

Cervical Spine Motion

A Fluoroscopic Comparison of the AirTraQ Laryngoscope versus the Macintosh Laryngoscope

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Background: The optimal technique to intubate the trachea in patients presenting with a potential or documented cervical spine (C-spine) injury remains unresolved. Using continuous fluoroscopic video assessment, C-spine motion during laryngoscopy with an AirTraQ Laryngoscope® (King Medical Systems, Newark, DE) was compared to that with intubation using a Macintosh blade.

Methods: Twenty-four healthy surgical patients gave written consent to participate in a crossover randomized controlled trial; all patients were subjected to both Macintosh and AirTraQ laryngoscopy with manual inline stabilization after induction of anesthesia. The C-spine motion was examined at four areas: the occiput-C1 junction, C1-C2 junction, C2-C5 motion segment, and C5-thoracic motion segment. The time required for laryngoscopy was also measured.

Results: C-spine motion using the AirTraQ was less than that during Macintosh laryngoscopy, averaging 66% less ($P < 0.01$) at three of the motion segments studied, occiput-C1, C2-C5, and C5-thoracic. There was no difference at the C1-C2 segment. There was no significant difference in the time to accomplish laryngoscopy between the two devices.

Conclusions: For patients in whom C-spine movement is undesirable, use of the AirTraQ Laryngoscope® may be useful to limit movement without an increase in the duration of intubation.

THERE is potential for spinal cord damage during tracheal intubation whenever the cervical spine (C-spine) is unstable¹⁻³. A previous study demonstrated that maximal C-spine movement occurs during intubation, as opposed to the movement observed with careful bag-mask ventilation, making the choice of intubation technique germane.⁴

The AirTraQ laryngoscope® (ATQ; King Medical Systems, Newark, DE) has features that may be advantageous for managing patients with unstable C-spine injuries. It is a single-use optical laryngoscope that has a shape similar to that of a Bullard laryngoscope⁵ (Gyrus Acmi Inc, Norwalk, OH). To use the ATQ, the endotra-

cheal tube (ETT) is preloaded in a track next to the optical pathway, and the device is inserted into the oropharynx. When the glottis is visualized, the ETT is advanced down the track into the trachea. The ATQ is then removed, disengaging the ETT from the ATQ track with a lateral movement. As a self-contained single-use product that requires minimal setup, the ATQ may have specific applicability to the emergency room and pre-hospital setting.

The topic of C-spine movement during laryngoscopy has been reviewed by Crosby.^{2,3} Recently, studies of the Bonfils® Stylet⁶ (Karl Storz Endoscopy, Culver City, CA) and Shikani Optical Stylet®⁷ (Clarus Medical, Minneapolis, MN) have been published. Only the Trachlight®⁴ (Laerdal Medical Corporation, Wappingers Falls, NY) has been shown to reduce C-spine movement without a significant increase in laryngoscopy duration, but it involves a blind technique. The reduced C-spine movement with the Bullard laryngoscope that was previously shown⁵ suggests potentially reduced C-spine movement with the ATQ, because of the similarity between the two devices with respect to shape and insertion technique. When compared to Macintosh laryngoscopy, the ATQ has demonstrated reduced C-spine movement in women,⁸ but the study conclusions are limited because it examined only a single X-ray in time for each modality and did not include manual in-line stabilization.¹ The ATQ has been shown to be as rapid⁹ as Macintosh laryngoscope (Welch Allyn, Skaneateles Falls, NY) use in the setting of manual in-line stabilization.¹

This prospective randomized controlled crossover trial investigated C-spine movement during tracheal intubation and duration of laryngoscopy, comparing the ATQ *versus* direct laryngoscopy with a Macintosh 3 blade. The C-spine was recorded over the entire time interval by using fluoroscopic video to measure the maximal relative angular displacement of the vertebrae.

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Materials and Methods

Approval for the study was obtained from the University of Western Ontario Health Sciences Research Ethics Board for Research Involving Human Subjects. The trial was registered at ClinicalTrials.gov (NCT00664612). Informed and written consent was obtained from each subject.

