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The Anesthesiologist's Role in Teaching Airway Management to Nonanesthesiologists

Who, Where, and How

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Keywords

• Airway management • Education • Simulation training • Intubation

Key points

- Whereas prior work in determining proficiency in airway management focused on achieving a specific number of intubation attempts with direct laryngoscopy, milestone or mastery achievement will become the new standard, targeting performance-based assessments.
- It is possible that emergency medicine programs with sufficient clinical volume may not benefit from additional clinical exposure in the operating room for airway management, although continued external rotations in airway management under anesthesiology supervision is likely to continue for many programs.
- A focus on video laryngoscopy over direct laryngoscopy for endotracheal intubation may be appropriate for specialist trainees who infrequently are tasked with performing direct airway management.
- Although there is no evidence supporting the use of simulation-based training for skill acquisition in airway management, it will continue to be an integral part of airway management training programs and should include a component focused on nontechnical skills.

INTRODUCTION

Once unquestioned airway experts, anesthesiologists now find themselves operating in an environment where multiple specialties, including emergency medicine (EM), critical care, and surgery, have accessed and practice an

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ever-increasing range of airway management techniques. As noted by Chrimes and colleagues [1] in a recent editorial, "The landscape on which airway management is practiced is rapidly changing." In the past 20 years, the introduction and widespread acceptance of video laryngoscopy (VL) [2,3]; increased emphasis on invasive rescue techniques for the cannot intubate, cannot oxygenate scenario [4]; and expanded airway training for nonanesthesiologists have disrupted the old paradigm of "Call anesthesia!" when the need for airway management outside the operating room (OR) occurs. This should be viewed as a disruptive, but positive, innovation by the anesthesia community, with a net effect of moving toward a universal airway management approach that can be applied independent of experience, specialty, or clinical context [1]. Although anesthesiologists continue to perform airway management routinely as a part of their practice, other clinicians across multiple specialties independently are performing airway management with increasing expertise.

In the United Kingdom, a significant impetus for examining and modifying their approaches to airway management and training started after release of the 4th National Audit Project (NAP4) of the Royal College of Anaesthetists and the Difficult Airway Society examining major complications of airway management across a spectrum of clinical settings [5,6]. They found that at least 1 in 4 major airway events was likely to occur in the intensive care unit (ICU) or the emergency department (ED), with an increased risk of permanent harm compared with intraoperative events. Many of the identified gaps in care related to inadequate or poor planning, inadequate provision of skilled personnel, delayed recognition of critical events, and failure to rescue due to interpretation of capnography. In their recommendations, the investigators highlight the need for improvements in training in several areas highlighted by these gaps. Taken together, the NAP4 findings and ongoing disruptive innovation in airway management suggest a need to examine how, where, and by whom airway training is best accomplished.

If anesthesiologists are to continue as the airway experts, it has been suggested that to rethink not only their own training paradigms [7–9] but also how to include interactions with other specialties in training [10]. The methods for providing airway management training to nonanesthesiologists have taken multiple approaches. Many residencies have established formal training programs utilizing simulation-based, cadaveric-based, and/or didactic-based formats combined with on-the-job clinical experience [11–18]. Unfortunately, there still are barriers to training and it often is difficult to achieve a sufficient volume of clinical cases to establish competency during rotations in a primary specialty [19]. Many of these programs have reached out beyond their specialty to associated anesthesiology departments for additional training and clinical experience. The OR always has been considered an ideal location for hands-on training in airway management. Given the large volume of procedures, varied patient population, stable conditions for teaching, and availability of highly trained staff, many programs have established rotations in the OR for training in airway management.

This review looks at the role anesthesiologists play in the training of nonanesthesiologists for airway management of the traditional OR while also examining some potential biases about how best this can be accomplished. What it means to be proficient in airway management, who should be teaching airway management skills, where is the best place to learn, what is the role of simulation and nonclinical teaching, which techniques should be emphasized, and what the likely paths forward are given the ongoing disruption in traditional practice are addressed. Although education theory and teaching methods clearly are important considerations when discussing adult learning, they have been covered elsewhere with respect to airway management training and are not reviewed in depth [20–22].

WHAT DOES IT MEAN TO BE PROFICIENT IN AIRWAY MANAGEMENT?

Before examining the questions posed previously regarding how best to accomplish airway management training, there should be some agreement on the outcomes to be achieved. Ideally, training programs produce individuals who are proficient in airway management across the clinical spectrum that they are likely to be involved in during their initial practice after residency. When it is stated that to have proficiency in airway management, it is implied that thorough knowledge, judgment, and skill have been derived from training and practice [23]. Used interchangeably with competency, there still is a value difference between competent and proficient. Competency is the bare minimum required for acceptability wereas proficiency implies a level of mastery that is above the minimum. To date, there have been numerous efforts made to define what constitutes proficiency or competency in airway management. These include, but are not limited to, global assessments, checklist mastery, case volume logs, simulation-based assessments, subjective rating systems, and, most recently in the United States, milestone achievements. This last element was introduced by the Accreditation Council for Graduate Medical Education (ACGME) in the United States in 2001 as graduate medical education switched from a focus on process and structure to one based on outcomes [24]. Sometimes referred to as mastery learning, milestone achievements rely on demonstrated performance rather than time-based metrics [25]. After defining 6 core competencies (patient care, medical knowledge, professionalism, interpersonal and communication skills, practice-based learning and improvement, and systems-based practice), the ACGME and each specialty further established milestones that described performance levels trainees are expected to demonstrate in subcompetencies for knowledge, behaviors, and skills in the competency domains. The 5 performance levels are based on the Dreyfus model, which are interpreted as (1) novice resident/fellow, (2) advanced beginner, (3) competent, (4) proficient, and (5) expert [26]. Graduates are expected, but not necessarily required, to achieve level 4 (proficient), with level 5 (expert) being an aspirational milestone. Although not a clearly identified category in the Dreyfus model, mastery (level 6) unlikely is obtained during a training program. In the United Kingdom and elsewhere, a similar approach to postgraduate training is evolving with a new focus on competency-based medical education [27].

With respect to airway management training, the specific ACGME milestones for anesthesiology, EM, and surgical critical care are shown in Table 1. As anticipated, the specific milestones focus on performance and the multiple aspects of airway management for all 3 specialties, with increasing autonomy as the milestones are met. One element to highlight is the requirement for a minimum of 35 intubations for EM trainees to achieve proficiency (level 4) [28]. For anesthesiology residents, it always has been assumed that the volume and variety of airway management procedures far exceed the number required for proficiency such that numbers are not tracked for common procedures, such as endotracheal intubation. This assumption, however, has been challenged, particularly with respect to difficult airways and selected procedures, such as awake fiberoptic intubation, as practice patterns have changed [29–32]. For example, an increased emphasis on supraglottic airway use in the OR would lead to decreased exposure to endotracheal intubation techniques with known or suspected difficult airway exposure. Although most anesthesiology residents still will achieve competency, it is possible that some may not realize an expert or proficient level in all techniques. Similarly, nonanesthesiology trainees in the OR may have less exposure to direct laryngoscopy (DL) if VL is used more often in that program. Most recently, the coronavirus disease (COVID-19) pandemic caused many anesthesiology programs to emphasize VL over DL to increase the distance between the intubator and patient, further reducing the number of DL attempts for trainees [33].

