

Endotracheal intubation in elective cervical surgery

A randomized, controlled, assessor-blinded study

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Abstract

Background: We compared the effectiveness and safety of endotracheal intubation using the GlideScope (GS) video laryngoscope, CTrach laryngeal mask airway (LMA), or Shikani optical stylet rigid laryngoscope (SOS) during elective cervical surgery.

Methods: Forty-five patients undergoing elective cervical surgery were randomly and equally assigned to endotracheal intubation via GS, LMA, or SOS airway management.

Results: Endotracheal intubation was successfully completed in all patients. The mean intubation times of the groups differed significantly ($P < .01$): GS, 17.9 ± 3.1 s; SOS, 40.4 ± 13.7 s; and LMA, 80.5 ± 22.5 s. The groups had similar heart rates and mean arterial pressures throughout the intubation, except that at 2 minutes after intubation the mean arterial pressure of the GS group (106.1 ± 18.5 mm Hg) was significantly higher than that of the LMA (89.7 ± 18.5 mm Hg) or SOS (89.7 ± 18.5 mm Hg; $P < .01$). The change in C2–5 Cobb angle from baseline was significantly higher in the GS group (GS, $34.2^\circ \pm 7.3^\circ$) than the LMA ($24.4^\circ \pm 5.8^\circ$) or SOS ($25.5^\circ \pm 6.4^\circ$); $P < .01$).

Conclusions: The CTrach LMA and SOS rigid laryngoscope are effective, safe alternatives to the GS video laryngoscope for patients undergoing elective cervical surgery.

Abbreviations: ASA = American Society of Anesthesiology, BMI = body mass index, GS = GlideScope video laryngoscope, JOA = The Japanese Orthopaedic Association, LMA = CTrach laryngeal mask airway, MAP = mean arterial pressure, SCI = cervical spinal cord injury, SOS = Shikani optical stylet rigid laryngoscope, SpO₂ = pulse oximetry, T₀ = time upon admission to the operating room, T₁ = time at facial mask oxygenation, T₂ = time at exposure of the glottis, T₃ = time upon completion of endotracheal intubation.

Keywords: cervical surgery, CTrach laryngeal mask airway, endotracheal intubation, GlideScope video laryngoscopy, Shikani optical stylet rigid laryngoscopy

1. Introduction

Surgical correction remains the mainstay treatment for complex cervical spine injury and requires general anesthesia with

endotracheal intubation. However, endotracheal intubation is subject to secondary iatrogenic cervical spinal cord injury (SCI) in patients with complicating cervical spine instability.^[1] The optimal method of airway management remains controversial in current anesthesia practice.^[2] Use of direct Macintosh laryngoscope requires overextension of the neck to align the oral, pharyngeal, and laryngeal axes; cervical immobilization may help reduce the risk of iatrogenic cervical SCI but complicates intubation in some cases. Thus, direct laryngoscopy is less effective and safe in the scenario of complex cervical surgery. An effective, safe alternative airway management method should be able to immobilize the cervical vertebrae, stabilize the cervical spine, and minimize secondary cervical SCI.^[3]

Multiple alternative laryngoscopic techniques have emerged as possible solutions to airway management in patients undergoing cervical surgery. For example, use of the GlideScope (GS) video laryngoscope can effectively improve visualization of the glottis and increase the success rate of difficult intubation.^[4] The CTrach laryngeal mask airway (LMA) is similar to intubating LMA with respect to mechanics, but contains an integrated fiber-optic unit for imaging the glottis.^[5] Shikani optical stylet (SOS) rigid laryngoscopy is a newly developed technique incorporating an optical stylet with fiber-optic endoscopic imaging for difficult intubation.^[6]

Previous comparative studies have evaluated the effectiveness of these 3 intubation techniques relative to direct Macintosh laryngoscopy and showed that they were more time-efficient and safer for patients with cervical instability.^[7–10] However, comparisons of these 3 intubation techniques with respect to

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effectiveness and safety, and especially their effect on cervical stability, are lacking.

