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REVIEW

Evidence base in airway management training

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S U M M A R Y

Suboptimal airway management is an ongoing cause of serious adverse events in anaesthesia. Education and training is thus of paramount importance but faces several challenges. Therefore the acquisition and maintenance of competences in airway management require sound teaching and learning strategies. The aim of this review is to provide important educational principles based on published evidence in order to guide the conception and the implementation of such training programs. The desired content of an airway course is discussed as well as the importance of technical and non-technical skills. A special focus is given to the contribution of non-clinical training modalities such as models, task-trainers and simulators to efficient training in complement to clinical practice.

Box 1: Key points.

Low fidelity simulators are effective for teaching technical skills.

Technical skills learned on simulators are transferred into clinical practice.

Simulation training is a complement to clinical training but not a surrogate to it.

The amount of training should be tailored to each learner.

Non-technical skills are as important as technical ones and can be taught and reinforced using high fidelity simulation.

Maintaining competence requires regular practice, refreshers and updates in knowledge.

1. Introduction

Airway management (AWM) skills are at the heart of anaesthesiologists' expertise and other specialists often consider us as the “airway experts”. Nevertheless, problems related to AWM remain a leading cause of anaesthesia related morbidity and mortality.[1] Inappropriate clinical practice and inadequate management may aggravate the situations and the severity of AWM difficulties.[2] Lack of education and training contributes to these complications in up to 50% of the cases.[1]

It is therefore of paramount importance to improve the quality and the dissemination of education, training and maintenance of competences in AWM among our community. The aim of this review is to provide important educational principles based on published evidence in order to guide the conception and the implementation of AWM training programs in anaesthesia and other specialties.

1.1. Is clinical training enough?

Trainees need sufficient time and practice to acquire AWM skills. For example, on average they will need more than 50 attempts at routine (easy) endo-tracheal intubation (ETI) to achieve a 90% success rate.[3] Interestingly, 18% of the trainees still needed expert assistance after 80 intubations. Obviously, in order to master difficult airway situations even more training is needed.

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Learning opportunities for anaesthesia residents is variable but tend to decrease partly due to the introduction of working time directives. Over the last decade in one Australian centre, even though the total caseload per trainee was stable the mean number of ETI decreased by 10% each year and the number of supraglottic devices decreased by 16%.[4] These data were not statistically significant but the trend was clear. The only significant fall was in obstetric anaesthesia where residents had as little as 6 intubation opportunities each year.

Clinical exposure to airway emergencies is scarce. In a survey, 92% of the anaesthesiology chief residents had never performed an emergency surgical airway.[5] Paradoxically, residents' confidence level was very high (82% rated over 8/10). AWM training was heterogeneous and not standardized. A similar survey conducted in France in 2013 by Duwat showed that 28% of the residents were insufficiently trained to use the Intubating Laryngeal Mask Airway (ILMA®) in an emergency situation and 91% insufficiently trained to setup a transtracheal oxygenation technique.[6] The rate of residents reaching educational objectives on patients was extremely low: 4% for ILMA®, 21% for fiberoptic intubation and 12% for cricothyroidotomy.

We are thus facing several challenges in anaesthesia education in general and in AWM training in particular. On the one hand clinical training under supervision is an essential component of our education but on the other hand exposure to relevant experience is unpredictable, tend to decrease, and moreover patients tend to find it less and less acceptable. In order to ensure a safe, acceptable, and efficient training alternative non-clinical training modalities have become necessary. This review will focus on these modalities and will detail their contribution to efficient AWM training in complement to supervised clinical practice and personal experience.