Patients enrolled in the study were American Society of Anesthesiologists physical status I-III, age 18-75 yr,

and scheduled for elective noncardiac surgery requiring general anesthesia with tracheal intubation. Exclusion criteria were gastroesophageal reflux disease, body mass index greater than 35 kg/m², possibility of pregnancy, previous neck surgery, unstable C-spine, or known difficult airway. Preoperative clinical assessment of the patients included height, weight, physical status, Mallampati score, dentition, tongue size, thyromental distance, and neck mobility.

While awake, patients were placed on the operating room table with a rigid board beneath them to simulate field spinal precautions or the table on which trauma patients are placed in the emergency department. The patient's head rested on a pillow in a position judged by the patient to be neutral. After verification that the patient was properly centered, the fluoroscopy unit and operating room table remained fixed for the remainder of the study. Standard monitors were placed. After breathing 100% oxygen for 3 min, anesthesia was induced with fentanyl (2–4 µg/kg IV) and propofol (2–3 mg/kg IV). Upon loss of eyelid reflex, paralysis was induced with rocuronium (0.6–0.8 mg/kg IV).

Manual in-line stabilization was provided by an assistant with Advanced Trauma and Life Support¹ certification. Care was taken to avoid obscuring the radiographic landmarks during the fluoroscopy. Study personnel used radiation-resistant surgical gloves and eyewear as well as upper and lower lead aprons with thyroid protection; patients were shielded with lead aprons for areas not under investigation.

After positioning and induction, a sealed opaque envelope containing a computer-generated random assignment was opened, assigning patients to the following groups: group 1, Macintosh laryngoscopy first, followed by ATQ laryngoscopy; group 2, ATQ laryngoscopy first, followed by Macintosh laryngoscopy. All patients underwent laryngoscopy using both techniques. The order of laryngoscopy was randomized to prevent a consistent bias in favor of one group.

After stabilization was completed, the operator ventilated the patient with sevoflurane in 100% oxygen *via* bag and mask until 90 s had elapsed from the administration of rocuronium. To minimize neck extension, a low threshold was adopted for use of an oral airway. Patients then underwent laryngoscopy using both techniques sequentially; intubation was completed as part of the second laryngoscopy. Intubation was not fully completed during the first laryngoscopy, as required by our ethics board to prevent potential trauma of multiple intubations; the distal end of the ETT was advanced just beyond the vocal cords and withdrawn. C-spine movement was recorded with continuous fluoroscopy during both laryngoscopies and intubation; the entire time interval was recorded to capture the maximal extent of C-spine movement.

The ATQ was used according to the instructions provided by the manufacturer, with the distal tip of the ATQ

placed in the vallecula. The large size ATQ was used for men and the small size was used for women. Protraction of the mandible was performed if necessary, but it was minimized in an attempt to limit displacement of the C-spine *via* connecting structures. With both techniques, the operator attempted to minimize neck movement, accepting the first view¹⁰ that offered a reasonable opportunity to adequately position the ETT at the glottic opening. Intubation completed the study; the rigid board was removed, and anesthesia and surgery continued in the usual fashion.

All laryngoscopies were performed by one operator (Dr. Turkstra) to minimize interoperator variability. Before this study, this operator had performed more than 50 intubations with the ATQ and more than 3,000 with the Macintosh blade. The fluoroscopy video monitor was not visible to the operator during the study.

Study Data and Data Analyses

Similar to previous work, fluoroscopy of the C-spine during laryngoscopy and intubation was recorded at four frames per second by a digital video fluoroscopy unit (Series 9800 mobile C-Arm with vascular package and 1 k × 1 k video monitor; GE Medical Systems, Salt Lake City, UT) for review by the radiologist (Dr. Pelz) to assess cervical vertebrae movement.^{4,7} The fluoroscopic video was analyzed using Centricity software (GE Centricity Picture Archiving and Communication System, Version 3.0.4; GE Medical Systems) to determine the duration of laryngoscopy. Duration was defined as the time from when the ATQ or Macintosh blade passed the central incisors to the time when the ETT was positioned just past the vocal cords. If the laryngoscopy sequence took longer than 120 s, it would be deemed a failure.