So how many intubations does it take to achieve a competent or proficient level of practice? According to Chuck Yeager, a decorated pilot, "If you can walk away from a landing, it's a good landing. If you can use the airplane the next day, it's an outstanding landing." [34] Applying this approach to airway management, the primary outcome for competency would be "getting the tube in the hole" with a secondary goal of not producing significant harm. Airway management, however, encompasses much more than endotracheal intubation. Nonetheless, many of the markers suggested for competency revolve around successful first-pass or subsequent-pass endotracheal intubation using DL. When looking at the available research on intubation numbers and proficiency, the different metrics used to define success and the variability within each measure makes it difficult to do direct comparisons. Table 2 highlights some of the studies and their approaches that have specifically targeted this metric for physician and advanced practice trainee populations [35–43]. The 2 most common approaches are use of a logistic regression model to create a learning curve and cumulative summation analysis (CUSUM). CUSUM in this application employs variations of sequential analysis techniques to detect relevant changes in an outcome of interest over time, such as endotracheal

Table 1
Accreditation Council for Graduate Medical Education milestone achievements for airway management

Level 1	Level 2	Level 3	Level 4	Level 5
Anesthesiology				
Patient care: technical skills: airway management				
Recognizes airway patency and adequacy of ventilation based on clinical assessment Positions patient for airway management; places oral and nasal airways; performs bag-valve-mask ventilation	Applies knowledge of the American Society of Anesthesiologist difficult airway algorithm to prepare equipment and supplies for airway management Performs basic airway management in patients with normal airways, including endotracheal intubation, supraglottic airways, and videolaryngoscopy Recognizes need for assistance and/or equipment and seeks help	Prepares appropriate equipment and supplies for management of difficult airways, including cricothyroidotomy Performs advanced airway management techniques, including awake intubations, fiberoptic intubations, and lung isolation techniques	Identifies and corrects problems and complications associated with airway management (eg, hypoxemia during 1-lung ventilation, airway hemorrhage) with conditional independence Manages all airways, including under special situations (eg, trauma, patients with tracheostomies, loss of airway), with conditional independence	Independently assesses and manages the airway for all clinical situations utilizing appropriate advanced airway techniques, including cricothyroidotomy Independently supervises and provides consultation to other members of the health care team for airway management
Surgical critical care				
Patient care: procedural competence (includes endotracheal intubation)				
Requires direct supervision to perform common ICU procedures	Performs some common ICU procedures independently	Demonstrates proficiency in the performance of common ICU procedures Can identify when a patient is at high risk for complications from a common ICU procedure	Proficient in performance of ICU procedures in patients at high risk for complications Proficient in management of procedural complications	Performs advanced procedures (eg, extracorporeal membrane oxygenation, intraaortic balloon pump transvenous pacing, inferior vena cava filter placement)

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Table 1
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Level 1	Level 2	Level 3	Level 4	Level 5
Emergency medicine				
Patient care: airway management performs airway management on all appropriate patients (including those who are uncooperative, are at the extremes of age, are hemodynamically unstable, and have multiple comorbidities, poorly defined anatomy, high risk for pain or procedural complications, sedation requirement), takes steps to avoid potential complications, and recognize the outcome and/or complications resulting from the procedure.				
Describes upper airway anatomy Performs basic airway maneuvers or adjuncts (jaw thrust/chin lift/oral airway/nasopharyngeal airway) and ventilates/oxygenates patient using bag-valve-mask	Describes elements of airway assessment and indications impacting the airway management Describes the pharmacology of agents used for rapid sequence intubation, including specific indications and contraindications Performs rapid sequence intubation in patients without adjuncts Confirms proper endotracheal tube placement using multiple modalities	Uses airway algorithms in decision making for complicated patients employing airway adjuncts as indicated Performs rapid sequence intubation in patients using airway adjuncts Implements postintubation management Employs appropriate methods of mechanical ventilation based on specific patient physiology	Performs airway management in any circumstance taking steps to avoid potential complications, and recognizes the outcome and/or complications resulting from the procedure Performs a minimum of 35 intubations Demonstrates the ability to perform a cricothyrotomy Uses advanced airway modalities in complicated patients	Teaches airway management skills to health care providers

Courtesy of The Accreditation Council for Graduate Medical Education and the American Board of Anesthesiology, Chicago, IL and Raleigh, NC. Available at: https://www.acgme.org/Portals/0/PDFs/Milestones/AnesthesiologyMilestones.pdf?ver=2015-11-06-120534-217; https://www.acgme.org/Portals/0/PDFs/Milestones/SurgicalCriticalCareMilestones.pdf and https://www.acgme.org/Portals/0/PDFs/Milestones/EmergencyMedicineMilestones.pdf. Accessed 14 June 2020.

Table 2
Summary of studies setting competency measures for direct laryngoscopy competency

Study	Trainee population	Number of trainees	Number of procedures	Success determined by	Success rate target (%)	Competency measure	Number needed
Konrad et al, [35], 1998	Anesthesiology residents	11	Approximately 90 per resident; actual numbers not reported	No physical intervention by attending anesthesiologist; maximum 2 attempts; verbal comments and suggestions allowed	90 (95% CI, 80%–99%)	Modified CUSUM to reach 90% success rate	57
de Oliveira Filho et al, [36], 2002	Anesthesiology residents	7	127 ± 46.29 (range 50–190 over 10 mo)	Failure defined as 1 failed intubation attempt or need for attending anesthesiologist to take over for patient safety	80	CUSUM with control lines for ≤20% acceptable failure rate	43 ± 37; in 4 of 7 residents crossing acceptable failure line with single attempt
Kopacz et al, [37], 1996	Anesthesiology residents	7	86 ± 13	Successful intubation without attending assistance	90	Modified CUSUM to maintain >90% success rate	45; 90% success rate achieved within 20 attempts on average but not maintained until after 45 attempts

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Table 2
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Study	Trainee population	Number of trainees	Number of procedures	Success determined by	Success rate target (%)	Competency measure	Number needed
Bernhard et al [38], 2012	Anesthesiology residents	21	Average 162 per resident; range not reported (up to 200 attempts evaluated; achieved by 52% of residents)	Interruption of intubation maneuver	Not defined	Observational study looking at longitudinal performance in 25 attempt increments	51–75 for 80% 1st pass success; 51–75 for 90% overall success
Chao et al, [39], 2015	Medical students	94	9.9 ± 2.7 (during 3-wk or 4-wk rotation in anesthesiology)	Up to 3 attempts or taken over by anesthesiologist	90	Observational study looking at longitudinal performance; logistic regression model to build learning curve	27; determined by extrapolation of learning curve
Komatsu et al [40], 2010	Nonanesthesia interns	15	45 ± 13 (range 28–72; during 3-mo anesthesiology rotation)	Up to 2 attempts with laryngeal manipulation allowed	80	CUSUM with control lines for ≤20% acceptable failure rate	26 ± 8; in 9 of 15 interns crossing acceptable failure line
Tarasi et al [41], 2011	Medical students	178	9 (median; range 1–23; during 2-wk anesthesiology rotation)	Successful intubation	Not defined	Observational study looking at longitudinal performance; mixed effects logistic regression model to build learning curve	17; Determined by extrapolation of learning curve

Rujirojindakul et al [42], 2014	Nurse anesthesia students	11	35.5 ± 5.1 (range 30–47; during first 3 mo in training)	Successful intubation	80	CUSUM with control lines for ≤20% acceptable failure rate	22 median; in 9 of 11 trainees crossing acceptable failure line
Kobzik et al [43], 2018	Critical care fellows	21 (9 anesthesiology/ EM; 12 other)	16.2 ± 8.0	Successful intubation	80	CUSUM with control lines for ≤20% acceptable failure rate	9.5 (anesthesiology and EM; in 8 of 9 fellows crossing acceptable failure line) 13.6 (all other fellows; in 10 of 12 fellows crossing acceptable failure line)

Data from Refs [35–43].

intubation success [44]. Using CUSUM and a cutoff failure rate less than 20%, the number of intubations from these studies suggest that between 22 and 45 attempts are needed to achieve this target, allowing for multiple passes, external coaching, and assistance [36,37,40,42]. When choosing a more conservative failure rate of less than 10%, the number jumps to 57 to 75 attempts, with continued improvement being seen after 100 procedures [35,45]. For a more detailed analysis of these studies and others targeting emergency response personnel, see the recent systematic review by Buis and colleagues [46].

