J Anesth (2011) 25:721–726
DOI 10.1007/s00540-011-1205-5

ORIGINAL ARTICLE

Fiberoptic-guided tracheal tube placement through the air-Q® Intubating Laryngeal Airway: a performance study in a manikin

Richard E. Galgon · Kristopher M. Schroeder · Christopher S. Schmidt · Adrian A. Matioc · Seungbong Han · Adin-Cristian Andrei · Aaron M. Joffe

Received: 2 May 2011 / Accepted: 1 July 2011 / Published online: 29 July 2011

Abstract
Purpose This study characterizes the performance and success rate for fiberoptic-guided tracheal tube placement through the air-Q® Intubating Laryngeal Airway (air-Q).
Methods Using a manikin, anesthesia trainees and staff anesthesiologists, experienced in fiberoptic-guided intubation, performed five consecutive fiberoptic-guided tracheal tube placements via the air-Q. Participant characteristics, procedure segment times, total procedure times, and observed failures were recorded. Linear mixed effect models with random slopes and intercepts were used to assess participant performance.
Results Ten anesthesia trainees and ten staff anesthesiologists participated. Anesthesia trainees were younger and had practiced for fewer years compared to staff anesthesiologists. Gender was equally distributed between the groups. Both segmental and overall procedure times decreased from the first to the fifth trial among all participants, independent of experience level and gender. Overall mean procedure time decreased from 102 ± 31 to 68 ± 14 s, representing a relative time reduction of 33% and a mean time difference of 34 s [95% confidence interval (CI) 22–47 s; $p < 0.0001$]. Tracheal tube placement was successful in all attempts; however, three tracheal tube dislodgements occurred during air-Q removal (overall procedure success 97%).
Conclusions Fiberoptic-guided tracheal tube placement through the air-Q can be performed in a clinically acceptable period of time with high success by operators skilled in fiberoptic-guided intubation. Tracheal tube dislodgement during air-Q removal remains a potential risk that should be emphasized.

Keywords air-Q · Supraglottic airway · Manikin study

R. E. Galgon (✉) · K. M. Schroeder · C. S. Schmidt · A. A. Matioc
Department of Anesthesiology,
University of Wisconsin School of Medicine and Public Health,
600 Highland Ave. B6/331, Madison,
WI 53792-3272, USA
e-mail: galgon@wisc.edu

S. Han · A.-C. Andrei
Department of Biostatistics and Medical Informatics,
University of Wisconsin School of Medicine and Public Health,
Madison, WI, USA

A. M. Joffe
Department of Anesthesiology and Pain Medicine,
Harbor View Medical Center, University of Washington,
Seattle, WA, USA

Introduction

Placement of supraglottic airways (SGAs) is an integral part of current difficult airway algorithms, as SGAs can bypass upper airway obstruction and/or act as a conduit for intubation [1, 2]. Multiple SGAs are now available. Use of any particular SGA in this situation may very well be life-saving; however, features unique to a particular device may superimpose limitations on direct tracheal tube placement [3].

The air-Q® Intubating Laryngeal Airway (air-Q; Mercury Medical, Clearwater, FL, USA) is a newer SGA available in four polyvinyl chloride (PVC)-based, disposable sizes (1.5, 2.5, 3.5, and 4.5) and three silicone-based, reusable sizes (2.5, 3.5, and 4.5). Notable features of the air-Q are its larger internal diameter (ID) airway tube, which is 2–3 cm shorter than that of the LMA-Classic™ (LMA North America, San Diego, CA, USA), a removable 15-mm circuit adapter, and a dedicated removal stylet