Using the radiology software, the orientation in the sagittal plane of the occiput and C1 through C5-C7 can be determined at any frame (point in time) in the fluoroscopic video, with a precision of 0.1 degree. The absolute rotation of the occiput or vertebrae in global coordinates was not the focus, but rather the motion of each relative to adjacent vertebrae. (*i.e.*, Trendelenburg rotation of the operating room table would result in global “extension” of all components, but no flexion or extension of the vertebrae relative to one another).

Motion segments were defined by two vertebrae, similar to previous work,^{4,7,11} and denoted M0-1 for Occiput-C1, M1-2 for C1-C2, and M2-5 for C2-C5 (fig. 1). Motion segment M5-T comprised C5 through whatever vertebrae remained stationary on the backboard. The relative angle between the two bones of each motion segment at any point in time was denoted A0-1_{TIME}, A1-2_{TIME}, A2-5_{TIME}, and A5-T_{TIME}.

The reference for the occiput was defined by a line between the base of the sella and the opisthion (fig. 1). The C1 reference was a line between the lower cortical margin of the anterior arch of C1 and the lower cortical

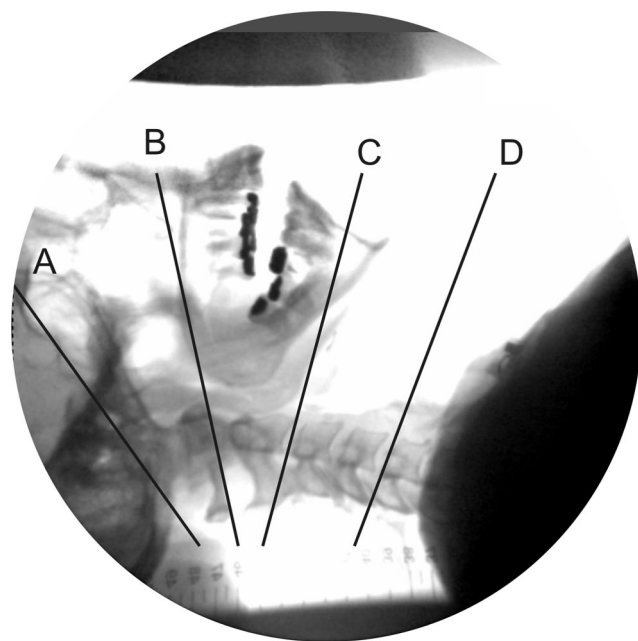


Fig. 1. Vertebral reference lines. The reference for the occiput was defined by a line between the base of the sella and the opisthion (*Line A*). The C1 reference was a line between the lower cortical margin of the anterior arch of C1 and the lower cortical margin of the C1 spinous process (*Line B*). The C2 reference was a line between the anterior, inferior margin of the C2 body and the lower cortical margin of the C2 spinous process (*Line C*). The C5 reference line was a tangent along the superior end-plate of the C5 vertebral body (*Line D*). The Occiput-C1 segment is defined by the angle between *Lines A and B*. The C1-C2 segment is defined by the angle between *Lines B and C*. The C2-C5 segment is defined by the angle between *Lines C and D*. The C5-Thoracic segment is defined by the angle between *Line D* and the global reference.

margin of the C1 spinous process. The C2 reference was a line between the anterior, inferior margin of the C2 body and the lower cortical margin of the C2 spinous process. The C5 reference line was a tangent along the superior endplate of the C5 vertebral body. Stationary vertebrae of Segment M5-T remained fixed relative to the fluoroscopy unit. When necessary, other anatomic landmarks were used by the radiologist, remaining consistent for a given subject. This was acceptable because the study compared the change in the angle of the motion segments, so any consistent landmarks would suffice.

The first frame of each fluoroscopic sequence provided the baseline angles for the motion segments. Viewing the sequence in real time at various speeds and on a frame-by-frame basis, the varying angle of each motion segment was analyzed to determine the maximum change in angle from the baseline values. Extension was arbitrarily defined as positive, and flexion as negative.^{4,8,11} The duration and maximal change for each ATQ laryngoscopy was compared to those with direct Macintosh laryngoscopy at each motion segment, using a repeated measures analysis of variance (ANOVA). Blinding of the radiologist was not feasible, so the fluoroscopic videos were presented to the radiologist in random order.