The primary objective of the present randomized controlled study was to compare the effectiveness and safety of endotracheal intubation using the GS video laryngoscope, CTrach LMA, or SOS rigid laryngoscope among patients undergoing elective cervical surgery. Specifically, we examined the effect of the intubation method on postoperative change in the cervical spine Cobb angle, relative to the baseline.

2. Methods

2.1. Study protocol

All experiments were conducted in accordance with the guidelines of the latest version of the Declaration of Helsinki, and were approved by the Institutional Review Board at PLA Shenyang Military Command General Hospital. Forty-five patients with cervical spine disease of either gender were consecutively and prospectively admitted to our hospital for elective anterior cervical surgery between February 2014 and April 2014. The inclusion criteria were age between 18 and 65 years; body mass index (BMI) 20 to 30 kg/m²; American Society of Anesthesiology (ASA) physical status class I or II; and New York Heart Association functional classification grade I or II. The exclusion criteria were mouth opening <3 cm, thyromental distance <6.5 cm, or micrognathia; a positive pregnancy test for a woman of child-bearing potential; previously medicated with any cardiovascular-active agent; complicating uncontrolled diabetes mellitus or serious cardiopulmonary or hepatorenal impairment; or rejecting participation in the study. All eligible patients were randomized using the computer-generated random number method and equally assigned to receive endotracheal intubation using the GS video laryngoscope (GS group), the CTrach LMA (LMA group), or the SOS rigid laryngoscope (SOS group). All patients volunteered to give informed consent in writing prior to participation in this study. All patients and researchers responsible for the outcome measurements were blinded to the group assignment.

2.2. Anesthetic procedure

All patients were instructed to fast for 8 hours prior to anesthesia and surgery. No premedication was given, and access to the upper limb vein was established using a 20G cannula needle on admission to the operating room. Cardiopulmonary monitoring included limb lead electrocardiography, pulse oximetry (SpO₂), and cuff sphygmomanometry. The baseline was set at 10 minutes after the patient was stabilized, before the induction. All intubation procedures were performed by a single, independent, and board-certified anesthesiologist.

A C-arm radiography unit (RADIUS R9; EICO S.R.L., Orsenigo, Italy) was used by an independent radiologist to capture lateral radiographs of the cervical spine at timepoint 0 (T₀) when the patient was positioned supine without a pillow. Intravenous medications consisted of sequential boluses of midazolam (0.05 mg/kg; Jiangsu Nhwa Pharmaceutical, Xuzhou, China), propofol (1.5 mg/kg; Jiabo Pharmaceutical, Qingyuan, China), sufentanil (0.4 μg/kg; Humanwell Pharmaceutical, Yichang, China), and rocuronium bromide (0.6 mg/kg; Zhejiang Xianju Pharma, Xianju, China).

Pressure ventilation was given using facial mask oxygenation for 5 minutes (T₁), and lateral cervical radiography was

performed. Lateral cervical radiography was repeated (T₂) when the laryngoscope was retracted to expose the glottis in the GS group; when the laryngeal mask was inserted through the oral cavity and tongue root until the maximum curvature of the larynx was reached in the LMA group; or when the glottis was clearly viewed through the eyepiece (with the light spot focusing on the middle of the thyroid cartilage and the laryngoscope maintained static) in the SOS group. No compression of the thyroid cartilage was allowed to expose the glottis during the intubation. Bilateral pulmonary auscultation was performed to determine whether the intubation was successful (T₃). Lateral cervical radiography was repeated at timepoint the Cobb angle reached the maximum, with a minimal difference between pre- and post-intubation on preliminary continuous cervical spine imaging.

The anesthesia machine (Aeon 7500A; Aeonmed, Beijing, China) was connected for intermittent positive pressure ventilation at a tidal volume of 8 mL/kg and frequency of 12 min⁻¹. Inhalational isoflurane was given at a dose of 0.6 minimum alveolar concentration at an oxygen flow rate of 2.0 L/min until 10 minutes after intubation. The anesthesia depth was adjusted according to the bispectral index monitoring. The endotracheal catheter was removed upon completion of the operation, and patients were followed up 1 week after surgery.