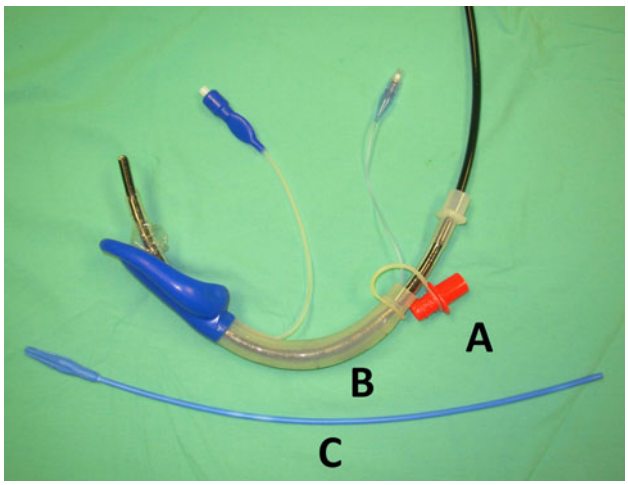

Fig. 1 air-Q® Intubating Laryngeal Airway (ILA) unique features. Fiberoptic scope and 7.0 endotracheal tube (ETT) through 3.5 air-Q®. **a** Removable 15-mm circuit connector. **b** Shorter, larger internal diameter (ID) airway tube. **c** Dedicated removal stylet

(Fig. 1). These features overcome the limitations on direct tracheal tube placement imposed by other SGAs and allow coaxial placement of standard tracheal tubes up to 8.5-mm ID directly through the device. In contrast to the LMA-Fastrach™ (LMA North America), which has a rigid airway tube limiting its use as a primary airway device for any length of time [4, 5], the air-Q can be left in situ after coaxial tracheal tube placement for later use as a primary airway device upon extubation, replacing the Bailey maneuver [6].

Blind placement of tracheal tubes through the air-Q was recently characterized [7]; however, fiberoptic-guided tracheal tube placement through the device was not studied. Insofar as visualization of the airway using a fiberoptic scope for intubation when the situation allows is preferable to a blind technique, as it provides visual confirmation of correct tracheal tube position in the airway, this represents a gap in our knowledge regarding the most efficacious way to use the air-Q as an intubation conduit.

Thus, the primary purpose of our study was to characterize the performance of fiberoptic-guided tracheal tube placement through the air-Q as a technique for using the device as an intubation conduit by observing the procedural time and success rates of the procedure on repeated attempts.

Materials and methods

The University of Wisconsin Health Sciences Minimal Risk Review Board exempted this study. Written informed consent was obtained from all participants. Both senior level anesthesia trainees and staff anesthesiologists experienced in the use of SGAs and fiberoptic-guided intubation through a laryngeal mask airway, but naïve to use of the air-Q, were invited to participate. Each subject's gender, professional status, and years of training or practice were recorded. Subjects unwilling to provide informed consent and those having a financial interest or relationship with the study device manufacturer were excluded.

All intubations were performed on an Airsim™ Advance airway management trainer (Trucorp, Belfast, Ireland) with the tongue equilibrated to atmospheric pressure and the head maintained in neutral position, through a size 3.5, reusable air-Q. The size 3.5 air-Q was chosen as this size fit best in the manikin during pilot testing. The study procedure consisted of three individually timed steps. Step 1 involved placement of the air-Q in the manikin using the manufacturer's recommended placement technique. This step started when the participant picked up the air-Q and concluded with correct placement confirmation observed by inflation and deflation (ventilation) of the manikin lung after connection of the air-Q to an anesthesia machine circuit (time 1). Specifically, with the air-Q cuff fully deflated, the device was inserted into the manikin mouth between the base of the tongue and palate. A jaw lift was performed and the device was advanced inwardly and rotated forward following the curve of the airway tube until a firm stop was encountered. Ten milliliters of air were then placed in the air-Q cuff and the device was connected to the anesthesia circuit. Step 2 involved fiberoptic-guided tracheal tube placement through the air-Q. This step started with disconnection of the anesthesia circuit from the air-Q. Following disconnection, the 15-mm circuit adapter was removed. A cuffed, 7.0-mm ID tracheal tube (Mallinckrodt, Hazlewood, MO, USA) was then placed into the airway tube to a depth of 18 cm. A 4.9-mm outer diameter (OD) fiberoptic scope (Pentax FB-15V; Pentax Medical, Montvale, NJ, USA) was advanced through the tracheal tube and guided through the manikin vocal cords. The tracheal tube was advanced over the fiberoptic scope and into visualized position above the carina. Step 2 concluded with removal of the fiberoptic scope and correct tracheal tube placement confirmation observed by inflation and deflation of the manikin lung (time 2). Step 3 involved removal of the air-Q over the tracheal tube. This step started with disconnection of the tracheal tube from the anesthesia circuit and removal of the tracheal tube 15-mm connector. A #1 ILA Removal Stylet (Mercury Medical) was inserted in the proximal end of the tracheal tube. While stabilizing the tracheal tube, the air-Q was withdrawn over the tracheal tube and stylet. The stylet was then removed, the tracheal tube connector reinserted, and the tracheal tube connected to the anesthesia circuit. Confirmation of maintenance of correct tracheal tube placement was confirmed by observation of inflation and deflation of the manikin lungs (time 3).

