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ORIGINAL ARTICLE

Distortion of anterior airway anatomy during laryngoscopy with the GlideScope videolaryngoscope

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Abstract
Purpose A non-line-of-sight view is expected to cause less movement of the anterior airway anatomy and cervical spine during laryngeal visualization. Reduced distortion of anterior airway anatomy during laryngoscopy with the GlideScope videolaryngoscope (GVL), compared with the Macintosh laryngoscope, could explain the relatively easier nasotracheal intubation with the GVL. The purpose of this radiographic study was to compare the degree of anterior airway distortion and cervical spine movement during laryngoscopy with the GVL and the conventional Macintosh laryngoscope.
Methods Twenty patients requiring general anesthesia and tracheal intubation were studied. Each patient underwent laryngoscopy using the first-generation GVL and a direct laryngoscope with a Macintosh blade. During each laryngoscopy, a radiograph was taken when the best view of the larynx was obtained. Independent radiologists with subspeciality training in musculoskeletal imaging evaluated anterior airway distortion and cervical spine movement.
Results The distance between the epiglottis and the posterior pharyngeal wall during the GlideScope procedure was 21% less than that during the Macintosh laryngoscopy ($P < 0.05$). Anterior deviations of the vertebral bodies from baseline were 27, 32, 36, and 39% less at the atlas, C2, C3, and C4 vertebrae, respectively, during the GlideScope procedure than those measured during Macintosh laryngoscopy ($P < 0.01$). Cervical extension between the occiput and C4 during the GlideScope procedure was 23% less than that during Macintosh laryngoscopy ($P < 0.05$).
Conclusion Both anterior airway distortion and cervical spine movement during laryngeal visualization were less with the GVL than with the Macintosh laryngoscope.

Keywords GlideScope videolaryngoscope · Macintosh laryngoscope · Airway anatomy

Introduction

Increasing evidence indicates that the GlideScope videolaryngoscope (GVL, Verathon Medical, Bothell, WA, USA) for nasotracheal intubation is superior to conventional direct laryngoscopy using the Macintosh laryngoscope [1–3]. Direct laryngoscopy using the Macintosh laryngoscope requires alignment of the oral pharyngeal and tracheal axes, resulting in noticeable distortion in the anterior airway anatomy. In contrast with the Macintosh laryngoscope, the GVL is designed to provide a view of the glottis without alignment of these three axes. It is possible that distortion of the anterior airway anatomy is minimized in the non-line-of-sight view.

Reduced distortion of anterior airway anatomy during the non-line-of-sight view, compared with the Macintosh laryngoscope, could explain the relatively easier nasotracheal intubation with the GVL [3]. To our knowledge, no studies have yet compared the anterior airway distortion produced by the GVL with that by the Macintosh laryngoscope. The purpose of this radiographic study was to evaluate the mechanical effects of laryngoscopy with the

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GVL on anterior airway anatomy and on cervical spine motion, compared with those by the Macintosh laryngoscope.

Methods

The study subjects were 20 patients classified as American Society of Anesthesiologists physical status I-II, who were scheduled to undergo general anesthesia with tracheal intubation for gynecological procedures. The exclusion criteria included history of cervical spine injury, difficult airway, gastro-esophageal reflux, or a body mass index >30 kg m^{-2}. The study protocol was approved by the Human Ethics Committee of Jichi Medical University, and all subjects provided written informed consent.

Patients rested flat in a supine position on the operating table without a pillow. General anesthesia was induced with fentanyl 2 μg kg^{-1} and target plasma concentration of propofol 4 μg ml^{-1} using a syringe pump (TCI-pump. TE-371, Terumo, Tokyo, Japan). Muscle paralysis was achieved with 1 mg kg^{-1} rocuronium and complete relaxation was monitored with a nerve stimulator (TOF-Watch SX, Organon, Dublin, Eire). Anaesthesia was maintained with propofol (target plasma concentration 4 μg ml^{-1}) and remifentanil 0.1 μg kg^{-1} min^{-1} during the examination. Each patient underwent laryngoscopy using the first-generation GVL (GlideScope Large, Verathon Medical) and a direct laryngoscope with a Macintosh blade (Emac #3, Welch Allyn Japan, Tokyo, Japan). Tracheal intubation was completed as part of the second laryngoscopy. The order in which the laryngoscopes were used was assigned randomly at the start of the study. Between laryngoscopies, the lungs were ventilated via a bag-mask to avoid hypoxemia. In all cases, the blade tip of the GVL and the Macintosh laryngoscope was placed in the vallecula, as recommended by the respective manufacturer. The same anesthesiologist performed all laryngoscopies.