2.3. Outcome measures

Baseline patient characteristics included age, gender, body weight, height, BMI, ASA classification, mouth opening, thyromental distance, and Mallampati score (ease of intubation). The primary outcome was changes in the C2–5 Cobb angles. The secondary outcome was improvement in the Japanese Orthopaedic Association (JOA) SCI scale. The outcome measures for efficacy included the following: the number of intubation attempts (withdrawing the laryngoscope or endotracheal catheter from the oral cavity); the success rate of single-attempt intubations (the number of single-attempt intubation/the total number of intubation × 100%); the failure rate of intubation (the number of >3 intubation attempts/the total number of intubation × 100%); and time to completion of intubation (between the insertion of the laryngoscope or laryngeal mask and completion of endotracheal intubation). The outcome measures of safety included: hemodynamic variables; changes in the Cobb angles; intubation-associated complications; and improvement in the JOA SCI scale expressed as percentage ([postoperative JOA score – preoperative baseline]/[17 – preoperative baseline] × 100%). An improvement of 25% to 60% indicated significant improvement, but <25% was considered no improvement.

Hemodynamic variables included heart rate and mean arterial pressure (MAP) upon operating room admission, and thereafter prior to induction, prior to intubation, and 1, 2, 3, 5, and 10 minutes after intubation. ZWSOFT CAD2010 computer-aided design software (ZWCAD Software, Guangzhou, China) was used to determine the changes in cervical spine curvature at T₀ (upon admission to the operating room), T₁ (at facial mask oxygenation), T₂ (at exposure of the glottis), and T₃ (upon completion of endotracheal intubation). The Cobb angle from C2–5 was determined using the 4-line method to evaluate the whole-length cervical spine curvature (Fig. 1A). The Cobb angles for C0–1, C1–2, C2–3, C3–4, and C4–5 were also determined using the 2-line method to evaluate the respective cervical spine curvature (Fig. 1B).^[11]

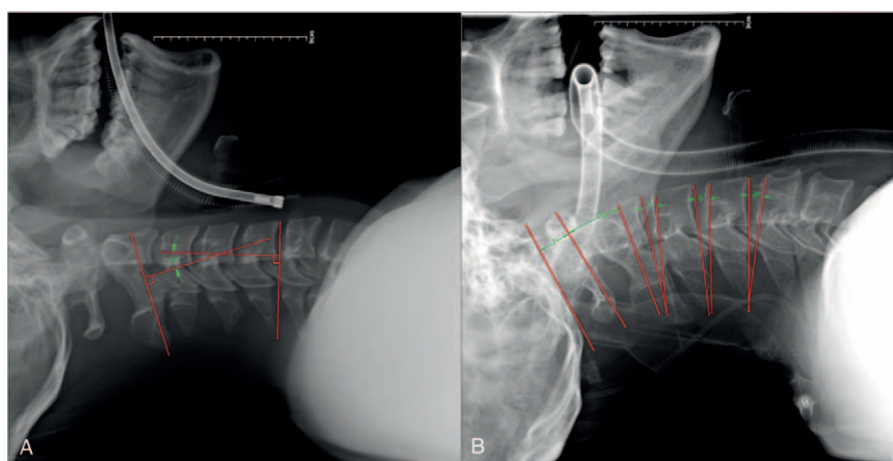


Figure 1. Measurement of (A) C2-5 and (B) 2-level Cobb angles.

One week after surgery, patients were followed up by a research nurse blinded to the intubation technique to assess intubation-related complications. The complications noted were oropharyngeal bleeding, hoarseness, laryngeal pain, and cervical SCI. Improvement of cervical SCI from the baseline was determined at the follow-up visit using the JOA score, which evaluates the spinal cord motor-sensory function with respect to upper and lower limb muscular strength, limb and trunk sensation, and urinary bladder function^[12] (Supplementary Table 1, <http://links.lww.com/MD/B894>).

2.4. Statistical analyses

The sample size calculation was based on the primary outcome, that is, the changes in the C2–5 Cobb angles. The standard deviation of mean changes in the 3 groups was estimated at 3.2 and the standard deviation of changes in the Cobb angles was estimated as 6.5, according to our preliminary data. The criteria for significance was $P < .05$, with power of 80%. The estimated sample size was 15 in each group. The total sample size required for this study was calculated to be 45.

