Video-assisted instruction improves the success rate for tracheal intubation by novices

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Background. Tracheal intubation via laryngoscopy is a fundamental skill, particularly for anaesthesiologists. However, teaching this skill is difficult since direct laryngoscopy allows only one individual to view the larynx during the procedure. The purpose of this study was to determine if video-assisted laryngoscopy improves the effectiveness of tracheal intubation training.

Methods. In this prospective, randomized, crossover study, 37 novices with less than six prior intubation attempts were randomized into two groups, video-assisted followed by traditional instruction (Group V/T) and traditional instruction followed by video-assisted instruction (Group T/V). Novices performed intubations on three patients, switched groups, and performed three more intubations. All trainees received feedback during the procedure from an attending anaesthesiologist based on standard cues. Additionally, during the video-assisted part of the study, the supervising anaesthesiologist incorporated feedback based on the video images obtained from the fibreoptic camera located in the laryngoscope.

Results. During video-assisted instruction, novices were successful at 69% of their intubation attempts whereas those trained during the non-video-assisted portion were successful in 55% of their attempts (P=0.04). Oesophageal intubations occurred in 3% of video-assisted intubation attempts and in 17% of traditional attempts (P<0.01).

Conclusions. The improved rate of successful intubation and the decreased rate of oesophageal intubation support the use of video laryngoscopy for tracheal intubation training.

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Endotracheal intubation using direct laryngoscopy is the standard method for establishing an airway, and a fundamental skill for acute care practitioners. This procedure is difficult to teach in a clinical setting because it is a complex psychomotor skill requiring repetition in order to achieve competency.¹–³ Instructors are limited in their ability to teach and evaluate intubation skills because only one individual can view the larynx during laryngoscopy.⁴ The inability to visualize the trainee’s perspective limits the instructor’s capability to give direct feedback and may contribute to low initial success rates.⁵

Anaesthesia residents training in the controlled setting of the operating theatre have an average intubation success rate of 50% or less during their first 10 attempts. Despite the fact that rapid improvement is seen in the first 20 attempts, after 80 intubations, 18% of residents still need assistance.⁶ The goal of this study was to determine if novice laryngoscopists, coached by experts who have access to the novices’ views, acquire laryngoscopy skills more effectively and with fewer complications than novices trained in the traditional manner.

Methods

Institutional review board (IRB) approval was obtained at two participating sites, a quaternary academic medical centre and an affiliated county medical centre. Novice laryngoscopists, defined as trainees who had performed less than six intubations, were eligible for enrolment in this prospective, randomized, crossover study. The subjects included third and fourth year medical students and
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non-anaesthesia residents. Informed consent was obtained as per local IRB requirements.

All trainees underwent the same anaesthesia clerkship orientation, which included a 20 min introductory airway video (Airway Cam Technologies Inc., Wayne, PA, USA) that described airway anatomy and intubation techniques. This was followed by supervised orotracheal intubation practice on a manikin. Enrolled trainees were randomized in blocks of six to one of the two groups: Group V/T or Group T/V. Trainees in Group V/T attempted intubations with video-assisted instruction on Patients 1 through 3, followed by intubation attempts with traditional instruction on Patients 4 through 6. In Group T/V, the order was reversed (traditional instruction for the first three patients followed by video-assisted instruction for the next three).

All intubation attempts occurred within a several day period on six consecutive patients who met the following criteria: age 12 yr or older, normal neck mobility, <$120\%$ ideal body weight, no history of myocardial ischaemia, and no findings suggestive of increased intracranial pressure. Emergency cases, those requiring rapid sequence induction (modified rapid sequence was acceptable), and those with non-reassuring airway examinations were excluded.

The video Macintosh intubating laryngoscopy system (Karl Storz Co. USA, Culver City, CA, USA), as described in a previous study, was used for all intubation attempts. The videolaryngoscope consisted of a standard laryngoscope modified to incorporate a camera in the handle and a fiberoptic light bundle in the Macintosh blade. The live video images from the tip of the laryngoscope, which were displayed on a TV monitor, approximated the view of the laryngoscopist and allowed the instructor to see the trainee’s view during the video-assisted portion of the study. Tracheal tubes containing a stylet were used during all intubation attempts.