A mobile X-ray machine (Sirius 125 MP, Hitachi Medical, Tokyo, Japan) was positioned for a lateral view of the cervical spine throughout the examination period. A baseline radiograph was taken before oxygenation. During each laryngoscopy, a radiograph was taken when the position of the laryngoscope was adjusted to optimize the glottis view (i.e., 3 images per patient). A straight bar made of steel was included in all images to serve as a global reference, and a radio-opaque scale was imposed at the midsagittal plane of the patient.

All measurements were made by use of the Picture Archiving and Communication System (Synapse, Fujifilm Medical, Tokyo, Japan) by two radiologists with subspeciality training in musculoskeletal imaging; they were aware of the purpose of the study, but were not familiar with any of the instruments, had no knowledge of head extension during each procedure, and were not aware of the laryngoscope order assigned for each patient. The references were determined by consensus between the two radiologists.

Distortion of the anterior airway anatomy

The distance between the tip of the laryngoscopy blade and the posterior pharyngeal wall (L–PW distance) was measured in millimeters, represented by the length of a vertical line between the blade tip and the posterior wall of the pharyngeal cavity. The distance between the tip of the laryngoscopy blade and the anterior edge of the vertebral body (L–V distance) was measured in millimeters as the length of a vertical line from the blade tip to a tangent line to the cervical spine. The distance between the epiglottis and the posterior pharyngeal wall (E–PW distance, Fig. 1a) was the length of a vertical line from the posterior edge of the epiglottis to the posterior wall of the pharyngeal cavity. The distance between the epiglottis and the anterior edge of the vertebral body (E–V distance, Fig. 1a) was the length of a vertical line from the posterior edge of the epiglottis to a tangent line to the cervical spine. The distance between the hyoid bone and the posterior pharyngeal wall (H–PW distance, Fig. 1a) was represented by a vertical line from the anterior edge of the hyoid bone to the posterior wall of the pharynx cavity. The distance between the hyoid bone and the anterior edge of the vertebral body (H–V distance, Fig. 1a) was measured in millimeters as the length of a vertical line from the anterior edge of the hyoid bone to a tangent line to the cervical spine. The distortion of the anterior airway anatomy from baseline was calculated as: (length during laryngoscopy) − (length at baseline).

Anterior movement of the vertebral bodies

Similar to previous work [4], the length of a vertical line drawn from the common line (the global reference line) to the edge of anterior arch of the atlas was measured in millimeters (Fig. 1b); the length of a vertical line drawn from the common line to the anterior, inferior edge of the vertebral body was measured at the C2 vertebra (Fig. 1b); and the length of a vertical line drawn from the common line to the anterior, superior edge of the vertebral body was measured at the C3 and C4 vertebrae (Fig. 1b). The anterior deviation of the spine from baseline was calculated as: (length during laryngoscopy) − (length at baseline).

Change in the angle of the cervical vertebrae

The reference for the occiput (C0, McGregor line, Fig. 1c) was defined by a line between the posterior margin of the