For anesthesiologists expecting to directly enter practice upon completion of a residency, a 20% failure rate and need for active assistance are unacceptable for a definition of proficiency. When surveyed, approximately 50% of US and Canadian anesthesiology program directors felt that greater than 100 supervised laryngoscopy attempts were needed to obtain proficiency in DL [47]. Although not within the scope of this review, the decision to provide dedicated airway rotations for anesthesiology residents has become a more common component of training, with some experts suggesting a need for an airway management fellowship to train a subset of anesthesiologists to perform at the highest level [8]. With this level of interest and concern for difficult airway training within anesthesiology residency training programs with abundant clinical opportunities, it is difficult to believe that other specialties can achieve proficiency across a broad range of clinical scenarios and techniques with fewer cases. The data comparing ED and anesthesiology performance are discussed in more detail later.

As discussed previously, case volume is only 1 metric used to assess proficiency. Because airway management encompasses more than the technical skill to include crisis management, risk assessment, preparation, medication selection, and other critical elements of patient care, assessments encompassing these elements also are necessary in the evaluation of trainee to evaluate proficiency. Going beyond the numbers required in the ACGME Emergency Medicine Milestone Project, a panel of residency education and airway management experts recently completed a standard-setting procedure to establish detailed elements of performance for comprehensive airway management with expectations for novice and mastery level learners [48]. Realizing that procedural volume does not inform residency educators about a trainee's proficiency with that procedure, the effort was aimed at bringing together experts to start the process of designing a more rigorous performance assessment with defined standards that realize the milestone goals. The panel identified 51 discrete elements associated with a predefined airway scenario assessing (1) preparation, (2) endotracheal tube placement, (3) backup airway placement (forced by airway loss in scenario if able to initially intubate), and (4) ventilation. For novice learners early in training, the panel felt correctly executing 25 specific items (49%) would meet criteria for safe task performance. For mastery learners, the standard was set at 49 of 51 items (96%), with noncritical items being use of cricoid pressure and a straight-to-cuff stylet curvature technique. To date, data on using this approach to better target performance assessments have yet to be presented but likely will help further refine the Milestone Project targets for airway management when it becomes available.

Looking at all the available data, there is no clear definition of proficiency in comprehensive airway management, which requires repetition, observation, and performance evaluation. Based on the limited data, a minimum of 75 attempts with DL seems a reasonable compromise. Although this may represent a target for competency, continued improvement toward proficiency and mastery with decreased complications and a higher first-pass success rate have been noted in an anesthesiology trainee population, requiring up to 200 intubation attempts [38]. To meet the requirements of a competency-based medical education program, however, more than numbers are required. The use of clinical or simulation-based assessments likely will become standard practice in the future but still requires evaluation and testing to establish appropriate performance standards.

WHERE SHOULD THIS TAKE PLACE AND WHO SHOULD BE TEACHING?

Up through the late 1990s, anesthesiologists performed the majority of trauma airway management in the United States both inside and outside the OR, with EM physicians handling most nontrauma cases in the ED [49]. This has continued to evolve with most patients now requiring advanced airway management in the ED being managed by EM physicians, particularly in the United States. Regional variation exists with multiple patterns for primary airway management, including shared models, particularly for trauma resuscitation [50]. For patients with direct trauma to the airway, management using a team approach, with EM physicians, anesthesiologists, and surgeons working in concert to achieve the best possible results, is a reasonable model. This includes determining the appropriate location to proceed with advanced airway techniques in complex cases when time allows. Internationally, there is considerable variation in the primary airway providers and capabilities available for emergency and acute-care patients [51–53].

For many anesthesiologists who consider themselves airway experts with the greatest amount of experience and access to a variety of techniques, there is an impression that they are best suited to provide training for nonanesthesiologists. This assumes that most practice by EM and critical care trainees, the largest populations of physicians outside of anesthesiology with a need for frequent airway management skills, mirrors what occurs in the OR environment. This typically is not the case [54]. Outside of the OR, multiple factors combine to make airway management more difficult for the anesthesiologist who is just arriving on the scene, including

1. Space limitations
2. Unfamiliar equipment, environment, and assistants
3. Lack of immediate capnography
4. Limited knowledge of underlying patient physiology

5. Time pressure limiting detailed patient examination or review of existing records
6. Limited ability to preoxygenate due to time or patient condition

Thus, the OR may be well suited for practice of psychomotor skills associated with airway management, but it may not necessarily reflect the future practice of nonanesthesiologists who need to train for practice outside the OR. When looking at published data from the United States, several EM programs have published their procedural numbers for trainees, suggesting a wide variability in exposure. April and colleagues [55] reported 259 intubations over a 12-month period for 48 residents (average 5.4 per year), which would not meet the current ACGME target without an outside rotation. By contrast, Bucher and colleagues [56] reported an average of 28.9 intubations per resident per year in their training program. Given this variability, it is likely that many programs will continue to seek the inclusion of an OR airway management experience for their nonanesthesiologist trainees.

A moderate amount of research has looked at the impact of adding dedicated airway management rotations into anesthesiology curriculum [7,9,21], focusing particularly on difficult cases, but little has looked at the impact of an OR-based airway rotation on subsequent performance of nonanesthesiology residents, despite the frequent use of anesthesiology airway rotations to expand the training and clinical case volume for nonanesthesiology programs [57,58]. Soleimanpour and colleagues [59] examined the impact of a 36-hour airway course on postgraduate year (PGY) 1 EM resident bag-mask ventilation and intubation success rates before and after an additional 1-month OR-based training program. As expected in the short term, the successful ventilation rate increased from 16.6% to 88.8% and intubation rate from 27.7% to 83.3% for individuals participating in the 1-month program. The average number of intubations was not reported but the trainees were required to bag-mask ventilate and intubate a minimum of 50 patients in the OR. In a more recent trial, Clark and colleagues [60] examined the impact of 4-week anesthesiology airway rotation on success and adverse event rates for EM residents. In a single-institution study, they found that intubation success rates were no different during the first 6-months of the PGY 2 after the addition of an anesthesiology rotation during the PGY 1. Residents starting the PGY 2 having completed the anesthesiology rotation averaged 53 intubation attempts whereas those having not completed the rotation averaged 21 attempts. The first-pass and overall success rates were not statistically different between the groups (78.4% and 95.7%, respectively, for the rotation group; 83.4% and 94.5%, respectively, for the no-rotation group). The incidence of adverse events also was similar. Although there are several limitations to the study, this suggests that training in the OR with anesthesiologists does not necessarily lead to improved outcomes compared with training solely within the ED when adequate clinical ED cases are available. The same may not be true for critical care medicine trainees. A survey in 2012 of pulmonary/critical care fellowship directors found that 77% of trainees attempted fewer than 50 DL attempts during their fellowship, with more than half of those having fewer than 25 attempts despite a majority of programs having a dedicated airway management rotation as part of the 3-year fellowship [57].

There also are limitations within the OR that do not translate well to having a compact, adequate airway training experience. In the OR, there frequently are many learners requiring the same access to clinical cases limiting the exposure of individual trainees. In a comparison of an academic versus private practice anesthesiology rotation, Fix and colleagues [61] found that a private practice rotation provided significantly more experience (average 4.6 vs 1.5 intubations, respectively, per day in the OR). From the perspective of anesthesiology training programs, there is only 1 report on the effectiveness of training nonanesthesiologists in the OR [58]. In an assessment of 4571 airway procedures by 96 airway trainees (EM residents and critical care fellows), trainee performance improved over the course of 1 month, with first-pass success increasing from 85% to 94% from week 1 to week 4 (Fig. 1). In addition, an improvement in the initial laryngoscopic grade of view improved over the course of the rotation (grade 1 view 61%–74%) (Fig. 2). This rotation is somewhat unique compared with most anesthesiology airway rotations because 29% of all procedures were performed outside of the OR in the trauma resuscitation or ICU with a sole trainee having access to the majority of airway management opportunities during a given shift. These improvements occurred even when trainees reported prior attempts at intubation, although this prior experience was associated with a higher overall first-pass success rate during the rotation. Given the unique features of this institution and lack of follow-up performance data, it is hard to extrapolate the results to other, more traditional rotations that focus solely on OR cases.