Statistical Analyses

Using data from the control group of a previous study⁴ and estimation that a 30% reduction in C-spine movement would be clinically relevant, the two-tailed sample size was calculated to be 11 patients for each group ($\alpha = 0.05$, $\beta = 0.20$). Twenty-four patients were recruited to allow for patient dropout and/or potential failure of the fluoroscopic equipment or recording device.

Statistical analysis was conducted using SAS version 9.1 (SAS Institute Inc., Cary, NC). For the study design, all patients received both the Macintosh and the ATQ device in random order. As a crossover study, a repeated measures analysis of variance with one within-subject factor (device) and one between-subject factor¹² (the sequence in which the devices were used) was used to analyze the C-spine movement data. The between-subject factor (sequence) tested for carry-over, *i.e.*, whether the use of one device was affected by previous use of the other device.¹²

Because of the skewed nature of the duration of laryngoscopy data, the median provides an estimate of the center of the distribution, and the interquartile range (IQR) provides a measure of variation.¹³ The IQR is the difference between the upper quartile (Q3) and the lower quartile (Q1). As a result of the crossover trial design, the duration of laryngoscopy data has also been compared using the repeated measures analysis of variance.¹² Kaplan-Meier curves have been used to graphically illustrate the distribution of laryngoscopy duration data for the two treatments.

Results

Twenty-nine patients were invited to participate in the study between January and May of 2008. Of the 29 patients, 5 declined; 24 patients were enrolled and gave written consent. No patients were lost to follow-up; all patients were analyzed in the group to which they were assigned. The patient characteristics are summarized in table 1.

Patients underwent ATQ use and direct Macintosh laryngoscopy in random order, and C-spine motion was

Table 1. Patient Characteristics

Characteristic	Group 1, Macintosh, then AirTraq, n = 13	Group 2, AirTraq, then Macintosh, n = 11
Age, years	48 ± 18	49 ± 15
Height, cm	168 ± 10	171 ± 10
Weight, kg	76 ± 15	80 ± 23
BMI, kg · m ⁻²	27 ± 3	27 ± 8
Gender, male/female	7/6	3/8
Mallampati Score, 1/2	5/8	9/2
TMD (3 fingers)	13 (100%)	11 (100%)
Any upper dentition	11 (85%)	9 (82%)
ASA classification, 1/2/3	2/6/5	2/5/4

Mean ± standard deviation.

ASA = American Society of Anesthesiologists Physical Status; BMI = body mass index; TMD = thyromental distance.

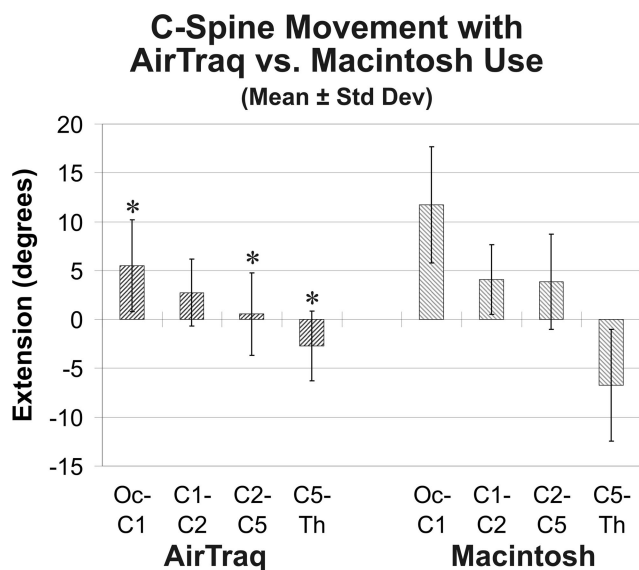


Fig. 2. Mean segmental cervical spine movement with AirTraQ laryngoscope® versus Macintosh use. * $P = 0.008$, 0.009 , and 0.005 , respectively, Oc-C1, C2-C5, and C5-Th. Oc = Occiput, Th = thoracic vertebra.