Table 1 Participant demographics

	Entire cohort ($n = 20$)	Anesthesia trainees ($n = 10$)	Staff anesthesiologists ($n = 10$)	P
Age (years)	40 ± 11	33 ± 4	48 ± 10	<0.001
Male gender (%)	60	60	60	1.000
Years practice/training	8 ± 9	3 ± 1	14 ± 10	0.008

Data are mean ± SD values unless otherwise noted

Statistical significance is p value <0.05

Each study participant completed the study procedures in the absence of other participants. Prior to starting, the study procedure was demonstrated once in a step-wise fashion for each participant and all questions were answered. Participants, however, were not allowed to perform hands-on equipment familiarization or practice the study procedure prior to commencing the study. Once the participant acknowledged an adequate understanding of the study procedure and had no further questions, he or she performed the study procedure five consecutive times. All study procedure segments were timed and the overall procedure time was calculated as the sum of times 1 through 3. All airway devices and the manikin were lubricated with either water-soluble surgical gel (manikin and all outer airway device surfaces) or silicone spray (tracheal tube lumen and fiberoptic scope). air-Q placement failure was defined as the inability to achieve correct device placement after three insertion attempts. One insertion attempt was defined as placement and subsequent full withdrawal of the air-Q from the mouth of the manikin. Manipulation of the air-Q (e.g., an up–down maneuver) to achieve correct placement without withdrawing it from the mouth of the manikin was allowed. If air-Q placement failure, tracheal tube dislodgement, or inability to ventilate through the tracheal tube after successful air-Q placement occurred, the procedure was halted and recorded as a trial failure. If a trial failure was recorded, the trial was immediately halted and the participant moved onto the next trial attempt until five trials or trial attempts were completed.

The primary study endpoint was overall procedure time. During pilot testing, we observed a mean ± SD trial 1 procedure time of 80 ± 15 s. Assuming a 10% relative time reduction for each subsequent trial, we calculated a required sample size of 6 participants ($\alpha = 0.05$, $\beta = 0.20$) to be able to detect the resultant difference between the first and fifth trial attempts. We increased the sample size to 20 participants with a goal of enrolling 10 staff anesthesiologists and 10 senior level anesthesia trainees to allow subgroup analyses and capture performance in a wider experience group. Secondary endpoints of the study included air-Q insertion (step 1), fiberoptic-guided tracheal tube placement (step 2), air-Q removal (step 3), and overall procedure (steps 1–3) success rates. Descriptive statistics were used to characterize participant demographics and study endpoint data. Statistical analyses were performed using SAS version 9.1.2 (SAS Institute, Cary, NC, USA). Linear mixed effect models with random slopes and intercepts were used to assess improvement in procedure time on repeated attempts [8]. Adjustments for gender, professional status, and years of training were performed. Log-transformation was used to improve normality. For all tests, statistical significance was defined as a p value of <0.05.

Results

Twenty participants (10 senior level anesthesia trainees and 10 staff anesthesiologists) volunteered to participate and completed all study procedures. Participant demographics are shown in Table 1. As expected, anesthesia trainees were younger and had fewer years of training/practice compared to staff anesthesiologists. Gender was equally distributed between the subgroups.