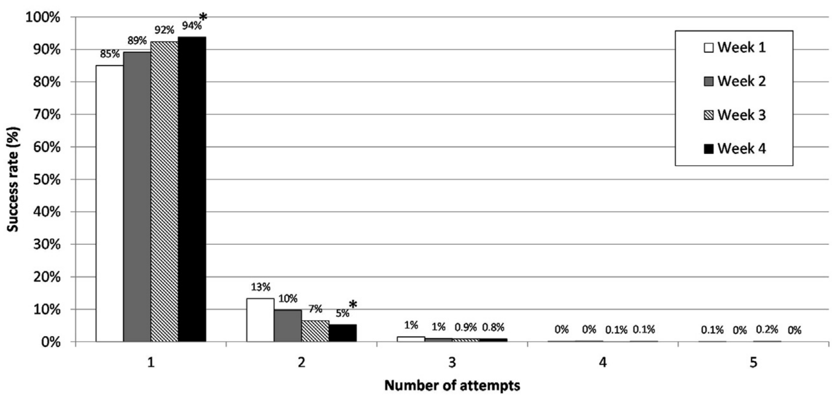

Fig. 1. Distribution of intubation attempts with corresponding success rate by week of rotation. *$P<.05$ for week 1 versus week 4. (*From* Grissom TE, Sappenfield J, Galvagno SM Jr., et al. Performance assessment in airway management training for nonanesthesiology trainees: an analysis of 4,282 airway procedures performed at a level-1 trauma center. *Anesthesiology.* 2014;120(1):185-195; with permission.)

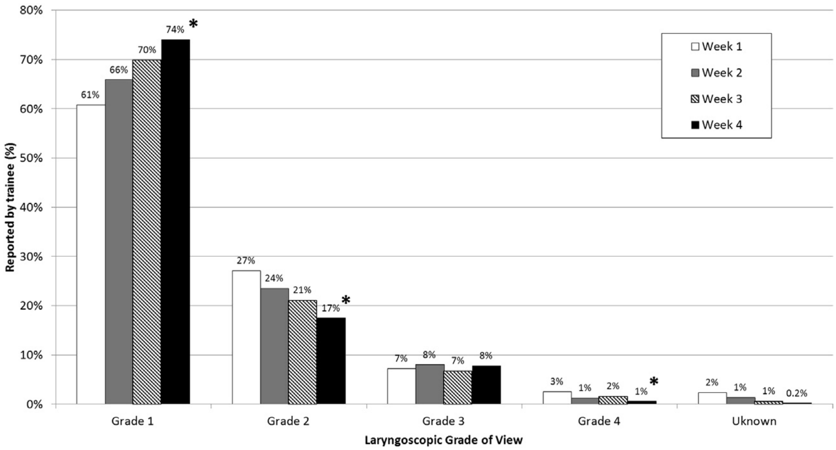

Fig. 2. Distribution of best laryngoscopic grade of view reported by trainee by week of rotation for all attempts by using DL as the first technique. *$P<.05$ for week 1 versus week 4. (*From* Grissom TE, Sappenfield J, Galvagno SM, Jr., et al. Performance assessment in airway management training for nonanesthesiology trainees: an analysis of 4,282 airway procedures performed at a level-1 trauma center. *Anesthesiology.* 2014;120(1):185-195; with permission.)

The question of who should be teaching airway management skills is one that has the potential to ignite spirited debate. As discussed previously, many nonanesthesiologists not only have achieved high-level performance in airway management but also have contributed extensively to knowledge, protocols, and rescue support outside the OR. When examined directly, there is no evidence of change in success or complication rate with transition to primary EM airway management in an ED or trauma resuscitation unit [62–66]. This has led to calls for the establishment of more collaborative approaches to airway management that also should extend to training [29,67,68]. Anesthesiologists involved in the training of nonanesthesiologists should recognize the experiences, advancements, and skills associated with non-OR airway management to incorporate them into ongoing didactic and hands-on clinical training to optimize trainees' performance gains. This applies not only to how they work with external trainees but also to the ability to expand the capabilities of anesthesiology residents and fellows.

In summary, there is no hard evidence to indicate that nonanesthesiology trainees benefit from an OR-based airway management rotation when sufficient clinical exposure is available within the parent program. Although psychomotor skills likely will be improved in the short term for rotations that provide sufficient clinical volume (>50 intubations), the failure to address other aspects of airway management, such as nontechnical skills (NTS), has the potential to limit the overall application of those skills outside the OR. In addition, the specific requirement to learn from anesthesiologists as opposed to other specialists has not been examined, although extrapolation from published studies suggest that this is not a requirement to meet general competency milestones.

DO YOU NEED TO TEACH DIRECT LARYNGOSCOPY, VIDEO LARYNGOSCOPY, OR BOTH?

When teaching nonanesthesiology trainees with limited clinical opportunities for practice, it has been suggested that VL is learned more easily with a higher success rate by individuals who intubate infrequently [69,70]. Several studies have demonstrated a higher success rate for novices with fewer complications for VL compared with DL, particularly outside of the OR [70–74]. This finding, however, is not consistent between studies and may be affected by the device, environment, and operator factors [75–77]. Additionally, it also has been suggested that novice trainees may have more rapid acquisition of DL skills when VL is practiced first with video-assisted instruction [78,79], although, again, this is not a consistent observation [80].

Although advanced practitioners, such as anesthesiologists and EM physicians, should be facile in multiple techniques, other trainees who can do an airway rotation outside their specialty may benefit from an educational approach emphasizing the use of VL. Although the number of procedures in a dedicated airway rotation is highly variable depending on structure and location, it is unlikely that most trainees would have more than 60 total procedures over 1 month, making it difficult to become truly proficient in multiple techniques. Future hospitalists, critical care physicians, and others who are likely to do fewer than 10 intubations per year with limited training experience may benefit from this more focused approach. Criticism of a VL-focused training approach correctly points out the heterogeneity of VL devices, which makes it difficult to generalize all previous work done with DL versus VL comparisons. The 2 major classes of VL devices using either a standard geometry (like a Macintosh blade) or a hyperangulated blade. This is important because evidence continues to show that the use of a standard geometry VL device combines the best of both techniques, allowing for direct visualization with video assistance as needed [81]. In addition, recent observations suggest this is the most common VL approach in US EDs with a very high success rate [66,72].

The implications for anesthesiologists involved with training other professionals is significant. An approach that combines VL using a standard geometry blade is likely a superior approach to working with a novice trainee population who have limited training opportunities. Excessive emphasis on DL or VL using hyperangulated blades may not provide the best support for future clinical responsibilities. From a clinical perspective, the use of VL is linked to a higher success rate in this population with fewer esophageal intubations [77].

WHAT IS THE ROLE OF SIMULATION?

The use of simulation-based training (SBT) as a component of airway management training has become almost ubiquitous in anesthesiology residency programs, although this is not internationally consistent [7,82,83]. The same is true for most nonanesthesiology training programs where airway management is considered a core skill [11,14,84]. Questions remain, however, as to whether SBT improves subsequent clinical performance and acquisition of skills. SBT encompasses a wide range of simulation modalities from online software programs, task trainers, virtual reality systems, animal models, and fresh frozen cadavers to high-fidelity, dynamically modifiable mannequins [85]. Whether via a simulated objective structured clinical examination format or with multiple disciplines practicing in a certified simulation center, proponents have argued that simulation offers improved training in technical skills and nontechnical skills (NTS) [86]. Familiarity and repeated practice with various airway equipment, techniques, and difficult airway algorithms in a no-risk environment ideally allow for the refinement of skills and as a confidence builder for real clinical situations. Of equal, if not more, importance is the value of simulation in improving the nontechnical skills of teamwork, coordinated care, communication, and crisis management. As with other critical tasks, the significance of assuming a leadership position, knowing when to call for help, remaining focused yet able to integrate the suggestions of others, and progressing through an organized algorithm is incredibly valuable for trainees who may encounter an emergent or difficult airway. It may be that having to make a difficult decision during simulation (eg, administering a second dose of muscle relaxant during a cannot intubate, cannot oxygenate situation or proceeding to a surgical airway) may lower the barrier to making that decision in real life. Finally, expert supervision and immediate feedback helps solidify the lessons learned.