2. What should we teach in AWM?

2.1. What techniques should we teach?

Undoubtedly, upper airway anatomy and airway evaluation should be taught. As underlined in the NAP4 report, lack of or inappropriate airway evaluation can lead to insufficient planning and serious problems.[1] However, the same report showed that even in instances of anticipated difficult intubation the anaesthetist in charge proceeded with induction of general anaesthesia in 81% of the cases. Similarly, a Danish study showed that 24% of patients with a previous recorded difficult intubation and 30% of patients with a previous recorded impossible intubation suffered the same event again.[7] It is therefore critical not only to teach airway evaluation but also to teach how to elaborate a proper strategy. Strategy for AWM should rely on pre-defined algorithms consisting in a series of plans such as those recommended by the Difficult Airway Society.[8]

Table 1 summarizes the minimum requirements in terms of airway skills that should be taught. Anaesthetists who are experienced with the use of one alternative technique are more likely to succeed in case of unexpected difficult airway.[9] Moreover, standardization of equipment within a given institution is linked with improved performance and patient outcomes.[10] Hence it seems that the type of equipment itself appears less important than the efforts and the strategies implemented to teach and disseminate their proper use. Therefore choice of a specific technique/equipment should be left at the discretion of each institution.

2.2. The importance of clinical practice guidelines

Difficult AWM, especially if unanticipated, can be a stressful situation. Stress alters decision making and performance.[11] It is therefore critical to rely on practice guidelines and adequate preparation to make the appropriate decision in a given clinical situation.[2,12] Important elements brought to us by these guidelines are prediction, shared mental concepts, early call for help and the implementation of difficult airway trolleys.

Table 1
Proposed "minimum requirements" in terms of airway skills that should be taught and practiced regularly in anaesthesia?

What AWM techniques should we teach?
Upper airway anatomy Airway evaluation Face mask ventilation Direct laryngoscopy (at least) One extraglottic device (at least) One alternative technique[a] for ETI Fiberoptic intubation One rescue technique for oxygenation
For what situations should we have guidelines and should we practice AWM skills?
Anticipated difficult AWM Unanticipated difficult AWM situations: 1) difficult face mask ventilation 2) cannot intubate can ventilate 3) cannot intubate cannot ventilate Extubation at risk
Non technical skills should be practiced within the context of the above situations

[a] (e.g.: ILAM, Videolaryngoscopes, Video intubating stylet, …).

Guidelines are based on critically reviewed evidence of the literature and several societies regularly publish such guidelines.[13–19] New airway devices become available daily but the quality of the evidence supporting their effectiveness is often poor.[20] As Crosby pointed out, since the literature is constantly evolving, guidelines need periodical updates.[2] The critical point of view of updated guidelines is thus of great help for practitioners.[2] Routine application of guidelines and implementation of the comprehensive AWM program raises the success rate in case of difficult intubation and decrease the occurrence of impossible intubation and surgical rescue.[21,22] This improvement appears sustained over time despite an increasing number of patients receiving anaesthesia and with difficult airway.[22]

Published guidelines slightly differ from each other. This reflects the fact that the best evidence is in part based on expert opinions. Which guidelines or algorithms are adopted is probably less important than adopting, promoting and applying one.

Table 1 summarizes several clinical situations at risk that should be part of a comprehensive AWM training program.[10] Extubation has been increasingly recognized as a potentially risky phase. Up to 40% of adverse events occur at the time of extubation.[1] Recommendations of effective strategies to minimize the risks of extubation have recently been published.[23,24]

2.3. Non-technical skills

As illustrated in the NAP4 report, when serious complications occur, management is often judged retrospectively as suboptimal or poor in more than 75% of the cases. Poor communication and poor teamwork contribute to poor outcome whereas good communication and teamwork favour better outcome. Poor judgment also often contributes to adverse outcome.[1]

Judgment, situation awareness, communication and teamwork are part of non-technical skills (NTS).[25] NTS have been defined by Flin et al. from the Aberdeen University as "the cognitive, social and personal resource skills that complement technical skills and contribute to safe and efficient task performance".[25] A formal evaluation system called Anaesthesia Non-Technical skills (ANTS) can be used to observe and teach these skills during every day clinical practice and bed side training.[25] Considering the critical importance of NTS, every comprehensive AWM training program should include teaching and practice of NTS when learning AWM skills and strategies.

