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REVIEW ARTICLE

Simulation-based airway management training: application and looking forward

Dong Yang[1] · Yu-Kui Wei[2] · Fu-Shan Xue[1] · Xiao-Ming Deng[1] · Juan Zhi[1]

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Abstract Within the airway management field, simulation has been used as a tool of training for over 40 years. Simulation training offers a chance of active involvement for the trainees. It can effectively enhance and upgrade the knowledge and skills of the trainees in airway management, and subsequently decrease medical errors and improve patients' outcomes and safety through a variety of airway management training modalities, such as common airway skills, difficult airway management strategies, and crisis management skills. To perform simulation-based airway management training effectively, not only are task trainers and high-fidelity simulators required but also instructors with rich experience in airway management simulation training and optimal curriculum design are essential.

Keywords Simulation · Airway management training · Airway skills · Difficult airway management strategies · Crisis management skills

Dong Yang and Yu-Kui Wei contributed equally to this work.

✉ Fu-Shan Xue
xuefushan@aliyun.com; fushan.xue@gmail.com

Dong Yang
yangdonglin28@126.com

Yu-Kui Wei
weiyukui74@163.com

Xiao-Ming Deng
dengxiaoming2003@sina.com

Juan Zhi
hnzhijuan@163.com

[1] Department of Anesthesiology, Plastic Surgery Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, 33 Ba-Da-Chu Road, Shi-Jing-Shan District, Beijing 100144, People's Republic of China

[2] Department of Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing, People's Republic of China

Introduction

While airway management is a fundamental skill set for many healthcare professionals, difficult airway management has long been recognized as one of the most challenging tasks that the healthcare providers must often face. In clinical practice, failure to properly manage airway conditions remains a significant source of patients' morbidity and mortality [1]. To avoid or reduce medical errors and improve patients' outcomes and safety, training airway management for medical professionals is essential.

In modern medicine, simulation-based medical education has actually been implemented in skill training of many clinical sub-specialties, such as anesthesia, nursing, surgery, as well as with medical students. Driven by concerns over patient safety and improving the quality of medical services, simulation has been rapidly developed during the last decades [2, 3]. Since the first article describing the use of a simulator to teach anesthesiology residents for endotracheal intubation in 1969 [4], simulation in the airway management field has become more popular and has made tremendous advances in many countries, affirming the validity and superiority of simulation-based skill training [1–5]. The main aims of this article are to present an overview of current simulation techniques used for airway management training and a look forward.

Common airway skills

The traditional "see one, do one, and teach one" model is no longer accepted in current medical education. Both increased attention to patient safety and decreased procedural exposure have led to the search for alternate teaching modalities for training and maintenance of clinical skills [6].

Airway management skills are operational and practical techniques. With the development of simulation-based medical education and the increase in medical education investment, simulation has been playing an important role in airway management training. Through the use of airway trainers, high-fidelity simulators and computer-based virtual airways, simulation-based airway management training can provide abundant opportunities for trainees to practice the technical and crisis management skills in a patient-safe environment. According to the meta-analysis by Kennedy et al. [1], simulation-based airway management training has been shown to be effective in increased learners' satisfaction, crisis management skill, behaviors, and patient effects compared with no intervention and non-simulation education, e.g., video, lectures, self-study, and/or training.

Furthermore, simulation can compensate for inadequate clinical practice and experience by providing the opportunity for senior anesthetists to perform multiple repetitions of an airway procedure within a short time. It has been shown that a simulation-based warm-up can facilitate more rapid and efficient endotracheal intubation in the operating room, and the benefits include improved patient safety and decreased operating room times [5]. In addition, Boet et al. [7] find that complex procedural skills can be retained for a minimum of 1 year after a single high-fidelity simulation training session.