The full benefits of simulation are highly dependent on available instruments, physical resources, experienced staff to provide structured content and feedback, and frequent intervals to establish and maintain competency. Refresher courses and periodic training sessions should be instituted every 2 years and possibly more often if worthwhile new airway equipment becomes available. Despite the logical assumption that SBT improves a learner's skill acquisition and subsequent performance with real patients, questions remain as to the ability of SBT to achieve these goals. In a recent meta-analysis, Sun and colleagues [87] reviewed 17 studies comparing airway SBT to non-SBT among trainees (medical students to physicians) with limited prior airway management experience across multiple specialties. Surprisingly, SBT was found superior only to non-SBT in improving behavior performance but failed to show a significant benefit in time to perform the skill and in procedural success in real-world clinical settings. The exception to this may be bronchoscopic-guided intubation where SBT improvements in psychomotor skills may alter performance in subsequent clinical experiences [88,89]. The magnitude of this improvement with bronchoscopic-guided intubations is unclear, although Wong and colleagues [90] recently demonstrated that short-term skill retention from a 60-minute SBT session significantly reduced intubation time in the clinical setting for relatively novice learners.

A newer approach to SBT may provide a better pathway to early skill acquisition. Simulation-based mastery learning (SBML) incorporates a simulation milestone into the pathway for achieving competency [91]. With SBML, trainees must meet or exceed predetermined standards of performance in a simulated environment before performing clinical procedures on patients. This has been suggested to be a more effective learning strategy than the traditional approach although it is more time consuming [92]. Combined with deliberate practice, the repetitive performance of intended psychomotor or cognitive skills combined with rigorous assessment and specific information feedback, SBML has been shown to improve performance in early learners across a broad range of procedural skills [91]. This approach has been used to a limited extent in airway management training although data about transfer to clinical skills are lacking [93,94].

Success may be a function of the type of simulation as well. Modifiable human simulators may be better for NTS focused training whereas partial task trainers and cadaver SBT may provide improved fidelity for technical skills, such as ventilation, laryngoscopy, intubation, and insertion of supraglottic airways. What is not known is whether the simulation environment or primary instructor's background plays a role in SBT. Airway management practice in a trainee's home environment, such as the ED or ICU, may provide more clinically relevant scenarios and environments like what would be encountered in subsequent practice. Increased SBT fidelity, however, has not been shown consistently to be a significant factor for educational effectiveness [95]. Additionally, the specialty of the individuals serving as the primary educators in airway management SBT has not been examined. Similar to fidelity, an instructor's specialty likely has little impact on learning outcomes assuming baseline competency in airway management and teaching.

Regardless of true clinical outcome differences, SBT has become an integral component of airway management training for all specialties. This is a vital component of residency training because familiarity with and comfort in performing in a simulation environment are necessary for trainees because simulation-based assessments are used more frequently for evaluating competency in a broad range of settings, including airway management. Using reproducible and validated scenarios, it should be possible to present increasingly more challenging scenarios to assess the learner's milestone achievements. Most commonly, learners are assessed with simulation at baseline, undergo training (simulated or real) and are reassessed under the same or similar conditions [93]. As described previously for the Milestone Project, different levels of performance commensurate with a learner's milestone progress may be awarded [48]. Improvements in performance hopefully translate to greater proficiency in clinical care, but as discussed previously, this remains unvalidated in airway management training.

Undoubtedly, SBT will continue to be a core element of all airway management training programs independent of the specialty. Although the current approach to SBT for airway management has not been shown to speed skill acquisition or have an impact on patient-centered outcomes, simulation may have a greater impact on NTS and will have an increasingly important role in competency assessment. Additional research specifically looking at the role of SBML and deliberate practice may change the training paradigm. The role of anesthesiologists in SBT is likely to continue due to the specialty's early adaptation of this training modality and integral involvement in many simulation centers. For airway management training, however, there is no evidence to suggest that other specialties are not capable of providing comparable training.

WHAT IS ON THE HORIZON FOR AIRWAY MANAGEMENT TRAINING?

As suggested previously, the attainment of true proficiency in endotracheal intubation may require upwards of 200 or more attempts [38]. Efforts to improve the learning curve largely have been unsuccessful and continue to rely on clinical repetition under direct supervision. One recent avenue for improving early success has focused on the differences between experienced and novice learners, which could be identified earlier and incorporated directly into training to accelerate skill acquisition. For example, head position relative to the patient, force vectors for application of DL, and hand movements may differ between these 2 groups [96,97]. Most of the studies looking at difference in movements rely on bulky technology that is not amenable to the clinical setting and does not allow for active feedback during the procedure. This may become less of a roadblock due to miniaturization and artificial intelligence algorithms capable of providing verbal, and, potentially, tactile feedback. Recently, Carlson and colleagues [98] evaluated the use of miniature inertial measurement units attached to the hands and wrists to capture bilateral movements during intubation in both novice and experienced providers. Using machine learning algorithms, they were able to identify patterns of movement that accurately discriminated between the 2 groups (91.17%; CI, 90.8%–91.5% Cl). Like work done with novices learning laparoscopic surgical skills, the ability to measure the movements, provide feedback, and reassess performance has the potential to accelerate the intubation learning curve and improve consistency at the novice level.

One other educational tool that recently has been evaluated for improving technical and NTS retention is the use of video-assisted reflection (VAR). Although not a new concept, VAR incorporates the use of video review of a training session, as opposed to recall-assisted reflection (RAR), that aids learners in adding perspective to a simulation training session, where they can objectively see how events occurred rather than relying on hindsight [99]. This has been suggested to reduce the cognitive load during the feedback session, allowing for better retention by contributing to visual memory. Prakash and colleagues [100] recently evaluated VAR versus RAR in critical care trainees following SBT for airway management in a critically ill patient. Debriefing after an initial simulation session was done using recorded video (VAR) or recall of events (RAR) by the participants. They found that compared with RAR, VAR resulted in similar improvement in airway skills but better retention over time when completing a similar session 1 month later. This is consistent with other work looking at skill acquisition [101,102]. There is potential to incorporate VAR into clinical training [103]. Although this approach is appealing, privacy issues related to recording may preclude widespread use.

Probably the most interesting development related to airway management training is not a specific training technique or strategy but the proliferation of difficult airway management guidelines. When discussing how and where to train nonanesthesiologists, trainers must first understand the context of where a trainee will be practicing and what airway management guidelines exist within that specialty. A recent review of difficult airway management guidelines found more than 35 different guidelines have been published in the past 20 years (Fig. 3) [104]. As noted by Chrimes and colleagues [1], "[t]he multiplicity of airway algorithms is both a cause and effect of the professional silos clinicians currently occupy: having different algorithms for specific clinical contexts reinforces the erroneous notion that the issues encountered and/or the strategies to address them are unique to each context, deterring collaboration." Regardless of who, where, or how is doing the training, a consistent or universal approach to airway management of the difficult airway is highly desirable and has been pushed in several editorials addressing this issue [1,10,29,105]. Collaboration within and between specialties is the key to providing a more universal approach that also would extend to training.

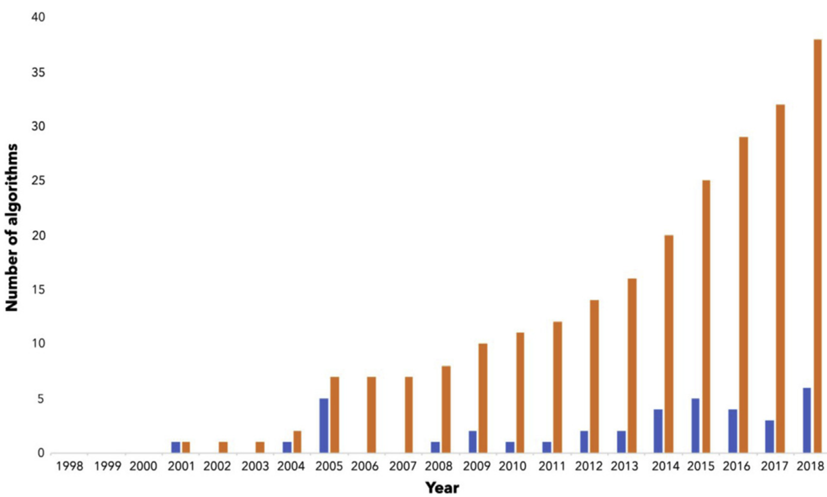

Fig. 3. Frequency of airway algorithm publication from 1998 to 2018 with number of publications per year (*blue bars*) and the number of cumulative airway algorithms published (*orange bars*). (*From* Edelman DA, Perkins EJ, Brewster DJ. Difficult airway management algorithms: a directed review. Anaesthesia. 2019;74(9):1175-1185; with permission.)