To familiarize attending anaesthesiologists to the videolaryngoscope, a brief orientation was provided before use. In each instance, before the novice’s attempt, the attending anaesthesiologist performed direct laryngoscopy. If the expert’s view was rated Cormack and Lehane grade 1, 2a, or 2b (visualization of the anterior commissure, a portion of the cords, or only the arytenoid cartilages, respectively), the novice was allowed to proceed. All supervisors were instructed to provide standard teaching cues, just as they would normally provide when teaching intubation to novices.

The only difference between the video-assisted and the traditional instruction was whether the instructors had access to the video images. During the video-assisted portion of the study, the trainees received feedback from an instructor using the live video images from the videolaryngoscope; instructors could use the monitor to confirm the trainee’s progress. During the traditional (non-video-assisted) part of the study, the video images were not available to the instructor (a drape was used to cover the monitor screen); instructors had to peer over the trainee’s shoulder to see the view.

Throughout the study, trainees did not have access to the video images; their laryngoscopy and intubation were guided by their view of the glottic opening and the instructor’s feedback. At all times, trainees received instructor assistance based on standard cues, which included guidance on body and hand positioning, laryngoscope placement, and anatomic landmarks. The instructors corrected patient positioning as needed. Trainees were allowed a maximum of 2 min for each intubation attempt.

All laryngoscopies were video recorded, reviewed, and reconciled to data sheets collected in the operating theatre. Two anaesthesiologists (M.B.K. and R.H.S.) blinded to the identity of the laryngoscopist (instructor or novice) independently graded all laryngoscope views using the Cormack and Lehane expanded grade scale and a second scale which rated the maximum per cent (by quartile) of vocal cords visualized. The quality of the instructor’s view was compared with the novice’s view in the same patient. The videotaped images were analysed for intubation success or failure, the primary outcome, and for the secondary outcomes such as oesophageal intubation, epiglottic lift, malposition of the blade (blade too deeply inserted or off the midline), evidence of minor trauma (any mucosal blood), number of tube insertions, and duration of the attempt.

Successful intubation was defined as the presence of end-tidal CO$_2$ after tracheal tube placement. Failure to intubate was defined as the inability to correctly place the tracheal tube after an attempt. Oesophageal intubation was recognized by clinical findings in the operating theatre and confirmed by visualization of the tracheal tube in the oesophagus on the video. All cases of oesophageal intubation were promptly corrected.

Laryngoscopy time was measured from the insertion of laryngoscope blade to the insertion of tracheal tube into the mouth. Tube placement time began with the insertion of the tracheal tube and ended with withdrawal of the laryngoscope blade. Each passage of the tracheal tube was considered an insertion attempt. The total time of the attempt was defined as the sum of the laryngoscopy time and the tube insertion time.

An independent statistical consultant performed data analysis. A logistic regression model with a random novice effect was used for binary outcomes to assess the impact of video-assisted instruction, period (first three vs last three patients), and order (V/T vs T/V). The effects of video-assisted instruction, period, and order on continuous outcomes were assessed using repeated measure analysis of variance. Observed variables were censored data if procedures were halted or interrupted before completion. The censored continuous outcomes—insertion time and total attempt time—were evaluated using a Tobit analysis of variance model with a random novice effect. The non-censored continuous outcomes, including number of tube insertions and time from start to tube insertion, were assessed by a linear analysis of variance model with a random novice effect, which is equivalent to a repeated measure crossover
model. The agreement between expert and novice views was assessed with simple and weighted kappa statistics. $P \leq 0.05$ was considered statistically significant.

The sample size was computed for intubation success, the primary outcome. Our pilot data led us to expect at least a 13% difference in intubation success between video-assisted and non-assisted instruction. Assuming six patients (intubations) per novice, a sample size of 34 novices and $34 \times 6 = 204$ patient-intubations provided 80% power under our repeated measure (paired) logistic model allowing for correlated observations among patients for the same novice. There was no attempt to control the type 2 error beyond the nominal $P < 0.05$ for the secondary outcomes.

Results

Thirty-seven novice trainees attempted intubation on 222 patients. Seventy per cent of the subjects were third year medical students, 19% were fourth year medical students, and 11% were non-anaesthesia residents. Prior intubation experience was similar in each group; subjects in both groups had a mean of 1.6 intubation attempts before study enrolment, and six subjects in each group had performed between three and five intubations (Table 1). Some of the data (six of 222; three in each group) were incomplete due to distortion of recorded images or inability to capture video, leaving 216 intubations for complete analysis.