Table 1 Baseline characteristics of patients undergoing elective cervical surgery*.

	GS	LMA	SOS	P value
Age, y	53.7 ± 5.7	45.9 ± 10.0	47.6 ± 14.2	.976
Gender, M/F	10/5	11/4	11/4	.897
Body weight, kg	72.3 ± 15.1	69.9 ± 12.9	75.0 ± 11.0	.878
Height, cm	169 ± 9	170 ± 6	174 ± 5	.869
BMI, kg/m ²	25.1 ± 4.2	24.1 ± 3.7	24.7 ± 3.2	.921
ASA class, I/II	10/5	8/7	9/6	.757
Mouth opening, cm	5.2 ± 0.6	5.6 ± 0.7	5.6 ± 0.8	.999
Thyromental distance, cm	7.3 ± 0.6	7.1 ± 0.6	7.2 ± 0.6	.986
Mallampati class, I/II/III	6/6/3	7/6/2	7/7/1	.877
Heart rate, bpm	73 ± 16.0	76 ± 16	65 ± 9	.704
MAP, mm Hg	101 ± 9	100 ± 13	103 ± 16	.899

ASA = American Society of Anesthesiology, BMI = body mass index, GS = GlideScope video laryngoscope, LMA = CTrach laryngeal mask airway, MAP = mean arterial pressure, SOS = Shikani optical stylet rigid laryngoscope.

* Expressed as mean ± SD unless specified otherwise.

The statistical software package SPSS version 19.0 (SPSS, Chicago, IL) was used for statistical analyses. All continuous data in normal distribution were expressed as mean ± standard deviation, and the means were compared using one-way analysis of variance. The post hoc multiple comparisons were performed using the adjusted Tukey-Kramer method. All categorical data are expressed as n (%) and compared using Fisher exact probability test. A P value $< .05$ was considered statistically significant.

3. Results

Forty-five eligible patients were randomized and equally apportioned to the 3 treatment groups (Table 1). The 3 groups were comparable in age, gender, body weight, height, BMI, ASA class, mouth opening, thyromental distance, Mallampati score, MAP, and heart rate prior to induction (all P values $> .05$).

Endotracheal intubation was successfully completed in all patients within 2 attempts (Table 2). The success rate for single-attempt intubation was similar among the GS, LMA, and SOS groups (100% vs 86.7% vs 86.7%, $P > .05$). Mean intubation time was shortest in the GS group (17.9 ± 3.1 s), shorter in the SOS group (40.4 ± 13.7 s), and longest in the LMA group (80.5 ± 22.5 s; $P < .01$). None of the patients experienced cardiopulmonary adverse events during intubation.

The 3 groups exhibited similar heart rate (Fig. 2A) and MAP (Fig. 2B) throughout the intubation (all P values $> .05$), except that at 2 minutes after intubation the LMA group had the lowest MAP (89.7 ± 18.5 mm Hg) whereas the GS group had the highest (106.1 ± 18.5 mm Hg, $P < .01$). SpO₂ remained $> 99%$ during the operation.

Table 2 Intubation outcomes.

	GS	LMA	SOS	P value
Overall success rate, n, %	15 (100.0)	15 (100.0)	15 (100.0)	1.000
Single-attempt success rate, n, %	15 (100.0)	13 (86.7)	13 (86.7)	.334
Second-attempt success rate, n, %	0 (0.0)	2 (13.3)	2 (13.3)	.334
Intubation time, s	17.9 ± 3.1	80.5 ± 22.5	40.4 ± 13.7	.005

GS = GlideScope video laryngoscope, LMA = CTrach laryngeal mask airway, SOS = Shikani optical stylet rigid laryngoscope.

