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Cervical Spine Motion: A Fluoroscopic Comparison During Intubation with Lighted Stylet, GlideScope, and Macintosh Laryngoscope

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Abstract

The question of which is the optimum technique to intubate the trachea in a patient who may have a cervical(C)-spine injury remains unresolved. We compared, using fluoroscopic video, C-spine motion during intubation for Macintosh 3 blade, GlideScope®, and Intubating Lighted Stylet, popularly known as the Lightwand or Trachlight®. Thirty-six healthy patients were randomized to participate in a crossover trial of either Lightwand or GlideScope to Macintosh laryngoscopy, with in-line stabilization. C-spine motion was examined at the Occiput-C1 junction, C1-2 junction, C2-5 motion segment, and C5-thoracic motion segment during manual ventilation via bag-mask, laryngoscopy, and intubation. Time to intubate was also measured. C-spine motion during bag-mask ventilation was 82% less at the four motion segments studied than during Macintosh laryngoscopy ($P < 0.001$). C-spine motion using the Lightwand was less than during Macintosh laryngoscopy, averaging 57% less at the four motion segments studied ($P < 0.03$). There was no significant difference in time to intubate between the Lightwand and the Macintosh blade. C-spine motion was reduced 50% at the C2-5 segment using the GlideScope ($P < 0.04$) but unchanged at the other segments. Laryngoscopy with GlideScope took 62% longer than with the Macintosh blade ($P < 0.01$). Thus, the Lightwand (Intubating Lighted Stylet) is associated with reduced C-spine movement during endotracheal intubation compared with the Macintosh laryngoscope.

Endotracheal intubation is frequently required for trauma patients as part of the resuscitative effort ([1]) or for patients with unstable cervical spine (C-spine) requiring surgery ([2]). When the status of the C-spine is unknown or when it is known to be unstable, there is potential for spinal cord damage during intubation ([1–3]). The Macintosh 3 blade is commonly used for direct laryngoscopy; two other methods often used for endotracheal intubation are the Intubating Lighted Stylet or Lightwand (Trachlight®, Laerdal, Armonk, NY) and the GlideScope® (Saturn Biomedical Systems, Burnaby, BC, Canada). These intubating techniques can be performed rapidly and safely and could involve less C-spine movement than direct Macintosh laryngoscopy.

Previous studies have evaluated direct Macintosh laryngoscopy, Bullard laryngoscope, bag-mask ventilation, fiberoptic-guided oral and nasal intubation, esophageal Combitube, Laryngeal Mask Airway, and Intubating Laryngeal Mask Airway with respect to C-spine movement during intubation ([3–9]). Agro et al. ([10]) compared quality of laryngeal view using the GlideScope versus the Macintosh blade, with in-line stabilization provided, but C-spine movement was not assessed. There have been no studies examining C-spine movement associated with GlideScope use.

A study of the Lightwand has examined success rates with C-spine precautions ([11]), but no controlled studies of C-spine movement with use of the Lightwand have been published. Konishi et al. ([12]) examined C-spine movement in 20 healthy patients tracheally intubated using a lighted stylet. This pilot study lacked a control group and used only one static radiograph during Lightwand use, which might not correspond to the maximal C-spine movement.

This prospective, randomized, controlled, crossover trial compared C-spine movement during use of the GlideScope or Lightwand versus direct laryngoscopy with the Macintosh 3 blade. The movement of the C-spine was recorded using fluoroscopic video to determine the maximal angular displacement of the vertebrae. The secondary endpoint was time to accomplish laryngoscopy. The hypothesis was that endotracheal intubation using the Lightwand or GlideScope would result in reduced C-spine movement compared with direct Macintosh laryngoscopy, as determined by fluoroscopic video.

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Methods

Approval for the study was obtained from the University of Western Ontario Health Sciences Research Ethics Board for Research Involving Human Subjects. Informed and written consent was obtained from each subject (Fig. 1).

Figure 1
Image Tools

Inclusion criteria included ASA physical status I–III patients, age 18–75 years old, and elective noncardiac surgery requiring general anesthesia with endotracheal intubation. Exclusion criteria included gastroesophageal reflux disease, body mass index > 35 kg/m^2, possibility of pregnancy, previous neck surgery, unstable C-spine, or difficult airway. Preoperative clinical assessment of the patients included height, weight, ASA physical status, Mallampati score, dentition, thyromental distance, and neck mobility.