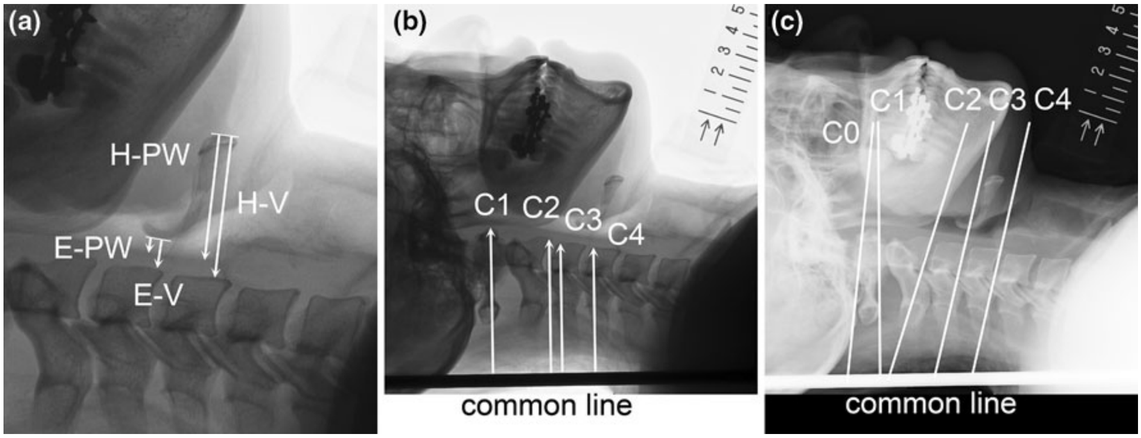

Fig. 1 Representative radiograph showing the measured distances of airway anatomy and the reference lines for cervical spine movement. **a** *E–PW*: the distance between the posterior surface of the epiglottis and the posterior pharyngeal wall: *E–V*, the distance between the posterior surface of the epiglottis and the anterior edge of the vertebral body: *H–PW*, the distance between the anterior edge of the hyoid bone and the posterior pharyngeal wall, and *H–V*: the distance between the anterior edge of the hyoid bone and the anterior edge of the vertebral body. *E* epiglottis, *PW* pharyngeal wall, *V* vertebral body, *H* hyoid bone. **b** Distances for assessment of the anterior movement of the vertebral bodies (*C1–C4*). **c** Reference lines for skull base (*C0*) and each vertebral level (*C1–C4*)

hard palate and the opisthion. The C1 reference line connected the anterior and posterior arches of the atlas (Fig. 1c). The C2–C4 reference was the tangent through the anterior and posterior basal plates of the respective vertebral bodies (Fig. 1c). These reference lines corresponded to those described previously by our group [4, 5]. The angles between adjacent levels were calculated on the basis of differences between the angles. For example, the C1–C2 angle = (C1 to common line angle) − (C2 to common line angle). Positive angles denote neck extension whereas negative angles denote neck flexion.

Sample size was calculated on the basis of our previous study [4], which demonstrated a standard deviation (SD) of 2.1–4.9 in adjacent vertebrae. Assuming an SD in the angle of 5°, a 17-patient cohort would provide 80% power at the 5% significance level in a two-sided test to detect a difference of 5° between two laryngoscopic techniques. Data are expressed as means (SD). Statistical analysis was tested by use of analysis of variance, followed by the Student–Newman–Keuls post-hoc test. The Student's paired *t* test was used for two-group comparisons. Significance was accepted at $P < 0.05$.

Results

The patients comprised 20 females of mean age 40 ± 11 (SD) years, mean weight 52 ± 7 kg, and mean height 157 ± 4 cm. The vocal cords were fully visible with both the GVL and the Macintosh laryngoscope in 14 cases. In five cases, the GVL and the Macintosh laryngoscope revealed two-thirds of the vocal cords. In the remaining case, the GVL visualized the posterior half of the vocal cords and the Macintosh laryngoscope revealed the posterior extremity of the glottis only, although both views were sufficient to allow the passage of the tracheal tube.

Distortion of the anterior airway anatomy

The tip of the blade during laryngoscopy showed lower positions with the GVL than with the Macintosh laryngoscope (L–PW distance, 35.5 ± 6.4 vs. 43.8 ± 6.4 mm, $P < 0.01$; L–V distance, 41.2 ± 5.4 vs. 49.6 ± 7.5 mm, $P < 0.01$).

Both laryngoscopy procedures caused significant anterior movement from baseline in the anterior airway anatomy, but the movement during use of the GVL was less than that during the use of the Macintosh laryngoscope ($P < 0.05$, Table 1). The movement from baseline during the GVL procedure was 21, 20, 13, and 13% less in E–PW, E–V, H–PW, and H–V distances, respectively, compared with those during the Macintosh laryngoscopy (Fig. 2).