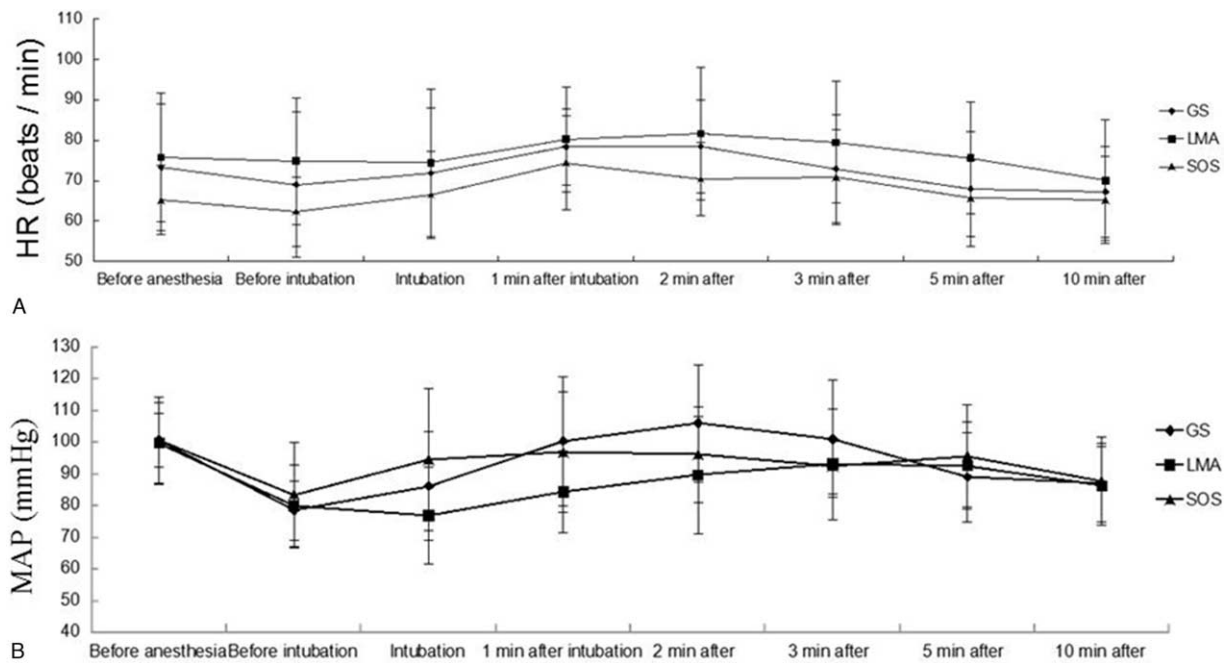


Figure 2. Changes in (A) heart rate and (B) MAP during intubation. MAP = mean arterial pressure.

The effect on cervical spine curvature at T₂ relative to the baseline (T₀) was significantly less in the LMA (24.4° ± 5.8°) and SOS (25.5° ± 6.4°) groups compared with the GS group (34.2° ± 7.3°; *P* < .01; Table 3). However, the 3 groups exhibited similar percentage changes in C0–1, C1–2, C2–3, C3–4, and C4–5 Cobb angles (all *P* values > .05) from the baseline.

Intubation-associated complications and improvement in the JOA score are shown in Table 4. The GS, LMA, and SOS groups experienced similar frequencies of oropharyngeal bleeding, hoarseness, and laryngeal pain (all *P* values > .05). The JOA scores for cervical SCI were similar among the 3 groups at the baseline and had significantly improved 1 week after surgery to a similar extent (both *P* values > .05; Table 4). All the 3 groups exhibited significant JOA improvement (38.0 ± 35.4%, 42.1 ± 32.5%, and 42.3 ± 42.8%; all *P* values < .05) as compared with the preoperative baseline.

4. Discussion and conclusions

A number of previous studies have shown that GS video laryngoscopy, CTrach LMA, and SOS rigid laryngoscopy are effective and safe alternatives to conventional laryngoscopy for management of difficult airway in patients undergoing non-

cervical surgery,^[13] and in those undergoing cervical surgery with rigid collar immobilization.^[14] However, it remained undecided which of these 3 advanced airway management techniques is optimal for patients undergoing cervical spine surgery without collar immobilization. To the best of our knowledge, the present work is the first randomized controlled study to undertake this issue. We found that the success rates of the 3 techniques were comparable in terms of single-attempt intubation, and were generally similar in hemodynamic variation and intubation-associated morbidity. However, compared with LMA and SOS laryngoscopy, the GS laryngoscope was associated with a significantly shorter intubation time and a significantly higher MAP at 2 minutes after intubation. Moreover, the effect of GS laryngoscopy on whole-length cervical spine curvature during intubation was relatively disadvantageous, although the respective 2-level Cobb angles were similar among the 3 groups.