Per protocol, each study participant attempted the study procedure five times. Segmental and overall procedure times are listed in Table 2. Times decreased from the first to the fifth trial among all participants, independent of experience (anesthesia trainees vs. staff anesthesiologists) and gender (male vs. female). Overall mean procedure time decreased from 102 ± 31 to 68 ± 14 s with a corresponding relative reduction of 33% and a mean difference of 34 s [95% confidence interval (CI) 22–47 s; $p < 0.0001$]. The majority of improvement in overall procedure time occurred during trials 1 through 3 and was attributable to shortened times occurring during steps 2 and 3 (fiberoptic-guided tracheal tube placement and air-Q removal) compared to step 1 (air-Q placement) (29 ± 27 vs. 3 ± 4 s, $p = 0.002$).

Segmental and overall procedure success rates are shown in Table 3. No failures occurred during air-Q placement (step 1) or fiberoptic-guided tracheal tube placement through the air-Q (step 2). All air-Q placements were successful on the first attempt. Tracheal tube dislodgement, leading to inability to ventilate, occurred in three instances when air-Q removal over the tracheal tube was attempted (step 3), yielding a 97% overall procedure

Table 2 Segmental and overall procedure times

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	*P*
Step 1	12 ± 4	10 ± 2	10 ± 3	10 ± 2	10 ± 3	0.012
Step 2	56 ± 20	46 ± 12	41 ± 11	40 ± 12	36 ± 8	<0.0001
Step 3	32 ± 15	29 ± 9	24 ± 6	23 ± 9	22 ± 6	0.0001
Overall procedure	102 ± 31	85 ± 19	75 ± 16	72 ± 18	68 ± 14	<0.0001

Data are seconds (mean ± SD)

Step 1, time for air-Q insertion; step 2, time for fiberoptic-guided tracheal tube placement through the air-Q; step 3, time for air-Q removal over the tracheal tube

Overall procedure = sum of times for steps 1, 2, and 3

p values are for differences between trials by linear mixed effect models with random slopes and intercepts with log-transformation to improve normality

Table 3 Segmental and overall procedure success rates

	Step 1	Step 2	Step 3	Overall procedure
Anesthesia trainees	50/50 (100%)	50/50 (100%)	48/50 (96%)	48/50 (96%)
Staff anesthesiologists	50/50 (100%)	50/50 (100%)	49/50 (98%)	49/50 (98%)
Entire cohort	100/100 (100%)	100/100 (100%)	97/100 (97%)	97/100 (97%)

Data are proportions (%)

Step 1, air-Q insertion; step 2, fiberoptic-guided tracheal tube placement through the air-Q; step 3, air-Q removal over the tracheal tube

Overall procedure = steps 1–3

success rate. The lower 95% confidence limits for the overall procedure success rates for anesthesia trainees, staff anesthesiologists, and the entire cohort were 91, 94, and 94%, respectively.

Discussion

The main finding of our study is that fiberoptic-guided tracheal tube placement through the air-Q can be performed in a clinically acceptable period of time with high success when tested in our simulation model. In addition, repeated use of the technique leads quickly to an improvement in overall procedure time, independent of experience (anesthesia trainees vs. staff anesthesiologists) and gender (male vs. female).

Compared to blind tracheal tube placement, the use of fiberoptic guidance may improve intubation success through the air-Q with a similar time improvement profile and overall procedure time. Wong et al. [7] studied blind tracheal tube placement through the air-Q in a manikin by anesthesiologists, fellows, and residents, and found a decrease (92.6 ± 22.7–60.8 ± 16.3 s) in overall procedure time over five consecutive attempts, similar to our findings, but observed a lower tracheal tube placement success rate. More than one in ten (34/325) blind intubation attempts resulted in failure due to esophageal intubation. We did not record any tracheal tube placement failures in our study using fiberoptic guidance. We did, however, observe three tracheal tube dislodgements during air-Q removal over the tracheal tube. This rate (3%) is similar to the 2% (6/291) rate reported by Wong et al. [7]. Two of the three tracheal tube dislodgements occurred during trial 1 and the third dislodgement occurred during trial 3. Whether these events occurred due to device handling unfamiliarity, participants hurrying to improve their time, or some other unknown effect is difficult to say as the participants were not questioned directly regarding the failures. Nonetheless, this is an important observation as it highlights a persistent, clinically relevant, potential procedure failure mode, as seen in our study and that of Wong and colleagues.