A one-day airway workshop (didactic presentations, skill stations, high fidelity simulation, introduction of CRM concepts) followed by a two-week rotation on airway surgery cases improved confidence of paediatric anaesthesia fellows in AWM.[26] A long-term evaluation on the impact of this educational intervention is still ongoing.

3. How should we teach AWM?

3.1. Is there evidence supporting the use of alternative training modalities?

Different alternative methods to clinical training have been described: cadaver practice for teaching cricothyroidotomy,[27] partial task trainers for simulated practice of various techniques (direct laryngoscopy,[28] extraglottic airway device (EAD) insertion,[29,30] videolaryngoscopes, fiberoptic intubation, cricothyroidotomy[31,32]), computer-based or smart phone applications for teaching fiberoptic intubation,[33,34] videolaryngoscopes to demonstrate and teach ETI in simulated or real life settings,[35] full scale manikin simulation,[36–38] to name the most frequently used methods.

Cadaver practice is often used to teach emergency rescue airway access such as cannula or surgical cricothyroidotomy.[27,39,40] Birnbaumer recently summarized the pros and cons of cadaver in stating that they have "already given consent" and reflect actual human anatomy but they are expensive and their availability is limited and requires dedicated facilities and staff.[41] Fresh cadavers can only be used in a limited period of time and may transmit disease while fixed cadavers' tissues may be less realistic. Last but not least, some students may be faced with ethical issues and concerns.

Partial task trainers solve the consent and ethical issues.[41] They are relatively inexpensive and can be available 24/7. Plummer and Owen designed a trial to quantify learning of orotracheal intubation.[28] The most interesting finding in their study is that when a trainee changed the task trainer, the chance to succeed was divided by half. It is therefore probably interesting to have several different airway trainers so that trainees can get used to some variations of anatomy.

Virtual reality software application for Smartphone or tablet using the built in accelerometer proprieties have been used to mimic hand movements for performance of fiberoptic skills.[33] When comparing anaesthesia residents with iLarynx® training to those who had only standard training there was fever failure in the intervention group. The use of the software appears to improve trainees' dexterity. Similar results were obtained with computer-based Virtual Fiberoptic Intubation software®.[34]

Several authors have suggested that learning ETI with a videolaryngoscope allows an easier demonstration and guidance by the teacher. Errors can be corrected while the trainee is completing the task.[42] Compared to direct laryngoscopy with the McIntosh blade the use of a videolaryngoscope (C-MAC®) facilitates teaching and learning of oral ETI on adult anesthetized patients.[35] Students trained with the videolaryngoscope had a higher success rate and intubated faster when using the Macintosh blade compared to those trained only with the later device. The incidence of difficult laryngoscopy was also less frequent in the videolaryngoscope-trained group. Similar results have been found with inexperienced students when comparing the Macintosh blade to the Glidescope®.[43]

Boet et al. studied the 6-month and 1-year retention of cricothyroidotomy using a high fidelity simulated scenario.[38] After a single simulation training session improvements in cricothyroidotomy skills were retained for at least 1 year.

A systematic review and meta-analysis of the studies comparing simulation based-education to other teaching techniques for AWM training was performed recently by Kennedy et al.[44] Simulation based-education was superior to "no intervention" for knowledge and skills teaching and to "non-simulation-based interventions" for learners' satisfaction, skills and patient outcomes but not for knowledge.[44] There were few studies exploring how to optimize simulation-based training and those had inconsistent results.

Ideally, the methods described above should be combined with lectures, personal reading of recommended literature and clinical training in order to create an affective comprehensive and multimodal AWM training program. Russo et al. described the self-reported impact of a multimodal AWM course.[36] Four months after the course 29% of the responding participants evaluated the airway more carefully, 29% established structural changes within their departments and 21% acquired new technical airway skills. The simulated scenarios and skill stations were rated as more helpful than lectures.

3.2. Do technical skills learned in the "classroom" transfer into clinical settings?

As discussed above, partial task trainers, models or full-scale manikins are frequently used as alternative non-clinical training modalities. The recommendation for adopting them to teach AWM should rely on some evidence. A legitimate question is therefore the following: is there any evidence that skills learned with these methods do actually transfer into the clinical setting? Few studies have actually attempted to evaluate such benefits but their results are mostly positive.