Our intubation data showed that all 3 intubation techniques were associated with a 100% overall success rate and had similar single-attempt success rates, although this prospective patient cohort included a small percentage (6/45, 13.3%) of patients with difficult airway (Mallampati class III). Maurtua et al^[15] reported

Table 3
Changes (%) in cervical spine Cobb angle at T₂ from T₀.

	GS	LMA	SOS	<i>P</i> value
C2–5	34.2 ± 7.3	24.4 ± 5.8	25.5 ± 6.4	.0081
C0–1	12.4 ± 4.9	6.7 ± 4.3	6.0 ± 2.3	.5380
C1–2	31.9 ± 2.1	27.3 ± 4.8	27.2 ± 6.4	1.0000
C2–3	7.4 ± 3.0	2.8 ± 1.6	5.8 ± 2.9	.9981
C3–4	5.4 ± 2.3	3.0 ± 1.9	2.7 ± 2.3	1.0000
C4–5	4.8 ± 3.7	5.4 ± 3.0	5.6 ± 3.7	1.0000

GS = GlideScope video laryngoscope, LMA = CTrach laryngeal mask airway, SOS = Shikani optical stylet rigid laryngoscope.

Table 4
Intubation-associated complications and improvement in the JOA score.

	GS	LMA	SOS	<i>P</i> value
Oropharyngeal bleeding, n, %	0 (0.0)	1 (6.7)	None	.360
Hoarseness, n, %	0 (0.0)	1 (6.7)	1 (6.7)	.593
Laryngeal pain, mean ± SD	0 (0.0)	2 (13.3)	3 (20.0)	.207
Preoperative JOA score, mean ± SD	11.1 ± 4.7	11.1 ± 4.7	11.6 ± 3.7	.391
Postoperative JOA score, mean ± SD	13.0 ± 5.0	13.0 ± 4.2	13.4 ± 3.9	.306
JOA improvement, %, mean ± SD	38.0 ± 35.4	42.1 ± 32.5	42.3 ± 42.8	N/A

GS = GlideScope video laryngoscope, JOA = The Japanese Orthopaedic Association, LMA = CTrach laryngeal mask airway, SOS = Shikani optical stylet rigid laryngoscope.

a relatively higher (~100%) failure rate of intubation using the CTrach LMA in a retrospective cohort, primarily due to poor visualization of the airway and inappropriate positioning of the LMA. In contrast, Phua et al^[14] reported in a randomized controlled study that SOS rigid laryngoscopy was similar to the GS video counterpart with respect to overall and single-attempt success rates of intubation, even in patients with difficult airway. However, CTrach LMA and SOS laryngoscopy were associated with a significantly longer intubation time compared with GS laryngoscopy. This was probably due to operator's variation and the learning curve effect; however the intubation time of each technique in this study was significantly shorter than that for GS laryngoscopy,^[14] CTrach LMA,^[16] and SOS laryngoscopy,^[14] as previously reported.

Hemodynamic variations in response to per-oral intubation mainly result from stimulation of the oral and pharyngolaryngeal smooth muscle tension sensor on laryngoscope retraction to expose the glottis, and that of the vocal cord and tracheal wall pressure sensor during the insertion of the tracheal catheter.^[17] The stimuli activates the sympathetic nervous system through the glossolaryngeal nerve and results in hypertension and tachycardia, which may be transient or long-lasting depending on the duration of endotracheal intubation. Dramatic hemodynamic variation is subject to serious cardiovascular and cerebrovascular events, especially in high-risk patients. Our hemodynamic monitoring results showed that these 3 intubation techniques were generally comparable in cardiovascular safety. However, the GS laryngoscopy was associated with a significantly higher MAP at 2 minutes after intubation, compared with CTrach LMA and SOS laryngoscopy. A possible explanation may be that insertion of the endotracheal catheter using GS laryngoscopy simultaneously stimulated the glottis, vocal cord, and tracheal wall within a relatively short time.