Sixty-nine per cent of intubation attempts were successful when video-assisted instructions were provided, whereas 55% were successful using traditional instruction methods (Table 2, $P = 0.04$). Oesophageal intubation occurred in 3% of intubation attempts during video-assisted instruction and 17% of attempts during traditional instruction (Fig. 1, $P < 0.01$). When period and order were accounted for, this difference remained significant ($P < 0.01$). Mucosal blood was present in 8% of intubation attempts during video-assisted instruction and 15% of intubation attempts during traditional instruction ($P = 0.17$). The incidence of direct epiglottic lift did not differ based on type of instruction. During video-assisted instruction, trainees were less likely to malposition the laryngoscope blade than when receiving traditional instruction (43.1% vs 57.1%, respectively), though this difference did not reach statistical significance ($P = 0.06$).

The mean laryngoscopy time was 41 s during video-assisted instruction and 39 s with traditional instruction ($P = 0.33$). Mean tube insertion time was 34 s with video assistance and 33 s without ($P = 0.44$). Subjects averaged four tracheal tube passages per attempt ($P = 0.72$). Mean total time of attempt was 76 s with and without video assistance ($P = 0.72$).

As shown in Table 2, the improvement in intubation success rate with video-assisted instruction was nearly identical regardless of order (video-assisted first vs traditional instruction first). However, period (or training) effects were observed in the trauma rate and laryngoscopy time: mucosal blood was present in an average of 17% of attempts on Patients 1–3 and 7% of attempts on Patients 4–6, though this failed to reach statistical significance ($P = 0.06$); mean laryngoscopy time was 47 s in Patients 1–3 and 33 s in Patients 4–6 ($P = 0.02$).

The Cormack and Lehane grades for the best view were similar between instructor and novices in the video and the traditional groups (89% and 90% agreement respectively, $P = 0.80$). The experts viewed more of the vocal cords (based on a quartile grading scale) compared with novices; however, the difference was not statistically significant.
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Discussion

Video-assisted feedback improved novices’ ability to successfully perform tracheal intubations in this prospective crossover trial. When videolaryngoscopy images were accessible to the instructors, subjects were more successful than when video-assisted instruction was withheld. The 14% improvement in success rate with video-assisted instruction is clinically significant to the trainee, the instructor, and the patients. Previous studies have shown that novices have a 90% chance of successful intubation after 47–57 intubation attempts.\(^6,^9\) Our results suggest that video-assisted instruction may shorten the time required to reach this level of competency.

The degree of improvement observed was attributed to the improved instructor interaction with the trainee as a result of the instructors’ use of the video image to guide the trainee. The improved success was not due to the trainees’ use of the video image, as the trainees did not have access to the video display. We intentionally did not allow trainees to view the video images because under most circumstances, they will not have access to a videolaryngoscope.

The video image afforded the instructor several advantages. Perhaps most importantly, the images allowed the instructor to make timely corrective suggestions to the novice during the course of the procedure. Specifically, the instructor was able to confirm the identity of the landmarks, to encourage the trainee to pass the tracheal tube at the appropriate time, and to direct the course of the tracheal tube towards the glottic opening. Each of these important manoeuvres, which must be performed in sequence, is impossible for the instructor to assess without access to the laryngoscopists’ view. In the traditional method of teaching intubation, it is often difficult to simultaneously achieve a view of the glottis for the instructor and trainee. Additionally, knowledge of the laryngoscopists’ view reassures the instructor that the intubation attempt was safe and atraumatic, and that the attempt is proceeding appropriately, avoiding the sense of uncertainty that is frequently encountered using traditional methods. In the event that the novice’s first attempt was not successful, an awareness of the landmarks encountered helps the instructor assess whether another attempt by the novice is warranted.

The decreased frequency of oesophageal intubations during the video-assisted portion of the study (3% vs 17% with traditional instruction) is statistically and clinically significant. Although an oesophageal intubation is unlikely to lead to a negative patient outcome if it is readily recognized, an oesophageal intubation typically leads to a termination of the trainee’s intubation attempt, which impedes learning.

