanding and comprehension of the events during the clinical simulation. Retention of the information provided during the simulation is often much better as well.

November 1999 saw the release of the US Institute of Medicine Report "To Err is Human", which estimated that 44 000 to 98 000 patients died annually in the US as a result of medical error.[16] This report strongly echoed earlier findings within the speciality of anaesthesiology that human error and system error accounted for the majority of mishaps and incidents in both the US[17] and Australia.[18] Although data from Hong Kong are not available, the local scene is not likely to differ substantially from these overseas reports.

An incident or mishap frequently results from unsatisfactory management of a crisis situation. Crises do not arise at random. Many 'latent' or 'system' errors that contribute to the initiation of the crisis can usually be identified.[5,19] These errors may include equipment problems, an unfamiliar environment, and conditions such as haste and fatigue of the operator. The evolution of the crisis into some mishap will usually also involve 'active' or 'human' errors.[5,19] These human errors are highly varied. One particularly common type is called 'fixation error', where the operator fails to adapt his/her mindset to a highly dynamic crisis situation.[5]

Clinical simulation in crisis management training allows trainees to learn more than just clinical skills. Through role-playing during crisis scenarios and detailed debriefing sessions, trainees can discover and gain useful insights into the various errors contributing to the initiation and evolution of a medical crisis. They can also learn other skills that are essential in managing a medical crisis, such as resource utilisation, communication skills, teamwork, and leadership skills.

On the other hand, clinical simulation has its deficiencies. Although a high-fidelity patient simulator may mimic the real-life situation, the unfolding scenarios at the 'simulator centre' may not present the realism associated with a genuine critical event, where the patient's life may be at stake. The participants, aware that they are working under simulated conditions, may not perform under similar pressure or as ardently and seriously as in a real event. After all, the patient is a mannequin. Furthermore, the patient-mannequin and computer programme simulating the scenarios may not fully represent the exact real-time characteristics of an event, because of limitations in current technology.

Benefits of clinical simulation

The popularity of using simulators in anaesthesiology training was well demonstrated in two recent surveys. In 1997, Riley et al[20] published a survey of anaesthesiologists' attitudes towards anaesthesia simulators. All clinical staff of the Department of Anesthesiology at the University of Pittsburgh Medical Center, and all anaesthetists attending the 1993 Annual General Meeting of the Australian Society of Anaesthetists, were invited to participate in a questionnaire survey. Of the 183 respondents, 73% were in favour of departmental purchase of a simulator, and 76% expressed willingness to undergo testing in their own time. Although clinical simulation appeared to be popular, 65% were not in favour of the compulsory use of a simulator for re-certification or re-accreditation of anaesthesia practitioners.

In another survey, 35 anaesthetists from the Toronto area who participated in Anaesthesia Crisis Resource Management workshops at the Canadian Simulation Centre, and completed an anonymous exit evaluation questionnaire, showed total support for the courses and considered them beneficial.[21]

Studies have also been performed to assess the validity and reliability of using simulators in medical training. Devitt et al[22] evaluated inter-observer reliability between two observers witnessing the same event during an anaesthetic simulation. Two clinical scenarios, each containing five anaesthetic problems and 30 events for assessment, were first developed. Videotape recordings of the role-playing during the two scenarios were then shown to two anaesthesiologists, who reviewed and scored each of the 30 problems independently. It was found that the two observers were in complete agreement on 29 of the 30 items. Following this, the same group went on to test a rating system developed to evaluate anaesthesiologists' performance in a simulated patient environment, and to determine whether the test scores could discriminate between resident and staff anaesthesiologists.[23] They found that the rating system had poor internal consistency and needed to be modified. Nevertheless, it did discriminate between resident and staff anaesthesiologists, and thus demonstrated one aspect of construct validity, namely, discriminant validity.

Gaba et al[24] also evaluated another rating system of anaesthesiologists' performance. Independent observers viewed the videotapes of 14 different teams who were managing the two scenarios. They scored each team for 12 crisis management behaviours, and then conducted a technical scoring for each scenario by identifying the presence or absence of defined clinical actions. It was found that there was good inter-rater agreement on technical performance, although the behaviour ratings showed greater inter-rater variability and needed more refinement.

Presently, few studies show strong evidence that simulator training improves clinician performance in the management of real-life crises. Chopra et al[25] studied 28 anaesthesiologists and anaesthesia trainees in one hospital. The participants were exposed to a pre-scripted simulated 'control' scenario of anaphylactic shock (phase 1). The performances of individual participants were evaluated using a standardised scoring scheme. During phase 2, the participants were randomised to undergo simulator training in the management of either anaphylactic shock (group A) or malignant hyperthermia (group B). After 4 months, each participant underwent a blinded evaluation session with a pre-scripted 'test' scenario of malignant hyperthermia (phase 3). It was found that participants in group B performed significantly better than those in group A. It was concluded that training on an anaesthesia simulator could improve the performance of anaesthetists in dealing with emergencies during anaesthesia.

Clinical simulation in Hong Kong

At present there are six high-fidelity patient simulators in Hong Kong. Five of the simulators are located at teaching departments of three universities (Polytechnic University, The University of Hong Kong, and the Chinese University of Hong Kong), while the sixth belongs to the Hospital Authority (HA) and is operated jointly with the Hong Kong College of Anaesthesiologists (HKCA). Simulators at the universities are currently being used for clinical skill teaching and assessment of medical and nursing undergraduates, and in some postgraduate settings. The simulator at the HA hospital is used for clinical skill and crisis management training for HA staff as well as members and fellows of the HKCA. Clinical simulation has a wide range of applications, such as in medical and nursing undergraduate training; trauma and resuscitation management and skill training especially for paramedics, anaesthesiologists, emergency medicine, and surgical residents; and continuing medical and nursing professional development and education. Although the efficacy and cost-effectiveness of simulation technology in clinical skill and crisis management training has not yet been clearly demonstrated, there is increasing evidence to suggest that it is useful in many aspects of such training. It is likely that its popularity in Hong Kong will increase over the next few years.

Conclusion

The concept of using simulation in crisis management training stems from solid and relevant theories in education and skills training. The proven success of simulation training in other disciplines such as aviation and military training further supports the application of this concept in medicine.

Training using simulators in many different medical specialities, particularly those involving crisis management training, is gaining popularity worldwide at an astonishing pace. However, many questions regarding clinical simulation remain to be answered. Thus, further research is required to clarify the effectiveness of clinical simulation when compared with conventional methods, the cost-effectiveness of simulators and simulation training programmes, and to improve on its present deficiencies.

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