Fifty-eight patients were invited to participate in the study between November 2003 and January 2004. Eighteen patients declined or had their surgery postponed prior to randomization. Near the end of the study, the radiology department suffered simultaneous failure of the main and back-up servers, and data for 11 patients were lost. As a result, an additional 7 patients were recruited before analysis, allowing 36 patients to be analyzed in the groups assigned.

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

Manual in-line stabilization was then simulated by taping the patient's head into the Mayfield horseshoe. The head was taped circumferentially around the forehead. This is similar to the accepted technique of taping the head to secure it with sandbags on a backboard ([1]), the aim being to maintain the patient's head in the neutral position and reduce neck movement during bag-mask ventilation and laryngoscopy ([1,2]). This technique of head and neck stabilization was preferable because it avoided x-ray exposure to a person providing stabilization and ensured that the area under study was not obscured by stabilizing hands.

After positioning, sealed envelopes containing computer-generated random assignments were opened, assigning patients to Group 1 (Lightwand and direct Macintosh laryngoscopy) or Group 2 (GlideScope and direct Macintosh laryngoscopy) (Fig. 1). The sealed envelopes also contained computer-generated random assignments to Macintosh laryngoscopy first or investigational technique first. The order of laryngoscopies was randomized in the groups to prevent information obtained by the operator during the first technique from consistently influencing the second technique. Block randomization was used to ensure an equal number of patients in each group.

After stabilization had been 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, we adopted a low threshold for use of an oral airway. Patients then immediately underwent laryngoscopy using the two assigned techniques; endotracheal intubation was completed as part of the second laryngoscopy. C-spine movement was recorded fluoroscopically during bag-mask ventilation, both laryngoscopies, and intubation. Between laryngoscopies, the lungs were ventilated via bag and mask for 1 min to avoid deoxygenation.

The Lightwand was used as described by Hung et al. ([13]) and Agro et al. ([14]). The endotracheal tube (ETT) was positioned at the glottic opening as determined by characteristic lighting of the anterior neck. Elevation of the mandible was minimized to reduce displacement of the C-spine via connecting structures. The GlideScope was used as per the instructions provided by the manufacturer ([15,16]). With Macintosh and GlideScope laryngoscopy, the operator attempted to minimize neck movement, accepting the first view ([17]) that offered a reasonable opportunity to adequately position the ETT at the glottis. Intubation completed the study; the rigid board and Mayfield horseshoe were removed, and the surgery continued in the usual fashion.

All laryngoscopies were performed by one person (TT) to minimize interoperator variability. Before this study, TT had performed >50 intubations with each of the Lightwand and GlideScope and >500 intubations using the Macintosh laryngoscope. The fluoroscopy video monitor was not visible to the laryngoscopist during the study.

Fluoroscopy of the C-spine during bag-mask ventilation, laryngoscopy, and endotracheal intubation were recorded at 8 frames/s 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 to assess cervical vertebrae movement. The fluoroscopic video was analyzed using eFILM software (MERGE eFILM Workstation version 1.3.8, Merge eFILM, Milwaukee, WI) to determine laryngoscopy duration. Duration was defined from when the blade or stylet passed the central incisors to when the ETT was positioned at the vocal cords. (If the intubation sequence took longer than 120 s, it would be deemed a failure and recorded as such.)

Using the eFILM software, the orientation in the sagittal plane of the occiput (Oc) and C1 through C5-7 can be determined at any frame (point in time) in the fluoroscopic video, with a precision of 1 degree. The absolute rotation of each component in global coordinates was not the focus but rather the motion relative to adjacent components. Trendelenburg rotation of the OR table would result in global extension of all components but no flexion or extension relative to one another.

Motion segments were defined by 2 vertebrae, similar to Sawin et al. ([7]), and denoted M0-1 for Oc-C1, M1-2 for C1-2, and M2-5 for C2-5 (Fig. 2). Motion segment M5-T comprised C5 through whatever vertebrae remained stationary on the backboard. The relative angle between the 2 bones of each motion segment at any point in time was denoted $A0\text{-}1_{TIME}$, $A1\text{-}2_{TIME}$, $A2\text{-}5_{TIME}$, and $A5\text{-}T_{TIME}$.