compared. Segmental C-spine movement using the ATQ was 6 ± 5 degrees, 3 ± 3 degrees, 1 ± 4 degrees, and -3 ± 4 degrees, at the Occiput-C1, C1-C2, C2-C5, and C5-Thoracic motion segments, respectively, versus 12 ± 6 degrees, 4 ± 4 degrees, 4 ± 5 degrees, and -7 ± 6 degrees using the Macintosh blade. Figure 2 shows the distribution of C-spine movement during laryngoscopy with the two techniques. C-spine motion was 53%, 95%, and 60% less during laryngoscopy with ATQ compared to the Macintosh blade at the Occiput-C1, C2-C5, and C5-Thoracic motion segments, respectively (all $P \leq 0.01$). The trend towards 33% reduced movement at the C1-C2 segment was not statistically significant ($P = 0.26$). Two-way ANOVA demonstrated no evidence of device carryover between the crossover sample sets.

There were no laryngoscopy failures using the ATQ or Macintosh blade. The median time required for ATQ laryngoscopy was 8.8 s (IQR 6.7–10.6 s) compared to 12.4 s (IQR 10.2–14.5 s) for the Macintosh, but this result was not statistically significant ($P = 0.32$). To illustrate the distribution of the laryngoscopy duration data, figure 3 shows a Kaplan-Meier plot illustrating the percentage of laryngoscopy completed versus time.

Discussion

The principal finding of this study is that, in healthy individuals with in-line stabilization, there is less C-spine motion with the ATQ in comparison to the Macintosh laryngoscope at the Occiput-C1, C2-C5, and C5-Thoracic motion segments, when the ETT is placed by an experienced operator. On average, C-spine movement was reduced 66% at these segments by using the ATQ versus

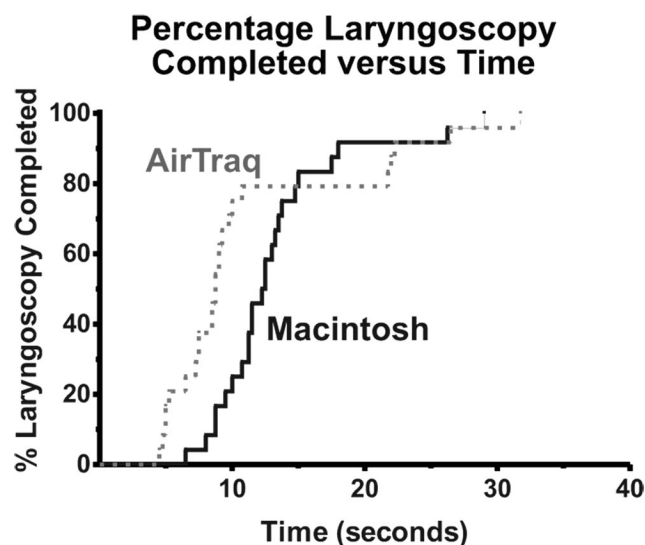


Fig. 3. Percentage of laryngoscopy completed versus time with AirTraQ and Macintosh laryngoscopes; $P = 0.32$.

direct Macintosh laryngoscopy. Thus, the ATQ may be a useful tool for experienced users to intubate patients with an “uncleared” C-spine, particularly if the C-spine injury is suspected in the Occiput-C1, C2-C5, or C5-Thoracic areas of the C-spine. This study agrees in general with previous work,⁸ although that study⁸ did not find a difference at the Occiput-C1 level as well. The significant methodology and measurement technique differences prohibit direct comparison, especially the examination of the entire time interval versus one point in time and the lack of in-line stabilization in the previous study.