There was no difference in laryngoscopy time, tube insertion time, or total intubation times based upon instruction techniques. The lack of difference in procedure length is probably attributable to the novices’ lack of experience with the psychomotor aspects of the procedure, which was unable to be overcome by any degree of instructor input. The incidence of minor trauma during the procedure was lower in the video-assisted portion of the study, but was not statistically significant. Although the complications tracked in this study are unlikely to lead to long-term morbidity, they are markers for a less effective technique and can be disconcerting to the instructor, which can cause the instructor to usurp the procedure and end the trainee’s learning opportunity.

Interestingly, the comparison of view quality between the instructors and the subjects, as assessed by Cormack and Lehane grade, showed no statistical difference. The reason for this is unclear, but probably related to the screening method used for patient selection, which excluded patients with airway anatomy known to be associated with difficult intubation. Another possible explanation is that instructors viewed their laryngoscopy merely as a screening exam to assess whether the patient met study inclusion criteria, and that efforts to obtain an optimal view were sacrificed to save time.

The main limitation to our study was the inability to control the number of attending anaesthesiologists who served as instructors. Maintaining a small pool of instructors was not feasible due to the use of two sites, varying work schedules and the logistics of patient selection. This may have added variability to the instructor views and their feedback. Although instructors with superior teaching abilities could have been overrepresented in the video portion of the study, this is unlikely due to the random assignment of instructors and the large instructor group size, which was similar for both study arms (mean number of instructors: 4.4 for video-assisted, 4.1 for traditional). Moreover, the use of multiple instructors is representative of training in the clinical environment. All instructors were faculty who routinely teach tracheal intubation; however, none of the instructors used videolaryngoscopy routinely before the study. The observed effect size would most likely have been larger if the instructors had been more familiar with video-assisted instruction.

The use of videolaryngoscopes with specialized, angulated blades has been shown to improve intubation success rates in specific populations with difficult airways such as paediatrics, the morbidly obese, and patients requiring cervical immobilization.\(^10\)–\(^13\) Although videolaryngoscopes with standard Macintosh blades have been used as an aid in managing difficult intubations,\(^7\) its utilization for teaching novices is less well studied. One of the earliest investigations was a study by Hung and colleagues\(^14\) that compared video and traditional teaching methods for teaching intubation using a standard fibreoptic bronchoscope attached to a standard laryngoscope. The device described by Hung and colleagues was assembled on site using tape to attach a flexible bronchoscope to a laryngoscope blade. Although the authors acknowledged that their setup occasionally led to obstructed views due to displacement of the fibreoptic bronchoscope during the procedure, their study did show a higher rate of successful intubation through the use of videolaryngoscopy.
Our study used a videolaryngoscope that is commercially available and provides a reproducible view.

Low and colleagues used a commercially available videolaryngoscope to teach laryngoscopy on manikins, then assessed the quality of the instruction using manikins. They found no difference in novices’ intubation success rate when video-assisted instruction with a videolaryngoscope (84%) was compared with traditional instruction with a conventional laryngoscope (87%) in standard manikins with normal airways. Intubation success rates of >80% for novices are uncommon in actual patients, calling into question the generalizability of this manikin study.

Konrad and colleagues and Mulcaster and colleagues generated a learning curve for intubation, and both noted a mean success rate of about 45% after 10 attempts. After only three attempts with video-assisted instruction, trainees in our study showed a 69% success rate, implying that videolaryngoscopy could potentially decrease the learning curve and shorten the time needed for teaching. However, as we did not specifically address the number of attempts required to achieve competence, a study with more intubation attempts per trainee would be needed to definitively support this conclusion.

Although our study yielded results favouring videolaryngoscopy, the use of this equipment may not be feasible in all training locations due to the added cost and decreased portability of the videolaryngoscopy equipment when compared with a standard laryngoscope. The extra time required for setup and cleaning adds to the cost and can prolong the procedure. Although we considered the fiberoptic bundle unobtrusive, others may disagree. The ability to record the event and subsequently review the tape with the learner was considered unique and helpful.

The goal of instruction is to lead to increased proficiency. The use of video-assisted instruction for tracheal intubation training furthers this goal. It enhances learning, increases proficiency, and minimizes patient risks. The introduction of a videolaryngoscopy system should be considered at academic centres and sites that provide airway management training. As the cost decreases and the portability of videolaryngoscopy equipment when compared with a standard laryngoscope increases proficiency, and minimizes patient risks. The intubation training furthers this goal. It enhances learning, and minimizes patient risks. The use of video-assisted instruction for tracheal intubation further improves the initial intubation success rates of paramedic trainees in an operating room setting.

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