Figure 2
Image Tools

The reference for the Oc was defined by a line between the base of the sella and the opisthion (Fig. 2). 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. 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 end-plate of the C5 vertebral body. The stationary vertebrae of Segment M5-T were not visible on the fluoroscopy but were defined by the global reference. When required, other anatomic landmarks were used by the radiologist, remaining consistent for a given subject. This was acceptable since 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 ([7]). The duration and maximum change (mean ± sd) for each experimental laryngoscopy technique was compared to those with direct Macintosh laryngoscopy at each motion segment using a Student's *t*-test. C-spine motion during bag-mask ventilation was also compared with direct Macintosh laryngoscopy. To test for carryover, motion segment change and laryngoscopy duration were compared for Macintosh laryngoscopy directly after the anesthetic induction and ventilation versus that after Lightwand or GlideScope laryngoscopy. As blinding of the radiologist was not feasible, the 108 fluoroscopic videos (bag-mask and two laryngoscopies for each patient) were presented to the radiologist in random order with no videos from the same patient within five in the sequence.

Using data from Watts et al. ([8]) (12.9 ± 2.1 degree extension) and a surmised 15% reduction in C-spine movement, the sample size was calculated to be 18 patients for each group ($P = 0.05$; power = 0.80).

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Results

The patient characteristics are summarized in Table 1. C-spine motion was compared for bag-mask ventilation versus direct Macintosh laryngoscopy for all 36 patients. The mean and sd of the maximal C-spine motion at each segment is shown in Figure 3. C-spine motion during bag-mask ventilation was 81%, 77%, 77%, and 95% less than during direct laryngoscopy at the Oc-C1, C1-2, C2-5, and C5-thoracic motion segments, respectively ($P < 0.001$).

Table 1 Image Tools

Figure 3 Image Tools

Patients in Group 1 underwent Lightwand use and direct Macintosh laryngoscopy in random order; C-spine motion was compared (Fig. 4). C-spine motion during use of the Lightwand was 49%, 72%, 64%, and 41% less at the Oc-C1, C1-2, C2-5, and C5-thoracic motion segments, respectively ($P < 0.03$). The magnitude of C-spine motion was reduced at every segment, and the (relative) distribution of motion among the segments was similar.

Figure 4
Image Tools

Patients in Group 2 underwent laryngoscopy with GlideScope and Macintosh blade in random order (Fig. 5). C-spine motion was reduced 50% at the C2-5 segment ($P < 0.04$) but unchanged at the remaining three segments ($P > 0.2$, 0.9, and 0.7, respectively).

Figure 5
Image Tools

Duration for Macintosh laryngoscopy was 16 ± 7 s for Group 1 and 17 ± 8 s for Group 2. Duration for Lightwand use was 14 ± 9 s, whereas that for GlideScope use was 27 ± 12 s ($P < 0.01$ compared with Macintosh blade).

Carryover analysis was completed. Duration and motion segment change during Macintosh laryngoscopy were compared between Groups 1 (Fig. 3) and 2 (Fig. 4). There was no significant difference between duration or motion segment change for any motion segment. Nine patients in each group had direct Macintosh laryngoscopy immediately after bag-mask ventilation, whereas the remaining 18 patients underwent Macintosh laryngoscopy after Lightwand or GlideScope use. There was no significant difference for duration or change at any motion segment comparing Macintosh laryngoscopy performed before or after the second technique.

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Discussion

The major findings of this study are that, in healthy individuals with in-line stabilization, there is less C-spine motion during bag-mask ventilation than during intubation with the Macintosh laryngoscope. There is also significantly less C-spine motion with use of the Lightwand versus the Macintosh laryngoscope.

The finding of less C-spine motion with bag-mask ventilation than endotracheal intubation suggests that maximal C-spine motion occurs during laryngoscopy and not during bag-mask ventilation, as some have suggested ([5]), illustrating that the choice of intubating technique is germane. Interestingly, maximal motion at the C2-5 segment was 1.6 ± 4.2 degrees of flexion during bag-mask ventilation versus 6.9 ± 5.2 degrees of extension during Macintosh laryngoscopy. Although flexion versus extension movement could be important for some types of injuries, the clinical relevance of this small flexion during ventilation is questionable compared with the magnitude of movement during laryngoscopy.

On average, C-spine movement was reduced 57% using the Lightwand versus direct Macintosh laryngoscopy. The distribution of C-spine motion was similar for Lightwand and Macintosh laryngoscopy, suggesting reduced movement in general and not specific to a particular C-spine location or mechanism of injury.