Anterior movement of the vertebral bodies

The anterior movement of the vertebral bodies from baseline was 27, 32, 36, and 39% less at the atlas, C2, C3, and C4 vertebrae, respectively, during use of the GVL than during use of the Macintosh laryngoscope ($P < 0.01$, Fig. 3).

Change in the angle of the cervical vertebrae

The measured angles in the neutral cervical spine position and during laryngoscopy using the GVL and the Macintosh laryngoscope are shown in Table 2. Both techniques

Table 1 Distances from the epiglottis to the posterior pharyngeal wall (E–PW), from the epiglottis to the anterior edge of the vertebral bone (E–V), from the hyoid bone to the posterior pharyngeal wall (H–PW), and from the hyoid bone to the anterior edge of vertebral bone (H–V), at baseline, during laryngoscopy with the GlideScope and Macintosh laryngoscopes

	Baseline	GlideScope	Macintosh
E–PW (mm)	6.0 ± 1.5	28.8 ± 5.6*†	36.3 ± 9.0*
E–V (mm)	11.0 ± 1.9	34.2 ± 5.4*†	41.4 ± 9.5*
H–PW (mm)	38.9 ± 4.6	58.4 ± 5.1*†	62.2 ± 7.2*
H–V (mm)	44.8 ± 5.4	63.7 ± 5.4*†	67.7 ± 7.4*

Values are mean ± SD, $n = 20$

* $P < 0.05$, relative to baseline

† $P < 0.05$, relative to the Macintosh laryngoscope

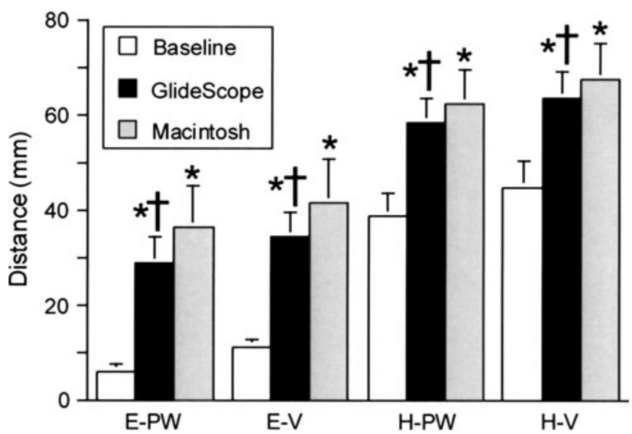

Fig. 2 Movement of the anterior airway anatomy during laryngoscopy with the GlideScope and Macintosh laryngoscopes. Data are mean ± SD. * $P < 0.05$, relative to baseline, †$P < 0.05$, relative to Macintosh laryngoscopy. For abbreviations, see Fig. 1

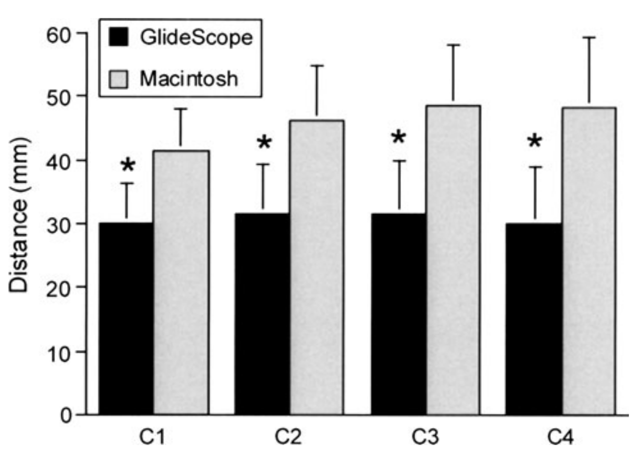

Fig. 3 Anterior deviation of the vertebral bodies from baseline during laryngoscopy with the GlideScope and Macintosh laryngoscopes at the C1 (*atlas*) to C4 vertebrae. *$P < 0.01$, relative to Macintosh laryngoscopy

Table 2 Angle between occiput and C1 (C0–C1) and adjacent vertebral bodies (C1–C2, C2–C3, C3–C4) and between occiput and C4 (C0–C4) at baseline, during laryngoscopy with the GlideScope and Macintosh laryngoscopes