The education and training of medical personnel within specialties typically occur in isolation. This may lead to different terminology, attitudes, and approaches to managing the airway when different specialties converge to manage a crisis. Interprofessional training involving staff from all acute care areas should be undertaken with a focus on creating a shared understanding or mental model of difficult airway approaches. Teams that have shared mental models have been shown to be more adaptable with improved processes and outcomes than those without this understanding [106]. Anesthesiologists who are actively training individuals from outside their specialty should be communicating regularly with the primary department to determine whether their program meets the needs of the sending program and how they can better interact to benefit the trainees and the clinical population they serve.

SUMMARY

Anesthesiologists will continue to be recognized as airway experts and other specialties will need ongoing access to the clinical volume available in the OR setting when looking for opportunities to meet their residents' and fellows' airway management training needs. At the same time, critical care, EM, and other physicians have acquired an ever-expanding array of skills and experience managing the airways of critically ill and injured patients. When considering the needs of nonanesthesiologist trainees coming to our domain, it is essential to recognize the differences inherent in practicing outside of the OR and to incorporate those aspects of airway management considerations into training paradigms. This should be viewed as an opportunity to work toward a more universal approach to training and airway management in our individual institutions incorporating a multidisciplinary approach to education and clinical activities.

Within this structure, the evolving aspects of mastery learning or milestone achievement require us to work toward establishing more objective measures of competency and proficiency wherever possible. This includes a more rigorous application of SBT-directed at mastery learning and deliberate practice with a focus not only on technical skills but also NTS. The location for and leadership of the training likely is less important than the individuals involved in program development. A focus on VL-based training for early learners appears to be supported by the data but must be balanced against the technical and environmental challenges.

As noted by Straker [107] in an editorial looking at airway management in the twenty-first century, "Airway management is no longer synonymous with only endotracheal intubation–it is finally recognized as a complex array of skills taking years to master to provide the utmost in terms of patient safety." True mastery requires years of experience and hundreds of patient encounters. In the meantime, anesthesiologists need to figure out how best to support the goal of improving airway management training to move all trainees to the point of proficiency and beyond.

CARE POINTS

- Target a minimum of 75 DL attempts for nonanesthesiologist trainees.
- Evaluate correlation of simulation-based testing with clinical performance.
- Instruction in airway management should be focused on a blended experience of simulation, clinical volume, and effective learning strategies rather than specific sites of instruction or who is providing the training.
- Use of VL with standard geometry rather than hyperangulated blades may improve overall training goals.
- Airway management simulation training has not been shown to provide significant psychomotor skill acquisition although it may help with NTS acquisition in team-based training.

Disclosure

The authors have nothing to disclose.

References

[1] Chrimes N, Higgs A, Sakles JC. Welcome to the era of universal airway management. Anaesthesia 2020;75(6):711–5.
[2] Avidan A, Shapira Y, Cohen A, et al. Difficult airway management practice changes after introduction of the GlideScope videolaryngoscope: A retrospective cohort study. Eur J Anaesthesiol 2020;37(6):443–50.
[3] Cook TM, Boniface NJ, Seller C, et al. Universal videolaryngoscopy: a structured approach to conversion to videolaryngoscopy for all intubations in an anaesthetic and intensive care department. Br J Anaesth 2018;120(1):173–80.
[4] Price TM, McCoy EP. Emergency front of neck access in airway management. BJA Education 2019;19(8):246–53.
[5] Cook TM, Woodall N, Frerk C, et al. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: anaesthesia. Br J Anaesth 2011;106(5):617–31.
[6] Cook TM, Woodall N, Harper J, et al. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments. Br J Anaesth 2011;106(5):632–42.
[7] Galway UA, Straker T, Foley LJ, et al. Anesthesia residency training in airway management: a competency-based model curriculum. A A Pract 2019;13(5):197–9.
[8] Straker T. Airway management. J Head Neck Anesth 2019;3(1):e11.
[9] Spaliaras J, Streiff S, Mann G, et al. Teaching and training in airway management: time to evaluate the current model? Airway 2019;2:28–35.
[10] Chrimes NC. Time for a collaborative approach to airway training. Anaesth Intensive Care 2018;46(5):545–6.
[11] Kho MHT, Chew KS, Azhar MN, et al. Implementing blended learning in emergency airway management training: a randomized controlled trial. BMC Emerg Med 2018;18(1):1.
[12] Trimmel H, Beywinkler C, Hornung S, et al. In-hospital airway management training for non-anesthesiologist EMS physicians: a descriptive quality control study. Scand J Trauma Resusc Emerg Med 2017;25(1):45.
[13] Sakles JC, Augustinovich CC, Patanwala AE, et al. Improvement in the safety of rapid sequence intubation in the emergency department with the use of an airway continuous quality improvement program. West J Emerg Med 2019;20(4):610–8.
[14] Marvin K, Bowman P, Keller MW, et al. Effectiveness of an Advanced Airway Training "Boot Camp" for Family Medicine Physician Trainees. Otolaryngol Head Neck Surg 2020;163(2):204–8.

[15] Brewster DJ, Nickson CP, Gatward JJ, et al. Should ongoing airway education be a mandatory component of continuing professional development for College of Intensive Care Medicine Fellows? Anaesth Intensive Care 2018;46(2):190–6.
[16] Gaiser RR. Teaching airway management skills. How and what to learn and teach. Crit Care Clin 2000;16(3):515–25.
[17] Wang EE, Quinones J, Fitch MT, et al. Developing technical expertise in emergency medicine–the role of simulation in procedural skill acquisition. Acad Emerg Med 2008;15(11): 1046–57.
[18] Long E, Cincotta D, Grindlay J, et al. Implementation of NAP4 emergency airway management recommendations in a quaternary-level pediatric hospital. Paediatr Anaesth 2017;27(5):451–60.
[19] Chichra A, Naval P, Dibello C, et al. Barriers to training pulmonary and critical care fellows in emergency endotracheal intubation across the United States. Chest 2011;140:1036A.
[20] Huitink JM, Bretschneider JH. Airway Management Academy: A global initiative to increase patient safety during airway management by medical education. Trends Anaesth Crit Care 2015;5(1):42–7.
[21] Chan JJI, Goy RWL, Ithnin F, et al. Difficult obstetric airway training: Current strategies, challenges and future innovations. Trends Anaesth Crit Care 2020;31:21–7.
[22] Hunyady A, Polaner D. Pediatric airway management education and training. Paediatr Anaesth 2020;30(3):362–70.
[23] Proficient. Merriam-Webster.com Dictionary. Available at: https://www.merriam-webster.com/dictionary/proficient. Accessed June 15, 2020.
[24] Edgar L, McLean S, Hogan SO, et al. The Milestones Guidebook. Version 2020. Accreditation Council for Graduate Medical Education. 2020. Available at: https://www.acgme.org/Portals/0/MilestonesGuidebook.pdf. Accessed July 31, 2020.
[25] Yudkowsky R, Park YS, Lineberry M, et al. Setting mastery learning standards. Acad Med 2015;90(11):1495–500.
[26] Carraccio CL, Benson BJ, Nixon LJ, et al. From the educational bench to the clinical bedside: translating the Dreyfus developmental model to the learning of clinical skills. Acad Med 2008;83(8):761–7.
[27] Frank JR, Snell L, Englander R, et al. Implementing competency-based medical education: Moving forward. Med Teach 2017;39(6):568–73.
[28] The Emergency Medicine Milestone Project. A Joint Initiative of The Accreditation Council for Graduate Medical Education and The American Board of Emergency Medicine. The Accreditation Council for Graduate Medical Education. 2015. Available at: https://www.acgme.org/Portals/0/PDFs/Milestones/EmergencyMedicineMilestones.pdf?ver=2015-11-06-120531-877. Accessed July 31, 2020.
[29] Marshall SD, Chrimes N. Time for a breath of fresh air: Rethinking training in airway management. Anaesthesia 2016;71(11):1259–64.
[30] Zoric L, Savoldelli GL. Evidence base in airway management training. Trends Anaesth Crit Care 2015;5(1):36–41.
[31] Wanderer JP, Ehrenfeld JM, Sandberg WS, et al. The changing scope of difficult airway management. Can J Anaesth 2013;60(10):1022–4.
[32] Aziz MF, Brambrink AM, Healy DW, et al. Success of intubation rescue techniques after failed direct laryngoscopy in adults: a retrospective comparative analysis from the Multicenter Perioperative Outcomes Group. Anesthesiology 2016;125(4):656–66.
[33] Zeidan A, Bamadhaj M, Al-Faraidy M, et al. Videolaryngoscopy intubation in patients with COVID-19: how to minimize risk of aerosolization? Anesthesiology 2020;133(2):481–3.
[34] Flying High with Chuck Yeager. NPR Day to Day. 2007. Available at: https://www.npr.org/templates/story/story.php?storyId=15229836. Accessed 31 July, 2020.
[35] Konrad C, Schupfer G, Wietlisbach M, et al. Learning manual skills in anesthesiology: Is there a recommended number of cases for anesthetic procedures? Anesth Analg 1998;86(3):635–9.