Motion of the cervical spine is a major safety concern during endotracheal intubation among patients undergoing cervical spine surgery.^[18] Previous studies suggested that intubation using the CTrach LMA had a minimal effect on cervical spine curvature in patients with collar immobilization.^[5,19] Our repeated lateral cervical spine radiography showed that intubation using the CTrach LMA and the SOS rigid laryngoscope had significantly less effect on the whole-length cervical spine curvature than did the GS laryngoscope, although these 3 intubation techniques were similar with respect to changes in 2-level Cobb angles.

A cadaveric study reported by Lennarson et al^[18] showed that any access to the trachea would result in motion of the cervical spine to some extent, with or without cervical SCI. Such access includes elevating the lower jaw, expanding the mouth, pressing the cricoid cartilage, facial mask oxygenation, advancing the laryngoscope, or inserting the endotracheal catheter. Cervical flexion and extension mainly occurs in C0–1 and C1–2, namely, the atlanto-occipital and atlanto-axial joints.^[20] A cervical biomechanics study reported that the physiological upper limit was 11° for a 2-level angular shift. A shift beyond this limit would cause cervical spine instability and potentially lead to iatrogenic cervical SCI.^[21] GS laryngoscopy was associated with a significantly greater change in the whole-length cervical spine curvature compared with the CTrach LMA and SOS laryngoscopy. Moreover, changes in the C0–1 and C1–2 Cobb angles for the GS group, as well as the C1–2 Cobb angle for the LMA and SOS groups, were above the physiological upper limit and potentially subject to secondary SCI.

Cooper and his colleagues^[22] reported in a case series of 728 patients that GS video laryngoscopy offered a better visualiza-

tion of the glottis compared with Macintosh direct laryngoscopy. However, GS laryngoscopy could not significantly reduce intubation-associated non-pathological cervical spine shift in SCI patients with cervical collar immobilization.^[8] In contrast, Kihara et al^[23] reported that, unlike cervical spine extension caused by Macintosh direct laryngoscopy, use of the intubating LMA resulted in a small (1.4–3.0°) C0–4 Cobb angle among lower-level cervical spine disease patients with the cervical spine axis immobilized. In the present study, we noted that the JOA score was similarly and significantly improved in all 3 groups 1 week after surgery (over 35%). This finding suggests that endotracheal intubation using any of these airway management techniques may not cause secondary iatrogenic SCI, even in patients with cervical collar immobilization, in the short term.

There were some limitations in this study. First, the sample size was relatively small (only 15 patients in each group). Second, the patients were not stratified by conditions such as severity of SCI or difficulty of airway, although the 3 groups were comparable in preoperative JOA score and Mallampati class. Third, the investigators (anesthesiologists) were not blinded to the intubation type, and thus results were subject to the investigator's bias. However, the radiologist evaluating changes in the cervical spine curvature and the research nurse assessing JOA scores were blinded. Last, the long-term improvement in cervical spine motor-sensory function is subject to some confounding factors other than anesthetic procedure. These include baseline medical or surgical conditions, operative access, and postoperative rehabilitative care; only the short-term cervical spinal cord function was followed up in this study.

In conclusion, GS video laryngoscopy, the CTrach LMA, and SOS rigid laryngoscopy had similar success rates for overall and single-attempt intubations among patients undergoing elective major cervical spine surgery without collar immobilization. GS laryngoscopy was associated with a significantly shorter intubation time but higher MAP after intubation, compared with the CTrach LMA and SOS laryngoscopy. GS laryngoscopy also had a significantly greater effect on the whole-length cervical spine curvature during intubation. These 3 intubation techniques were associated with similar anesthetic morbidities and short-term improvement of cervical spinal cord function. Large-scale, randomized controlled studies are needed to validate the effectiveness and safety of these 3 intubation techniques in complex SCI cases.

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