	Baseline	GlideScope	Macintosh
C0–C1 (deg)	−9.1 ± 6.0	2.6 ± 5.2*	4.8 ± 5.5*
C1–C2 (deg)	25 ± 7.3	35.7 ± 6.6*	37.3 ± 6.1*
C2–C3 (deg)	−1.0 ± 3.9	3.1 ± 3.1*	4.2 ± 3.3*
C3–C4 (deg)	−1.3 ± 2.8	5.3 ± 3.7*†	8.7 ± 4.0*
C0–C4 (deg)	13.8 ± 9.9	46.6 ± 7.9*†	55.0 ± 7.4*

Values are mean ± SD, $n = 20$

* $P < 0.05$, relative to baseline

† $P < 0.05$, relative to the Macintosh laryngoscope

required significant extension of the cervical spine at all levels, compared with the respective baseline ($P < 0.05$). However, extension of the cervical spine was 31% less during the GVL technique than during Macintosh laryngoscopy at the C3/C4 motion segment ($P < 0.05$, Fig. 4), and no difference was observed at the C0/C1 (15%), C1/C2 (16%) motion segments. Cervical extension between the occiput and C4 (C0/C4) during the GVL procedure was 23% less than that measured using the Macintosh laryngoscope ($P < 0.05$, Fig. 5).

Figure 6 shows representative radiographs in a 34-year-old female, demonstrating the position of the anterior airway and cervical spine at baseline and during both laryngoscopy techniques. Compared with the Macintosh laryngoscope, the GVL required less elevation of the laryngoscope blade for laryngeal visualization. Movement of the hyoid bone from baseline was less using the GVL than those using the Macintosh laryngoscope and the deviation of the vertebral body axes from baseline was smaller using the GVL than using the Macintosh laryngoscope (Fig. 7).

Discussion

The results of this radiographic study indicated that the GVL causes less distortion of the anterior airway anatomy than Macintosh laryngoscopy in patients whose cervical spine motion was not restricted during laryngoscopy. The movement of the epiglottis from baseline during the GVL procedure was 21% less than that during Macintosh laryngoscopy. The cervical spine movement during laryngoscopy was also less with the GVL than with the Macintosh laryngoscope.

The Macintosh laryngoscope requires alignment of the tracheal, pharyngeal, and oral axes to visualize the glottis. The Macintosh laryngoscope blade elevates obstacles located anterior to the oral airway, including tongue,

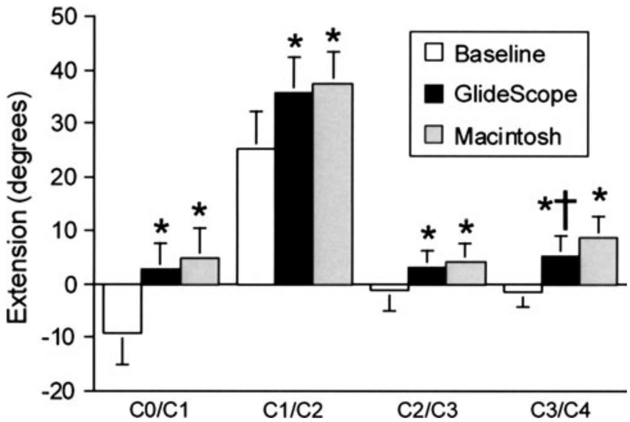

Fig. 4 Extension of the cervical spine (angle C0/C1–C3/C4) during laryngoscopy using GlideScope and Macintosh laryngoscopes. Data are mean ± SD. *$P < 0.05$, relative to baseline. †$P < 0.05$, relative to Macintosh laryngoscopy levels