[36] de Oliveira Filho GR. The construction of learning curves for basic skills in anesthetic procedures: an application for the cumulative sum method. Anesth Analg 2002;95(2):411–6.
[37] Kopacz DJ, Neal JM, Pollock JE. The regional anesthesia "learning curve". What is the minimum number of epidural and spinal blocks to reach consistency? Region Anesth 1996;21(3):182–90.
[38] Bernhard M, Mohr S, Weigand MA, et al. Developing the skill of endotracheal intubation: implication for emergency medicine. Acta Anaesthesiol Scand 2012;56(2):164–71.
[39] Chao A, Chou WH, Huang HH, et al. Evaluation of tracheal intubation: A retrospective study of skill acquisition by medical students in the operating theater. J Formos Med Assoc 2015;114(9):855–9.
[40] Komatsu R, Kasuya Y, Yogo H, et al. Learning curves for bag-and-mask ventilation and orotracheal intubation: an application of the cumulative sum method. Anesthesiology 2010;112(6):1525–31.
[41] Tarasi PG, Mangione MP, Singhal SS, et al. Endotracheal intubation skill acquisition by medical students. Med Educ Online 2011;16:1–5.
[42] Rujirojindakul P, McNeil E, Rueangchira-Urai R, et al. Learning curves of macintosh laryngoscope in nurse anesthetist trainees using cumulative sum method. Anesthesiol Res Pract 2014;2014:850731.
[43] Kobzik A, Hahn Z, Emlet L, et al. Quantifying airway skill acquisition and estimating competency during critical care fellowship. Crit Care Med 2018;47(1 Supplement):1021.
[44] Biau DJ, Williams SM, Schlup MM, et al. Quantitative and individualized assessment of the learning curve using LC-CUSUM. Br J Surg 2008;95(7):925–9.
[45] Je S, Cho Y, Choi HJ, et al. An application of the learning curve-cumulative summation test to evaluate training for endotracheal intubation in emergency medicine. Emerg Med J 2015;32(4):291–4.
[46] Buis ML, Maissan IM, Hoeks SE, et al. Defining the learning curve for endotracheal intubation using direct laryngoscopy: A systematic review. Resuscitation 2016;99:63–71.
[47] Pott LM, Randel GI, Straker T, et al. A survey of airway training among U.S. and Canadian anesthesiology residency programs. J Clin Anesth 2011;23(1):15–26.
[48] Panchal AR, Way DP, King AM, et al. Performance standards of comprehensive airway management for emergency medicine residents. AEM Educ Train 2019;3(1):39–49.
[49] Nayyar P, Lisbon A. Non-operating room emergency airway management and endotracheal intubation practices: a survey of anesthesiology program directors. Anesth Analg 1997;85(1):62–8.
[50] Chiaghana C, Giordano C, Cobb D, et al. Emergency department airway management responsibilities in the United States. Anesth Analg 2019;128(2):296–301.
[51] Nakao S, Kimura A, Hagiwara Y, et al. Trauma airway management in emergency departments: a multicentre, prospective, observational study in Japan. BMJ Open 2015;5(2): e006623.
[52] Wong EG, Gupta S, Deckelbaum DL, et al. Prioritizing injury care: a review of trauma capacity in low and middle-income countries. J Surg Res 2015;193(1):217–22.
[53] Booth A, Steel A, Klein J. Anaesthesia and pre-hospital emergency medicine. Anaesthesia 2013;68(Suppl 1):40–8.
[54] Asai T. Airway management inside and outside operating rooms-circumstances are quite different. Br J Anaesth 2018;120(2):207–9.
[55] April MD, Schauer SG, Brown Rd CA, et al. A 12-month descriptive analysis of emergency intubations at Brooke Army Medical Center: a National Emergency Airway Registry study. US Army Med Dep J 2017;(3–17):98–104.
[56] Bucher JT, Bryczkowski C, Wei G, et al. Procedure rates performed by emergency medicine residents: a retrospective review. Int J Emerg Med 2018;11(1):7.
[57] Joffe AM, Liew EC, Olivar H, et al. A national survey of airway management training in United States internal medicine-based critical care fellowship programs. Respir Care 2012;57(7):1084–8.

[58] Grissom TE, Sappenfield J, Galvagno SM Jr, et al. Performance assessment in airway management training for nonanesthesiology trainees: an analysis of 4,282 airway procedures performed at a level-1 trauma center. Anesthesiology 2014;120(1):185–95.
[59] Soleimanpour H, Gholipouri C, Panahi JR, et al. Role of anesthesiology curriculum in improving bag-mask ventilation and intubation success rates of emergency medicine residents: a prospective descriptive study. BMC Emerg Med 2011;11:8.
[60] Clark TR, Brizendine EJ, Milbrandt JC, et al. Impact of an anesthesiology rotation on subsequent endotracheal intubation success. J Grad Med Educ 2013;5(1):70–3.
[61] Fix ML, Enslow MS, Blankenship JF, et al. Emergency Medicine resident anesthesia training in a private vs. academic setting. J Emerg Med 2013;44(3):676–81.
[62] Bushra JS, McNeil B, Wald DA, et al. A comparison of trauma intubations managed by anesthesiologists and emergency physicians. Acad Emerg Med 2004;11(1):66–70.
[63] Levitan RM, Rosenblatt B, Meiner EM, et al. Alternating day emergency medicine and anesthesia resident responsibility for management of the trauma airway. Ann Emerg Med 2004;43(1):48–53.
[64] Varga S, Shupp JW, Maher D, et al. Trauma airway management: transition from anesthesia to emergency medicine. J Emerg Med 2013;44(6):1190–5.
[65] Kerslake D, Oglesby AJ, Di Rollo N, et al. Tracheal intubation in an urban emergency department in Scotland: a prospective, observational study of 3738 intubations. Resuscitation 2015;89:20–4.
[66] Brown CA 3rd, Bair AE, Pallin DJ, et al. Techniques, success, and adverse events of emergency department adult intubations. Ann Emerg Med 2015;65(4):363–70.e1.
[67] Nolan J, Clancy M. Airway management in the emergency department. Br J Anaesth 2002;88(1):9–11.
[68] Mort TC. Anesthesia practice in the emergency department: overview, with a focus on airway management. Curr Opin Anaesthesiol 2007;20(4):373–8.
[69] Long MT, Kory PD, Steuerwald MT, et al. Videolaryngoscopy and direct laryngoscopy equal for air medical intubation? The operator matters. Crit Care Med 2020;48(3): e254–5.
[70] Arulkumaran N, Lowe J, Ions R, et al. Videolaryngoscopy versus direct laryngoscopy for emergency orotracheal intubation outside the operating room: a systematic review and meta-analysis. Br J Anaesth 2018;120(4):712–24.
[71] Okamoto H, Goto T, Wong ZSY, et al. Comparison of video laryngoscopy versus direct laryngoscopy for intubation in emergency department patients with cardiac arrest: A multicentre study. Resuscitation 2019;136:70–7.
[72] Brown CA 3rd, Kaji AH, Fantegrossi A, et al. Video laryngoscopy compared to augmented direct laryngoscopy in adult emergency department tracheal intubations: A National Emergency Airway Registry (NEAR) study. Acad Emerg Med 2020;27(2):100–8.
[73] Sakles JC, Mosier JM, Chiu S, et al. Tracheal intubation in the emergency department: a comparison of GlideScope(R) video laryngoscopy to direct laryngoscopy in 822 intubations. J Emerg Med 2012;42(4):400–5.
[74] Kaji AH, Shover C, Lee J, et al. Video versus direct and augmented direct laryngoscopy in pediatric tracheal intubations. Acad Emerg Med 2020;27(5):394–402.
[75] Monette DL, Brown CA 3rd, Benoit JL, et al. The impact of video laryngoscopy on the cinical learning environment of emergency medicine residents: A report of 14,313 intubations. AEM Educ Train 2019;3(2):156–62.
[76] Sulser S, Ubmann D, Schlaepfer M, et al. C-MAC videolaryngoscope compared with direct laryngoscopy for rapid sequence intubation in an emergency department: A randomised clinical trial. Eur J Anaesthesiol 2016;33(12):943–8.
[77] Rombey T, Schieren M, Pieper D. Video versus direct laryngoscopy for inpatient emergency intubation in adults. Dtsch Arztebl Int 2018;115(26):437–44.
[78] Howard-Quijano KJ, Huang YM, Matevosian R, et al. Video-assisted instruction improves the success rate for tracheal intubation by novices. Br J Anaesth 2008;101(4):568–72.