There was no significant difference in the duration of laryngoscopy between the ATQ and Macintosh laryngoscopes. There was a trend toward faster intubation using the ATQ; however, even if a larger study were to find a statistically significant finding, the clinical significance of a 4 s difference would be questionable. This suggests that there is no inherent “time penalty” associated with using the ATQ to minimize C-spine movement, similar to the lighted stylet.⁴ It is important to note that this duration data include only equipment use and not equipment set-up time, which might favor Macintosh laryngoscopy in time-critical situations because the ATQ may require 30–60 s to warm the lens and prevent fogging. These data are similar to a previous study that found a statistically significant difference of 7 s favoring the ATQ with a similar sample size.⁹

During direct Macintosh laryngoscopy, the ETT was positioned at the glottic opening while attempting to minimize C-spine movement, which resulted in Cormack and Lehane¹⁰ Grade 1, 2, and 3 views 20%, 70%, and 10% of the time, respectively. During ATQ use, the optical view resulted in a Grade 1 view for 90% of laryngoscopy attempts ($P < 0.0001$). The remaining two patients had a Grade 2 view during ATQ use and a Grade 1 and a Grade 2 view during Macintosh Laryngoscopy. This im-

proved view might be valuable in situations of suspected trauma to the larynx or vocal cords.

The reduction in C-spine movement with the ATQ is similar to that observed in a previous study of the lighted stylet⁴ at segments Occiput-C1, C2-C5, and C5-Th. The ATQ did not reduce C-spine movement at segment C1-C2, unlike the lighted stylet, which did reduce C-spine movement at segment C1-C2.

Although the operator was technically more experienced with the Macintosh blade by approximately two orders of magnitude, the ATQ performed better in terms of minimizing C-spine movement. It is likely that the results still compare reasonably experienced use of both devices; no learning effect was observed in the study data for ATQ use.

To facilitate laryngoscopy, the ideal initial position for the patient's head and neck in the setting of possible C-spine injury has not been standardized.^{2,4,11,14} As a result, patients in different studies may begin with different initial extension and/or flexion of the C-spine. Accordingly, the amount of extension or flexion observed during laryngoscopy will likely be different. For this reason, patients in this study were randomized after positioning to prevent a potential "initial position" bias from influencing the results.

Each patient underwent laryngoscopy twice, but intubation only once. With the first laryngoscopy, the ETT was not fully inserted into the trachea to avoid the potential trauma of multiple intubations, as required by our institution's ethics review board. With initial ATQ and Macintosh use, visualizing the ETT tip just past the cords defined successful placement; identical criteria were used for the second laryngoscopy, all of which proceeded to successful intubation. In addition, the fluoroscopic images were reviewed with "soft tissue windows" (contrast and brightness settings); which confirmed the position of the ETT tip at the glottis for each laryngoscopy.

Cricoid force¹⁵ was not used during this study. There is still some controversy in regard to actual benefit in patients with C-spine injury,^{1,15} and it is the authors' experience that few anesthesiologists would apply cricoid force in the setting of an unstable C-spine. The application of cricoid force was also avoided because it would have involved additional hand X-ray exposure and could potentially obscure areas of interest on fluoroscopy.

A limitation of this study is that healthy patients were examined as a model for C-spine injured patients. It is likely, however, that an intubating technique that reduces C-spine motion in healthy patients may also result in reduced vertebral movement in the setting of an unstable C-spine; the technique may involve less force being applied to the cervical structures. Indirect video laryngoscopy has been shown to employ less force than direct Macintosh laryngoscopy.¹⁶

Although this study examined elective patients in the operating room, the data are perhaps more relevant to

the prehospital setting, where patients with uncleared C-spines could be expected more frequently. In the prehospital setting, the AirTraq has a number of benefits. It is self-contained, it requires no maintenance, and it can be used with minimal setup delay. As a single-use product, the potential for infectious disease transmission is minimized. Also the cost to equip multiple prehospital units would be much lower than other video laryngoscopy devices. However, the per-use cost of this disposable product and potential restocking costs (shelf-life is rated at 3 yr) should not be ignored by potential purchasers.

In conclusion, average C-spine motion was reduced 66% using the AirTraq laryngoscope® as compared to the Macintosh blade in the setting of in-line stabilization (at the Occiput-C1, C2-C5, and C5-Thoracic segments). There was no difference in time to intubation between the two techniques. When used by an experienced operator, the AirTraq laryngoscope® may be beneficial to reduce C-spine movement during tracheal intubation.

The AirTraq® laryngoscopes for this trial were provided by King Medical Systems, Newark, Delaware, for the trial. King Medical Systems had no input with respect to study design or data analysis and provided no financial support.

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