Of note, we used identical definitions for segmental and overall procedure times, but a slightly different simulation model than Wong and colleagues. Their model employed a Laerdal airway management trainer (Laerdal Medical, Wappinger Falls, NY, USA) and a size 4.5, first-generation version of the air-Q, whereas we used an Airsim™ airway management trainer and a smaller size 3.5, second-generation, silicone-based reusable air-Q, which incorporates a slight increase in height of the posterior cuff compared to the first-generation device [9], a distal intubation ramp, and a built-in bite block. Thus, while our methodology was quite similar and provides a reasonable basis for comparison [10–12], it was not identical. Although differences in

the devices, manikins, and operator experience [13, 14] may contribute to the lower success rate for blind intubation, we believe the improvement in tracheal tube placement success seen in our study is attributable to the ability to negate trajectory misalignments between the air-Q airway tube and glottic opening with fiberoptic scope advancement under visualization, followed by advancing the tracheal tube over the fiberoptic scope. As mentioned above, we used a 7.0-mm ID tracheal tube over a 4.9-mm OD fiberoptic scope, which produced a very small (approximately 2 mm) combination mismatch. Tracheal tube/fiberoptic scope combinations with a larger mismatch allow more wobble and may produce difficulties in advancing the tracheal tube over the fiberoptic scope due to hang-up on the posterior arytenoids, as seen with Eschmann stylet use.

Our study has several limitations. First, it was performed in a manikin with a routine airway, which is advantageous for assessing the procedure performance characteristics and success rate under consistent airway conditions, but may not reflect the true performance characteristics and success rate in clinical practice, where patient anatomy and airway conditions (e.g., blood, secretions, edema) vary and generally prolong times required to achieve tracheal intubation. As such, our results may overestimate the procedure performance characteristics and success rate for clinical practice, where longer procedure times and additional experience may be observed and required to attain similar results. Second, we did not ensure optimal air-Q placement in relation to the glottic opening prior to each tracheal tube placement attempt. Thus, our results may have been affected by suboptimal air-Q placement. If so, however, we believe this effect is likely to be small in our study, as our experience with the manikin suggests the device generally follows the same path during insertion. Suboptimal air-Q placement, if it occurred, would better simulate the variance of actual clinical conditions, where device positioning in relation to the glottis varies with patient characteristics. Third, the participants in our study were experienced with fiberoptic scope use and so our results may not reflect the performance of operators less experienced in fiberoptic scope use. Lastly, based on pilot testing we selected a size 3.5, reusable air-Q as a best fit for our manikin. Thus, our model represents a best case scenario to ensure a maximum rate of successful intubations, but may have limited applicability to actual clinical use, where choosing the appropriate device size may be less clear and where suboptimal device selection may negatively impact the fiberoptic-guided tracheal tube placement success rate. Early clinical results shed some light here though. We previously reported our initial experience using the air-Q as an everyday airway device and intubation conduit, finding median airway leak pressures of 25 and 30 cmH_2O for the single-use and reusable devices, respectively, and successful fiberoptic-guided tracheal tube placement in 12/13 (92%) cases of anticipated and unanticipated difficult airways [15]. Blind intubation after two attempts has also recently been reported to be successful in over 75% of healthy adult elective surgical patients. Using fiberoptic guidance to facilitate a third attempt increased the overall success rate to 95% [16].