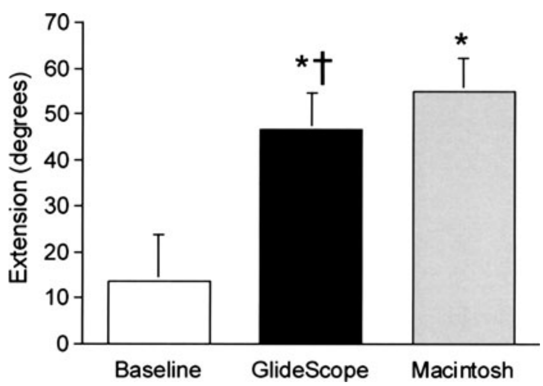

Fig. 5 Cervical extension (angle C0/C4) during laryngoscopy using GlideScope and Macintosh laryngoscopes. Data are mean ± SD. *$P < 0.05$, relative to baseline. †$P < 0.05$, relative to Macintosh laryngoscopy levels

epiglottis, and others, resulting in significant distortion of the anterior airway anatomy. In theory, laryngeal exposure through non-line-of-sight view should reduce the ventral force that causes the distortion of the anterior airway anatomy. In this radiographic study we showed that the GVL caused less distortion of the anterior airway anatomy than did the Macintosh laryngoscope. Reduced airway distortion during laryngeal exposure with the GVL is likely to provide better conditions for nasotracheal intubation, because it can potentially create a more direct route from the nasopharynx to tracheal inlet and can enable easy entry of the tube tip through the glottic opening. Indeed, better conditions for nasotracheal intubation as a result of using the GVL have been reported in clinical studies [1–3]. All of these investigations show easy entry of the tube tip into the glottic opening using the GVL without the use of Magill forceps, whereas Macintosh laryngoscopy often required use of the Magill forceps to align the tube tip to tracheal inlet. This may result from the fact that the GVL involves minimum movement of the larynx from the original position. In contrast with use of the GVL, Macintosh laryngoscopy induces a significant distortion of the anterior airway anatomy from the original position, resulting in the need to use the Magill forceps to align the tube tip with the tracheal inlet.

In our study, both the GVL and the Macintosh laryngoscope showed significant anterior movement of the vertebral bodies, movement which was less with the GVL than with the Macintosh laryngoscope. This is in agreement with our previous study [4], in which the Airtraq laryngoscope, an indirect rigid laryngoscope, caused less anterior movement of the vertebral bodies than the Macintosh laryngoscope. Non-line-of-sight view of the glottis is most

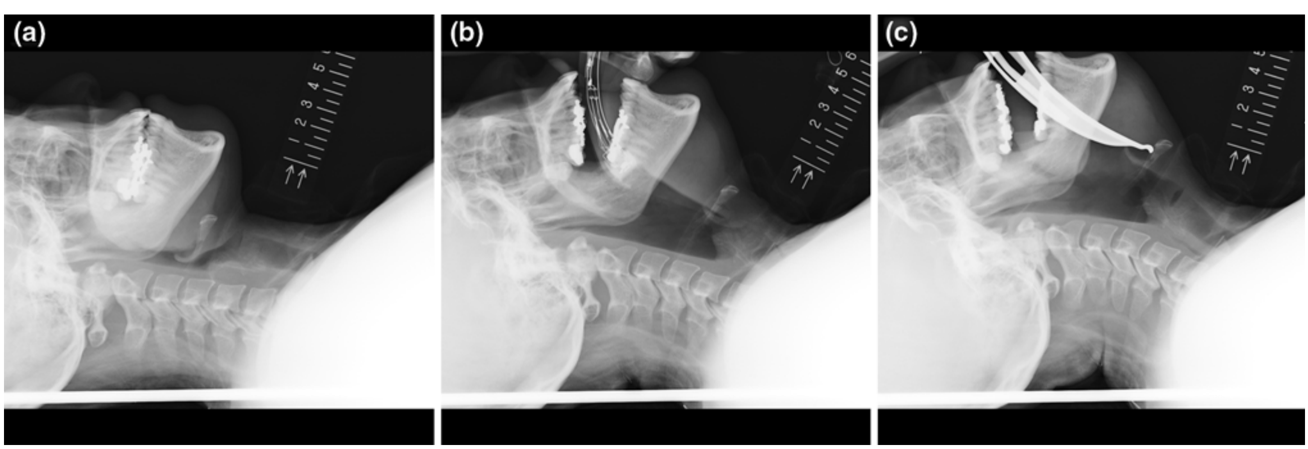

Fig. 6 Lateral radiographs of a representative patient showing the anterior airway anatomy and cervical spine at baseline (**a**) and during laryngoscopy with the GlideScope (**b**) and Macintosh (**c**) laryngoscopes. The pharyngeal airway is less expanded during laryngoscopy with the GlideScope (**b**) than with Macintosh laryngoscopy (**c**). The distance between the epiglottis and the posterior pharyngeal wall was 4.8, 26.6, and 41.0 mm, in **a**, **b**, and **c**, respectively. The angle between the occiput and C4 (C0/C4) was 24, 40, and 52°, in **a**, **b**, and **c**, respectively