C-spine motion was reduced by 50% at the C2-5 segment for GlideScope versus Macintosh laryngoscopy. C-spine motion was not statistically different at the remaining three motion segments studied. This suggests that use of the GlideScope might be beneficial if the injury is known to be confined to between C2 and C5. The GlideScope offers a theoretical advantage in that the axes need not be aligned to affect a good view, but manipulation of the GlideScope to position the camera can cause extension of the Oc and C1 level of the C-spine.

C-spine motion during Macintosh laryngoscopy was greater in this study than that during Watts et al. ([8]), although direct comparison is difficult. As only one radiograph was used in that study, the maximal excursion may not have been seen ([5]). In addition, it is possible that the initial position of the patients with more initial extension or sniffing, the different method of in-line stabilization, or the application of cricoid pressure resulted in less C-spine motion in Watts et al.'s study. C-spine motion was also greater in this study than found by Sawin et al.

([7]) when no in-line stabilization was provided and no attempt was made to restrict cervical motion in any way. Reduced C-spine motion in Sawin et al.'s study could be due to easier airways (lower Mallampati scores) or patients being initially positioned in greater extension. It is often assumed that application of in-line stabilization results in reduced C-spine motion at all segments. It is possible, however, that with stabilization of the Oc, the manipulation of the airway required to obtain an adequate view may result in increased C-spine motion at other segments ([6,18]).

One challenge in interpreting studies of this nature is the difficulty in comparing data from apparently similar studies. There is no standard initial position for the patient's head and neck. As a result, different studies will begin with different initial extension or flexion of the C-spine, and the amount of extension or flexion observed during laryngoscopy will likely be different. It was for this reason that patients in this study were randomized after positioning to prevent potential initial-position bias from influencing the results.

There was no significant difference in duration between the Lightwand (14 ± 9 seconds) and Macintosh (16 ± 7 seconds) use, in agreement with Hung et al.'s ([13]) study of 844 patients. This suggests a potential advantage of the Lightwand over fiberoptic intubation or use of the Bullard laryngoscope, both of which have been shown to reduce C-spine motion at the cost of significantly longer times to intubate ([1,8,19]). Laryngoscopy with GlideScope averaged 27 ± 12 seconds, slightly faster than Agro et al.'s ([10]) mean of 38 seconds, although definition of duration is not clarified in that study. Laryngoscopy with GlideScope in this study took 62% longer than that with the Macintosh blade ($P < 0.01$), suggesting that, in the setting of in-line stabilization, there is a time cost associated with the improved view the GlideScope affords.

Each patient underwent two laryngoscopies. It is possible that the ETT was not properly positioned at the glottis during the first laryngoscopy, but that is unlikely. With Macintosh and GlideScope use, the position of the ETT tip was visualized at the glottis. The characteristic lighting pattern was observed with Lightwand use. Identical criteria were used for the second laryngoscopy, and in each case, the ETT was successfully advanced into the trachea. In addition, when the fluoroscopic video was reviewed for measuring the laryngoscopy duration with soft tissue windows (contrast and brightness settings), the position of the ETT tip at the glottis was confirmed in each case.

Cricoid pressure ([20]) is often applied during emergency endotracheal intubation but it was not used during this study. There is still some controversy in regard to actual benefit in patients with C-spine injury ([20]). Cricoid pressure may also require modification of the Lightwand technique, requiring a separate learning curve ([21]). In addition, application of cricoid pressure would involve additional hand x-ray exposure and could potentially obscure areas of interest on fluoroscopy.

A limitation of this study is that it used healthy patients as a model for injured patients. It is likely, however, that techniques that reduce the cervical vertebrae motion do so because they transmit less force and bending moment to the connecting structures and cervical vertebrae. Techniques that transmit less force and bending moment in healthy individuals will likely result in reduced vertebral movement in the setting of an unstable C-spine, and therefore may be safer to use.

We conclude that C-spine motion was greater during laryngoscopy and tracheal intubation than during ventilation via bag and mask. C-spine motion was reduced 57% using the Lightwand as compared with the Macintosh blade in the setting of in-line stabilization. C-spine motion was reduced 50% at the C2-5 motion segment only using the GlideScope as compared with the Macintosh blade. There was no difference in time taken to intubate between Lightwand and Macintosh blade, whereas the GlideScope took 60% longer on average. For patients in whom C-spine movement is undesirable, use of the Lightwand may be advantageous to the experienced user.

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