Use of airway equipments

A number of studies have shown that trainees can master the techniques and skills required for common airway equipments after trained with the task trainers and high-fidelity simulators [1, 8–10]. In a review of the literature including 11 published articles using randomized controlled trials to examine the effectiveness of simulation-based training to develop airway management skills, Vanderbilt et al. [9] conclude that it is one effective way to teach video laryngoscopy intubation skills. Hirabayashi [11] shows that a short demonstration of the Pentax-Airwayscope and a brief practice with a mannequin is the only requirements for trainees to perfect an endotracheal intubation with this device.

With the significant advances in medical technology, the number of new airway tools and equipments available to health professionals has significantly increased. Undoubtedly, these new tools and equipment have greatly improved the routine practice of airway management and simplified the approach to managing difficult airways [12]. However, many tool choices may lead to confusion among healthcare professionals as they attempt to use the most appropriate tools for management of a particular situation. In the simulation training, thus, it is important to introduce the airway management tools that are easily used and have been shown to produce the most reliable clinical results, such as laryngeal mask airway and video laryngoscope. Moreover, the techniques and equipment included in the simulation training course should comply with difficult airway guidelines and be reflected in the practices and equipments held in local hospitals.

Considering that simulation resources are limited, trainees must carefully review the didactic materials before taking a simulation course. These materials include videotaped examples of airway management techniques, indications, contraindications and notices regarding the use of airway devices, and the reference books and guidelines about airway management [12, 13]. During the simulation course, trainees can master the essential skills through systematic "skill station" practice and repetition on the simulator with various individual airway management devices and techniques under the supervision of experienced instructors [8]. Once trainees have achieved competence with airway management by simulation training, they should progress to clinical airway management training under supervision.

Fiberoptic bronchoscope-guided intubation

As a gold standard tool for difficult airway management, fiberoptic bronchoscope (FOB) has become a ubiquitous tool for airway management professionals. However, FOB-guided intubation is a more technically challenging procedure as it needs hand–eye coordination that must be learned and maintained.

The available literature indicates that FOB-guided intubation instruction incorporating low- and high-fidelity simulation is superior to the traditional didactic training methods and can greatly reduce the time and pressures that accompany when teaching this skill in the operating room [14–20]. Although the best simulation training method for FOB-guided intubation has still to be determined, but in general, hands-on teaching of manual skills is necessary in addition to conventional didactic instructions [16]. Even self-directed practice using virtual fiberoptic intubation software may improve the acquisition of FOB-guided intubation skills [17, 18]. It has been shown that simulation can train the novices in the fiberoptic airway skills to become an expert level in a relatively short period of time [20]. Furthermore, Graeser et al. [15] find that simulation-based fiberoscopy training is useful for improving performance regardless of the fidelity of the simulators ranging from non-anatomical trainers to high-fidelity virtual reality simulators. Thus, local practical issues, such as cost and portability of simulators, should dictate available simulation modalities in each teaching hospital.

Davoudi and Colt [21] stressed the importance of successfully transferring the skills from the simulation to the bedside. The prerequisite for the successful transfer of a skill is consensus-based competency-oriented curricula design; that is, curricula combines the positive attributes of simulation, model-based practice, and the traditional apprenticeship mode of learning [15].

Cricoid pressure

Cricoid pressure is a technique used worldwide to reduce the risk of aspiration during endotracheal intubation. However, the effectiveness of cricoid pressure by untrained healthcare professionals has been questioned [22, 23]. By a systematic review and meta-analysis, Johnson et al. [22] conclude that simulation training with feedback can significantly improve the efficacy of cricoid pressure and some inexpensive homemade low-fidelity trainers are equally effective as the high-fidelity simulators. Thus, they tentatively propose that all healthcare providers should receive a training before performing cricoid pressure in clinical practice. Flucker et al. [24] use a 50-ml syringe as a simple device to help train anesthetic assistants to apply cricoid pressure correctly. They suggest that practitioners must develop the appropriate muscle memory to be able to consistently perform the maneuver, which appears to require frequent evaluation and repetition.