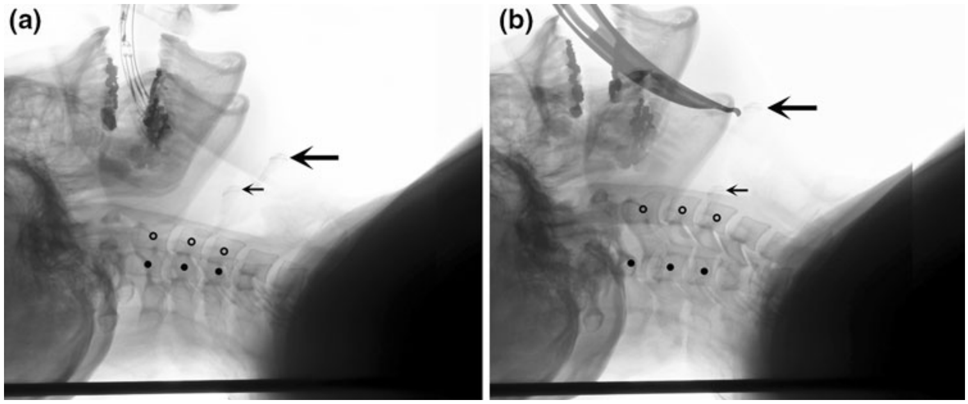

Fig. 7 Deviation of the hyoid bone and cervical vertebral bodies from baseline during the two laryngoscopic techniques. The X-ray figures during GlideScope (**a**) and Macintosh (**b**) laryngoscopy were superimposed over the same baseline figure. *Thin arrow* the position of the hyoid bone at baseline, *thick arrow* the position of the hyoid bone during laryngoscopy, *solid circles* centers of the vertebral bodies (C2, C3, and C4) at baseline, *open circles* centers of the vertebral bodies (C2, C3, and C4) during laryngoscopy

likely to require less ventral force, compared with conventional Macintosh laryngoscopy.

Visualization of the glottis for tracheal intubation requires extension of the cervical spine. In this study, both the GVL and Macintosh laryngoscope techniques required significant extension of the cervical spine at all levels compared with the baseline. The overall cervical extension (C0/C4) during the GVL procedure was statistically less than that measured using the Macintosh laryngoscope. However, with regard to motion of the adjacent segments, only motion of the C3/C4 segment was different between the two techniques. The results of our previous work using the Airtraq laryngoscope [4] are in agreement with those of this study using the GVL. In contrast, studies using the Pentax-AWS [5] and Bullard laryngoscope [6, 7] showed differences in motion of C0/C1 and C1/C2 segments, in addition to the C3/C4 segment. The ventral forces exerted on the C0/C1 and C1/C2 segments during laryngoscopy may be greater with the GVL and the Airtraq laryngoscope than with the Pentax-AWS and Bullard laryngoscopes. The position where the tip of the blade is placed to visualize the glottic opening may be critical to movement at the cranial end of the cervical spine. The use of the GVL and Airtraq laryngoscope requires placement of the blade tip in the vallecula, whereas the tip of the blade must be placed under the epiglottis during laryngoscopy with the Pentax-AWS and Bullard laryngoscopes.