In a randomized study, nurses trained in Laryngeal Mask Airway (LMA®) insertion either on a manikin alone or on a manikin plus on real patients were similar in terms of success measured on real patients.[45] In a non-randomized study the transfer to patients of facemask ventilation and LMA Supreme® insertion learned on a manikin was examined.[29] During training, success rates on manikin were 100% for both techniques. Success rates on real patients were as low as 66% for facemask ventilation but reached 90% for the insertion of the LMA Supreme®. From these two studies one can conclude that manikin training appears effective to learn basic LMA® insertion and skills do transfer to patients. The efficacy of manikin training to learn facemask ventilation appears smaller. This may be to the influence of anatomical variations encountered on patients insufficiently reflected on manikin.

Similar mitigated results have been found when using manikin to teach ETI using direct laryngoscopy. One randomized controlled study reached the conclusion that for novices 10 hours of simulator-based training was comparable to 15 real intubation attempts in terms of the overall success rate and first attempt success rate on real patients.[46] Another study showed that manikin training of novices did not appear to significantly reduce the number of ETI attempts on real patients required to achieve a 90% success rate. However, it seems that manikin improved the quality of the intubation attempts compared to no training.[47] These findings suggest that simulation training can be a useful introduction to clinical training but is definitely not a complete surrogate to it.

Fiberoptic skills are difficult to acquire. In a randomized controlled study, Naik et al. demonstrated that a simple low fidelity model was a more effective method to help residents acquire basic skills compared to a classical didactic lecture.[48] Model-trained residents had better performance scoring, better success rate and acted much faster than the didactic group when performing their first fiberoptic intubation on a sleeping patient.

3.3. Impact of model fidelity

After proving that model training was better than didactic training, Naik and colleagues tested the impact of model fidelity on the acquisition of cricothyroidotomy skills in novice anaesthesiology residents[49] and on the acquisition of fiberoptic intubation skills in respiratory therapists[50] in randomized controlled studies. In both studies, model fidelity didn't impact on the amount of improvement from pre-test to post-test. Performances were measured either on cadavers (cricothyroidotomy) or during fiberoptic intubation in anesthetized patients. The conclusion is that even relatively low fidelity models can be effective especially when teaching novices.

3.4. Is there a minimal amount of non-clinical training for specific techniques?

Some studies attempted to determine how many attempts should be made before to acquire a given skill.

Concerning LMA® insertion, intense manikin training (repetition until participants were proficient) on a task trainer did not improve success rates on real patients compared to brief manikin training.[30]

As mentioned earlier, direct laryngoscopy is a difficult skill to acquire, 18% of residents still needing expert assistance after 80 attempts.[3] Savoldelli et al. found that the learning curves (on a manikin with a normal airway) of videolaryngoscopes were much steeper, with only two attempts for the Airtraq® and five attempts for the Glidescope® and the McGrath® required to mirror the performance of the Macintosh blade.[51] Participants were practitioners mastering direct laryngoscopy. The manikin learning curve is also short in novice operators.[52] Learning curves in clinical practice appear slightly longer than on manikins.[53,54]

For fiberoptic upper airway endoscopy skills, the number of attempts necessary to achieve proficiency varies greatly from 27 to 58.[55] A standard number of attempts can probably not be determined and training should be tailored to individual needs.

Regarding cricothyroidotomy, Wong et al. found significant improvement performance up to the fourth cricothyroidotomy attempt on a manikin.[32] By the fifth attempt, 96% of participants were able to successfully perform a cricothyroidotomy in 40 s or less. Shetty et al. recently found similar results and recommended that professionals undergo at least five attempts of cricothyroidotomy on a manikin to achieve success in less than 60 seconds.[31]

3.5. Are there advantages in using a full scale simulation?

Full-scale simulation using high fidelity offers additional advantages in AWM training compared to task trainers and simple models. Technical skills can be performed on a realistic manikin and simultaneously the “high fidelity environment” increases the realism of the teaching by adding important features such as changes in vital signs and clinical feedback (decrease in oxygen saturation, cyanosis, bradycardia and eventually cardiac arrest) as well as a certain level of stress for the trainees. Technical skills and NTS can thus be integrated and actively practiced together in an environment close to real practice.