[79] Volz S, Stevens TP, Dadiz R. A randomized controlled trial: does coaching using video during direct laryngoscopy improve residents' success in neonatal intubations? J Perinatol 2018;38(8):1074–80.
[80] Gu M, Lian M, Gong C, et al. The teaching order of using direct laryngoscopy first may improve the learning outcome of endotracheal incubation: A preliminary, randomized controlled trial. Medicine (Baltimore) 2019;98(21):e15624.
[81] Kovacs G, Levitan R. Redirecting the Laryngoscopy Debate and Optimizing Emergency Airway Management. Acad Emerg Med 2020. Available at: https://doi.org/10.1111/acem.14043. Accessed July 31, 2020.
[82] Armstrong L, Harding F, Critchley J, et al. An international survey of airway management education in 61 countries(dagger). Br J Anaesth 2020;125(1):e54–60.
[83] Grande B, Kolbe M, Biro P. Difficult airway management and training: simulation, communication, and feedback. Curr Opin Anaesthesiol 2017;30(6):743–7.
[84] Nguyen LHP, Bank I, Fisher R, et al. Managing the airway catastrophe: longitudinal simulation-based curriculum to teach airway management. J Otolaryngol Head Neck Surg 2019;48(1):10.
[85] Kennedy CC, Cannon EK, Warner DO, et al. Advanced airway management simulation training in medical education: a systematic review and meta-analysis. Crit Care Med 2014;42(1):169–78.
[86] Myatra SN, Kalkundre RS, Divatia JV. Optimizing education in difficult airway management: meeting the challenge. Curr Opin Anaesthesiol 2017;30(6):748–54.
[87] Sun Y, Pan C, Li T, et al. Airway management education: simulation based training versus non-simulation based training-A systematic review and meta-analyses. BMC Anesthesiol 2017;17(1):17.
[88] Goldmann K, Steinfeldt T. Acquisition of basic fiberoptic intubation skills with a virtual reality airway simulator. J Clin Anesth 2006;18(3):173–8.
[89] Graeser K, Konge L, Kristensen MS, et al. Airway management in a bronchoscopic simulator based setting: an observational study. Eur J Anaesthesiol 2014;31(3):125–30.
[90] Wong DT, Mehta A, Singh KP, et al. The effect of virtual reality bronchoscopy simulator training on performance of bronchoscopic-guided intubation in patients: A randomised controlled trial. Eur J Anaesthesiol 2019;36(3):227–33.
[91] Barsuk JHC RR, Wayne DB. Mastery learning of bedside procedural skills. In: McGaghie WCB, Barsuk JH, Wayne DB, editors. Comprehensive healthcare simulation: mastery learning in health professions education. Cham (Switzerland): Spinger Nature Switzerland AG; 2020. p. 225–58.
[92] Cook DA, Brydges R, Zendejas B, et al. Mastery learning for health professionals using technology-enhanced simulation: a systematic review and meta-analysis. Acad Med 2013;88(8):1178–86.
[93] Couto TB, Reis AG, Farhat SCL, et al. Changing the view: impact of simulation-based mastery learning in pediatric tracheal intubation with videolaryngoscopy. J Pediatr (Rio J) 2020. [Epub ahead of print].
[94] Ahn J, Yashar MD, Novack J, et al. Mastery learning of video laryngoscopy using the Glidescope in the emergency department. Simul Healthc 2016;11(5):309–15.
[95] Hamstra SJ, Brydges R, Hatala R, et al. Reconsidering fidelity in simulation-based training. Acad Med 2014;89(3):387–92.
[96] Hindman BJ, From RP, Fontes RB, et al. Intubation biomechanics: laryngoscope force and cervical spine motion during intubation in cadavers-cadavers versus patients, the effect of repeated intubations, and the effect of type II odontoid fracture on C1-C2 motion. Anesthesiology 2015;123(5):1042–58.
[97] Sakakura Y, Kamei M, Sakamoto R, et al. Biomechanical profiles of tracheal intubation: a mannequin-based study to make an objective assessment of clinical skills by expert anesthesiologists and novice residents. BMC Med Educ 2018;18(1):293.

[98] Carlson JN, Cho S, Ohu IPN, et al. Preliminary experience with inertial movement technology to characterize endotracheal intubation kinematics. Simul Healthc 2020;15(3):160–6.
[99] Zhang H, Morelius E, Goh SHL, et al. Effectiveness of video-assisted debriefing in simulation-based health professions education: a systematic review of quantitative evidence. Nurse Educ 2019;44(3):E1–6.
[100] Prakash S, Bihari S, Laver R, et al. Prospective randomized controlled trial of video- versus recall-assisted reflection in simulation-based teaching on acquisition and retention of airway skills among trainees intubating critically ill patients. Crit Care Med 2020;48(9):1265–70.
[101] Savoldelli GL, Naik VN, Park J, et al. Value of debriefing during simulated crisis management: oral versus video-assisted oral feedback. Anesthesiology 2006;105(2):279–85.
[102] Sawyer T, Sierocka-Castaneda A, Chan D, et al. The effectiveness of video-assisted debriefing versus oral debriefing alone at improving neonatal resuscitation performance: a randomized trial. Simul Healthc 2012;7(4):213–21.
[103] Shah RT, Makaryus MR, Kumar R, et al. Simulation training for critical care airway management: assessing translation to clinical practice using a small video-recording device. Chest 2020;158(1):272–8.
[104] Edelman DA, Perkins EJ, Brewster DJ. Difficult airway management algorithms: a directed review. Anaesthesia 2019;74(9):1175–85.
[105] Asai T, Hillman D. Current difficult airway management-not good enough! Anesthesiology 2019;131(4):774–6.
[106] Mathieu JE, Heffner TS, Goodwin GF, et al. The influence of shared mental models on team process and performance. J Appl Psychol 2000;85(2):273–83.
[107] Straker T. Airway management in the 21st century. Int Anesthesiol Clin 2017;55(1):1.