Although the current study showed reduced cervical anterior movement of vertebral bodies and change in angle of cervical vertebrae during use of the GVL, these factors might have little effect on nasotracheal intubation. Extension of the head and neck facilitates introduction of a nasotracheal tube into the pharynx, because the extension reduces the angle between the axis of the inferior nasal meatus and the posterior pharyngeal wall. The physician, however, inserts the tube through the nasal passage and into the pharynx first and then performs laryngoscopy and intubation. The tip of the tube already lies on the posterior pharyngeal wall before visualization of the glottis. The passage through the tracheal inlet requires alignment of the tube tip with the glottis opening. The difficulty in passage of the tube into the tracheal inlet depends on the distance between the glottis opening and the tube tip that lies on the posterior pharyngeal wall. In this respect, the GVL is superior to Macintosh laryngoscope for nasotracheal intubation, because the anterior movement of airway component, e.g., epiglottis and hyoid bone, is less during laryngoscopy with the GVL. Less cervical anterior movement of the vertebral bodies and extension of the cervical vertebrae during laryngoscopy with the GVL might have little effect on the distance between the glottis opening and the tube tip that lies on the posterior pharyngeal wall. On the other hand, from the viewpoint of reduced movement of the cervical spine, the GVL would be better for the spinal cord, especially in patients with an unstable spine.

In this study, we made no attempt to restrict cervical motion during laryngeal visualization. Use of the GVL resulted in significant cervical spine movement relative to baseline at all motion segments examined. This is in agreement with the results of a continuous radiographic study by Wong and colleagues [8], in which the GVL caused greater cervical movement than flexible bronchoscopic intubation. In their hands, examination was performed using the second generation GVL with lower vertical profile in patients without cervical stabilization, and they did not evaluate cervical spine movement during Macintosh laryngoscopy. With regard to examination under manual in-line stabilization, two studies have been reported. One is the study of Robitaille and co-workers [9], who found no significant difference between the GVL and the Macintosh laryngoscope with regard to segmental spinal movement at any adjacent levels. The other is that of Turkstra et al. [10], who found a small but statistical reduction with the GVL at the C2/C5 motion segment compared with Macintosh laryngoscopy, but no change at the C0/C1, C1/C2, and C5/T1 motion segments. Manual in-line stabilization to minimize cervical spine movement, prohibits direct comparison with our study, in which no attempt was made to restrict cervical motion during examination.

This radiographic study has several limitations. First, the patients rested without pillows during laryngoscopy. Tracheal intubation is usually carried out with pillows to make the airway component anatomically straight for orotracheal and nasotracheal intubation. This may affect the measurements in this study. We previously reported similar investigations in which the cervical spine movement during laryngoscopy with the Airtraq laryngoscope [4] and Pentax-AWS airway scope [5] was measured in patients without pillows. For comparison with the results from those studies we decided to have the patients with the same head and neck positions in the current study. Second, the airway operator could not be blinded to the laryngoscope used. It is impossible to escape recognition during each laryngoscopy in this type of clinical study. Third, radiographic biases cannot be ruled out because the type of the laryngoscope was evident on the radiographs. However, the radiologists who examined the radiographs were unfamiliar with the laryngoscopes and completely blinded to the position of the anterior airway and cervical spine during actual laryngoscopy. Fourth, the use of a single-operator protocol may be of concern. Distortion of the anterior airway anatomy during laryngoscopy might be different with other operators. However, the intubation technique may vary in multiple-operator protocols and could result in bias in this type of study. In this study, the operator was familiar with both devices, and the technique was consistent for the best glottic exposure between the two devices. Fifth, a difference of 5° in spinal movement amplitude was estimated to be significant in the current study. A reduction in 5° of spinal vertebrae movement would indicate 30% reduction in the motion of the C0/C1 segment against Macintosh laryngoscopy, and 40% reduction in the C1/C2 motion segment. However, there are no clinical outcome data in which this reduction in spinal movement during laryngoscopy suggests better neurologic outcomes in patients with or without cervical spine instability. Last, our measurements were not made during actual nasotracheal intubation. Many nasotracheal intubations using the Macintosh laryngoscope require the use of Magill forceps to introduce the tip of the tube into the glottic opening. The effect of using Magill forceps on distortion of the anterior airway anatomy was not clear from this study.

In conclusion, when compared with the Macintosh laryngoscope, the GVL causes less distortion of the anterior airway anatomy and less cervical spine movement in patients without manual in-line stabilization. Less movement of the airway anatomy relative to the original position during non-line-of-sight view may facilitate nasotracheal intubation with the GVL.

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