Learning objectives during full scale simulation are usually based on recommended algorithms and used as inputs and events embedded into one (or several) scenario. During the exercise, the instructor can observe and measure the performance of the trainees and compare them with the standards of performance mentioned in the algorithms. The exercise is then followed by a debriefing session during which constructive feedback is provided.[56] Regarding crisis management and NTS principles, Rall and Dieckman have described how to apply some of these principles to AWM.[57]

Recent evidence supports the transfer of NTS acquired during simulation to the clinical setting.[58] However, despite theoretical advantages, few data support the efficacy of structured courses that integrate high-fidelity simulation for AWM training.[46]

Mehta et al. designed a multidisciplinary difficult airway course with full scale simulations and debriefings.[59] After the course, candidates self-reported improvement in knowledge, teamwork, leadership and non-technical skills, and in mutual understanding and respect. Kuduvalli et al. tested the adherence to the difficult airway society guidelines before, 6 weeks after and 6 months after a course that included simulated scenarios with a full scale manikin.[37] Six to eight months after training anaesthetists had a more structured approach to the “cannot intubate cannot ventilate” (CICV) situation. In the “cannot intubate can ventilate” situation, use of standard and ILMA® increased and in both situations there was less equipment misuse.

A recent narrative summary by S. Boet concluded that crisis resource management learned in simulated environments are transferred to clinical settings and the acquired CRM skills may translate to improved patient outcomes, including a decrease in mortality.[60] This was a systematic review on all simulation based CRM courses, in all healthcare professionals independently of their level of training or specialty.

3.6. How to maintain the competence?

Maintenance of competences faces two main difficulties. First the natural decay in skills after initial training especially if the skills are not regularly performed in daily practice (e.g., judgment and decision making in a CICV situation, performance of cricothyroidotomy). Second, knowledge, skills and techniques evolve continuously and must be updated regularly in order to be in accordance with the latest recommendations.

Overcoming these challenges can be particularly difficult for the “aging” practitioners. A 2005 systematic review reported decreasing performance with increasing experience in medicine.[61] The quality of technical care tends to deteriorate over the years unless deliberate practice is maintained.[61,62] Many senior anaesthetists are self-taught and have adopted the use of new equipment without any formal instruction.[63] Despite standardized training, age and years from residency are independent factors influencing cricothyroidotomy performance measures by performance time, checklist scores and global rating scale scores.[64] Finally, senior anaesthetists are less likely to follow guidelines and specific AWM training is not always effective.[65]

The natural decay in skills can be counterbalanced by regular practice combined with the provision of periodic feedback.[66] For the skills that are rarely performed in clinical practice (such as difficult AWM) practitioners should engage in continuing education activities in the form of refresher courses. These courses should include updates of current clinical guidelines and hands-on training based on principles described in this review. Not surprisingly, several national anaesthesia societies include maintenance of AWM competencies in their continuous professional development programs. The validation of these programs is mandatory for recertification of professionals.[67]

4. Conclusion

Throughout this review, we have underlined that AWM training remains a significant challenge in anaesthesiology. Learning opportunities are declining in clinical practice but innovative teaching methods based on simulation can be effective for learning technical skills that can be transferred into clinical practice. Even simple models and manikins are valuable tools to develop skills in novices. Technical skills are essential but not sufficient and improvement in NTS is essential for successful management of difficult airway situations. These NTS can be taught through high fidelity teamwork simulations. Borovcanin et al. have recently applied many of the principles discussed in this review in order to establish the concepts of AWM rotations.[68] Such initiatives should be encouraged and promoted at all levels of anaesthesia training.

Conflict of interest statement

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