Invasive airway access

Invasive airway access includes surgical or percutaneous airway, transtracheal jet ventilation, and retrograde intubation. The invasive airway procedures are seldom used in patients, but they are important for life-saving in difficult airway management, especially when endotracheal intubation and facemask ventilation are not possible, namely, a "can't intubate and can't ventilate (CICV)" situation [25].

It is generally believed that thorough knowledge of anatomy, a clear understanding of insertion and ventilation techniques, and good practical skills are essential for performing an invasive airway procedures rapidly and successfully [26]. The best way to master the required skills is simulation training on animal, human cadavers, a local airway-trainer, or high-fidelity simulator. For example, a simple airway-trainer enables learning of basic invasive airway techniques, while an isolated pig trachea is a relatively inexpensive model for more realistic training of invasive airways. The available literature provides compelling evidence that systematic teaching in simulation training can improve both confidence and practical skills of healthcare professionals to perform the invasive airways [27–29]. To maintain an adequate skill level of invasive airway access, simulation training is also required to repeat at intervals of 6 months or less [30].

Difficult airway management strategy

Although rare, airway disasters occur irregularly and unexpectedly, causing the majority of anesthetic-related mortality. In addition, inadequate skill and poor judgment in airway management continue to lead to avoidable death in occasional patients [26]. As a result, the societies of anesthesiologists in many countries have developed the evidence-based practice guidelines for difficult airway management [13, 31]. It is generally believed that strict adherence to these practice guidelines can resolve most airway problems.

The strategies for difficult airway management according to the "algorithm", which needs to be mastered by healthcare professionals, can be strengthened through repeated practices in managing patients with various difficult airways, but this exercise can increase the risk of patient harm and may be considered unethical. Furthermore, the unpredictable number of difficult airway cases may affect the time it takes for trainees to achieve an acceptable level of safe, unsupervised practice. In contrast, because there are no ethical issues or patient harm, simulation training has been shown as the best way to master the skills required by the difficult airway management guidelines [32]. For experienced airway practitioners, the instructor-based real-time multimedia simulation has been shown as a fast, useful, and systematic renewal educational method to update their knowledge about difficult airway management, and acquire improved decision-making and communication capabilities, and skills of specific airway management [33]. Kuduvalli et al. [30] show that simulation training significantly improves anesthetists' ability of managing difficult airways and a CICV situation according to the difficult airway guidelines and adherence to the difficult airway guideline process can be sustained for 6–8 months after simulation training.

For teaching each step of the difficult airway guidelines effectively, however, more than one type of airway simulators is required. An advantage of using multifarious airway simulators is the finding that trainees tend to adapt their skill to a particular task trainers or high-fidelity simulators, and therefore providing them with a variety of airway simulators can result in a broader range of skills [34].

Airway crisis management

Simulation training is not only a valuable tool for technical skills (medical knowledge and procedural ability), but also for non-technical (i.e., crisis management) skills, which are behavior-based and include leadership, teamwork, communication, situation awareness, decision-making, and awareness of stress and fatigue [2]. It is generally believed that both technical and non-technical skills are required to improve clinical outcomes and safety of patients. Furthermore, non-technical skills have been identified as particularly important for managing emergency and crisis situations, for example in a CICV situation, which is dynamic, evolving, and requires constant re-assessment. However, non-technical skills are not inherent despite being based on behavior. They must be formally taught as many of these skills are commonly required in managing emergency or crisis situations, even though they are increasingly rare in modern-day medicine.

In fact, more time is required to develop a curriculum for non-technical skills because they are more difficult to teach and assess than their technical skill counterparts [5]. One advantage of simulation training over traditional medical training methods is provision of a safe environment for crisis management training, it is a powerful enabler in the development of lifelong learning strategies to manage these crises as it is to manage knowledge translation and retention more effectively [5].