In summary, we performed a prospective study using a simulation model to characterize the performance of fiberoptic-guided tracheal tube placement through the air-Q as a technique for using the device as an intubation conduit. We found the technique can be performed in a clinically acceptable period of time with high success by operators skilled in fiberoptic scope use, but naïve to use of the air-Q. Visualization and guidance provided by the fiberoptic scope likely led to the improved tracheal tube placement success rate compared to the use of a blind technique. Tracheal tube dislodgement during air-Q removal remains a potential danger and clinicians using the device should be made aware of this. Preliminary results of our technique in patients are encouraging; however, additional clinical investigation is warranted to corroborate our findings further.

Acknowledgments We are grateful to the anesthesia trainees and staff anesthesiologists of the Department of Anesthesiology, University of Wisconsin School of Medicine and Public Health, for their participation, without which, this study would not have been possible. This research was supported by intradepartmental funding.

Conflict of interest Adrian A. Matioc has received royalties from King Systems for the ergonomic face mask product.

References

1. Henderson JJ, Popat MT, Latto IP, Pearce AC. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. Anaesthesia. 2004;59:675–94.
2. ASA Task Force on Difficult Airway Management. Practice guidelines for management of the difficult airway—an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology. 2003;98:269–77.
3. Asai T, Latto IP, Vaughan RS. The distance between the grille of the laryngeal mask airway and the vocal cords—is conventional intubation through the laryngeal mask airway safe? Anaesthesia. 1993;48:667–9.
4. Brain AIJ, Verghese C, Addy EV, Kapila A. The intubating laryngeal mask. I: development of a new device for intubation of the trachea. Br J Anaesth. 1997;79:699–703.
5. Brain AIJ, Verghese C, Addy EV, Kapila A, Brimacombe J. The intubating laryngeal mask. II: a preliminary clinical report of a new means of intubating the trachea. Br J Anaesth. 1997;79:704–9.
6. Nair I, Bailey PM. Use of the laryngeal mask for airway maintenance following tracheal extubation. Anaesthesia. 1995;50:174–5.
7. Wong DT, Apichatibutra N, Woo JA, Venkat Raghaven L. Repeated attempts improve tracheal tube insertion time using the

intubating laryngeal airway in a mannequin. J Clin Anesth. 2010;22:619–24.
8. Lindstrom MJ, Bates DM. Newton–Raphson and EM algorithms for linear mixed-effects models for repeated-measures data. J Am Stat Assoc. 1988;83:1014–22.
9. Joffe AM, Galgon RE, Liew EC. The air-Q, old or new? Anaesth Intensive Care. 2010;38:952–3.
10. Cook TM, Green C, McGrath J, Srivastava R. Evaluation of four airway training manikins as patient simulators for the insertion of single use laryngeal mask airways. Anaesthesia. 2007;62:713–8.
11. Silsby J, Bayley G, Cook TM. Evaluation of four airway training manikins as simulators for inserting the LMA Classic™. Anaesthesia. 2006;61:576–9.
12. Jackson KM, Cook TM. Evaluation of four airway training manikins as patient simulators for the insertion of eight types of supraglottic airway devices. Anaesthesia. 2007;62:388–93.
13. Hodzovic I, Petterson J, Wilkes AR, Latto IP. Fibreoptic intubation using three airway conduits in a manikin: the effect of operator experience. Anaesthesia. 2007;62:591–7.
14. Hodzovic I, Janakiraman C, Sudhir G, Goodwin N, Wilkes AR, Latto IP. Fibreoptic intubation through the laryngeal mask airway: effect of operator experience. Anaesthesia. 2009;64:1066–71.
15. Joffe AM, Liew EC, Galgon RE, Viernes D, Treggiari MM. The second-generation air-Q® intubating laryngeal mask for airway maintenance during anaesthesia in adults: a report of the first 70 uses. Anaesth Intensive Care. 2011;39:40–5.
16. Karim YM, Swanson DE. Comparison of blind tracheal intubation through the intubating laryngeal mask airway (LMA Fastrach™) and the Air-Q™. Anaesthesia. 2011;66:185–90.