It must be emphasized that the most important factors for simulation-based crisis management training are environmental fidelity [2, 5] and deliberate practice [5, 33]. Improving environmental fidelity means incorporation of all the structural and mechanized elements that would be present when managing similar scenarios in the clinical realm [2, 5]. Deliberate practice refers to a process that allows learners to focus on the intensive practice of specific tasks in a controlled setting while receiving coaching and formative assessment through timely and thoughtful feedback from an expert supervisor [5]. Simulation is ideal for deliberate practice because it offers standardized conditions and the ability to repeat the same tasks frequently without the risk of compromising patient safety.

Limitations of simulation training

Fidelity

The matter of simulation "fidelity" has been becoming a controversial issue. Schebesta et al. [35] show that there are major differences in the pharyngeal airspace and other airway measurements in adult patient high-fidelity simulators and low-fidelity airway trainers compared with an actual patient's anatomy, Also, anatomy abnormalities or pathophysiology (cough, secretion, bleeding, aspiration) cannot be adequately represented in a simulator. Thus, some question the results of simulation airway research and the appropriateness of simulation-based research translating the care of real patients [36].

Cost

High-fidelity simulation-based airway management training is cost intensive. Not only are the mannequins or simulators expensive, they also need experienced faculty and the courses are usually held in small groups. Cost issues are subjected to question whether there are financial constraints in present-day healthcare economy, especially since it is difficult to prove the effectiveness of highly resource-intensive simulator training with the terms of evidence-based medicine [37].

Translation

A significant challenge for simulation-based airway management training is how to translate that which is learned and perceived to be beneficial into behavioral change and improved patient outcomes. The ideal study would therefore try to address behavioral changes of simulation-trained participants in their daily practice, along with their rate of critical events, which admittedly would be a difficult thing to do [37].

Looking forward

Despite some limitations, the benefits of simulation-based teaching are still significant, as these tools offer outstanding training options for teaching technical skills. In view of the high cost of fidelity simulators and the requirements for a large number of experienced instructors and other staff, more studies validating the educational and cost-effectiveness benefits of simulation-based training are still needed to support the funding of medical education in the future [38, 39]. Moreover, future studies should strive to determine to what extent simulation-based airway management training can reduce medical errors and improve clinical outcomes and safety of patients.

To improve the effectiveness of simulation-based airway management training and obtain the ideal knowledge translation, several issues must also be noted. First, the training of simulation instructors and facilitators should be highlighted. Instructors should change the traditional apprenticeship model; that is, to learn and master the method and technique of simulation training, to provide more helpful guidance, and debriefing for trainees [2, 40]. Second,

optimal curriculum design should conform with the clinical practice and have the characteristics of typicality, standardization, and universal guidance following the actual airway management guidelines. Third, simulation training must be ongoing. The refresher courses appear to be beneficial, but further clarity on how many and for how long is needed. Fourth, the simulation training center should be good at using various resources, such as endotracheal tubes and other airway equipment no longer used in operating rooms to maximize cost-effectiveness. Fifth, communication and cooperation between national and international simulation centers should be further strengthened in order to expand, enrich, and perfect the fields and modalities of simulation-based airway management training.

Finally, it is worth mentioning that more educational investment can constantly improve and increase the effect and influence of simulation-based airway management training on clinical practice, and let more and more healthcare professionals and patients benefit from simulation training.

Conclusions

Simulation training serves to bridge the gap between classroom instruction and the practical application in airway management education. It can effectively improve the technical and non-technical skills of trainees through the trainings of common airway skills, difficult airway management strategies, and crisis management skills. With the wide application and rapid development of simulation-based airway management training, it is becoming an effective and novel way of teaching. However, instructors experienced in simulation-based airway management training and the best curriculum design are indispensable in optimizing the benefits of simulation training. We believe that, in the near future, there will be more studies to offer evidence for identifying the effectiveness and superiority of simulation-based airway management training.

Compliance with ethical standards

Conflict of interest None of the authors has any financial support or potential conflicts of interest to disclose in this work.

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