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A Comparison of Video Laryngoscopy to Direct Laryngoscopy for the Emergency Intubation of Trauma Patients

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Abstract

Background Direct laryngoscopy (DL) has long been the gold standard for tracheal intubation in emergency and trauma patients. Video laryngoscopy (VL) is increasingly used in many settings and the purpose of this study was to compare its effectiveness to direct laryngoscopy in trauma patients. Our hypothesis was that the success rate of VL would be higher than that of DL.

Methods Data were collected prospectively on all trauma patients, from January 2008 to June 2011, who were intubated emergently in an academic level I trauma center. After intubation, the physician that performed the intubation completed a structured data collection form that included demographics, complications, and the presence of difficult airway predictors. Our primary outcome measure was overall successful tracheal intubation, which was defined as successful intubation with the first device used.

Results During the study period, 709 trauma patients were intubated by either VL or DL. VL was performed in 55 % of cases. The overall success rate of VL was 88 % compared to 83 % with DL ($P = 0.05$). Cervical (C-Spine) immobilization was predictive of higher initial success with VL (87 %) than with DL (80 %) ($P < 0.05$). In multivariate regression analysis DL was associated with higher risk of intubation failure compared to VL (OR 1.82, CI: 1.15–2.86).

Conclusions In trauma patients intubated emergently, VL had a significantly higher success rate than DL. These data suggest that, in select circumstances, VL is superior to DL for the intubation of trauma patients with difficult airways.

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Introduction

Conventional direct laryngoscopy (DL) has been the standard of care for airway management since the invention of the Macintosh and Miller blades in the 1940s [1]. The standard technique used for intubation involves aligning the oral, pharyngeal, and laryngeal axes to create a direct view of the glottic inlet, For proper positioning of the patient in routine intubations, significant cervical spine (C-spine) manipulation is required, but trauma patients pose a unique challenge: many of them have a C-spine injury and/or an extrication collar immobilizing the neck. In addition, trauma patients may have other factors that make intubation more difficult, such as blood in the airway, facial trauma, hemodynamic instability, and respiratory compromise.

Advances in technology have resulted in Video Laryngoscopy (VL), which is now being used in many clinical scenarios with significant success. One of the advantages of VL is purported to be that it can be more successful in challenging airways [2]. Video laryngoscopes are indirect laryngoscopes with small video cameras attached distally on the undersurface of the blade. The video camera brings an external view of the airway onto a screen, obviating the need for alignment of the three airway axes, and thus eliminating the need to manipulate the C-spine. Multiple VL devices are available, but two of the most common are the GlideScope (Verathon Inc, Bothell, Washington) and the C-MAC (Karl Storz, Tuttlingen, Germany) [3, 4]. The blade of the GlideScope has a 60-degree anterior curvature, whereas the blade of the C-MAC is identical in shape to a Macintosh blade, except for the camera attached to the distal portion of the blade. Several studies in recent years have suggested that VL offers better visualization of the laryngeal inlet and may be a better technique for tracheal intubation in patients with a difficult airway [3–15]. However, many of these studies focused on manikins, on patients undergoing elective intubations, or on cadavers. Therefore, this study was undertaken to compare the success rate of video laryngoscopy to direct laryngoscopy in trauma patients in a trauma center. We hypothesized that the success rate of VL would be higher than that of DL in trauma patients.

Materials and methods

Data were collected prospectively on all trauma patients who required intubation in an academic level I trauma center from January 1, 2008, through June 30, 2011. The University of Arizona's Institutional Review Board approved the study.

This trauma center has a trauma volume of 4,800 patients and 2,500 admissions. Our trauma team activations are staffed with attending faculty and residents from both the trauma surgery and emergency medicine (EM) service. The airway management of our trauma patients is primarily performed by emergency medicine (EM) residents, supervised by the EM attendings. The choice of method of intubation and device type was at the discretion of the EM attending. If the first intubation attempt was not successful, the EM attending decided whether to switch devices or not. For DL, the Macintosh, Miller, and Grandview blades were available. For VL, both the GlideScope and C-MAC were available. For the GlideScope intubations, potential options were the GlideScope standard (reusable blade, size 2, 3, and 4), the GlideScope Cobalt (disposable blade, size 3 and 4), and the portable GlideScope Ranger (reusable blade). The C-MAC options included a size 2, 3, or 4 MAC blade. In trauma patients who presented with a C-collar, the anterior portion of the C-collar was removed and manual in-line immobilization was used prior to intubation.

All trauma patients of any age who required intubation in our ED were included in this study. We excluded patients previously intubated by prehospital providers and patients initially thought to have suffered trauma but subsequently found to have medical diagnoses. Patients were also excluded if they were not intubated using one of the above techniques.

A one-page data collection sheet was completed by the intubator after every intubation (Appendix). For any intubation without a completed form, the intubator was sent a blank form to complete immediately. Approximately 94 % of intubation forms were filled out in real time with only 6 % being filled out on a delayed basis.

The form included space for the following information: indication for intubation, diagnosis, presence of difficult airway predictors (DAPs), including short neck, cervical immobility, obesity, small mandible, large tongue, blood or vomit in the airway, airway edema, and facial or neck trauma, the Cormack–Lehane (CL) view (Table 1), the type and size of device used, the number and type of complications, as well as the experience level (postgraduate year) of the intubator. We obtained additional data on demographics, injury characteristics, and outcomes from the trauma registry by matching patients using their unique visit numbers.

Our study's primary endpoint was successful tracheal intubation without the need to change the intubation

Table 1 Grading of Cormack–Lehane views

Grade I	Visualization of the entire laryngeal aperture
Grade II	Visualization of parts of the laryngeal aperture or the arytenoids
Grade III	Visualization of only the epiglottis
Grade IV	Visualization of only the soft palate

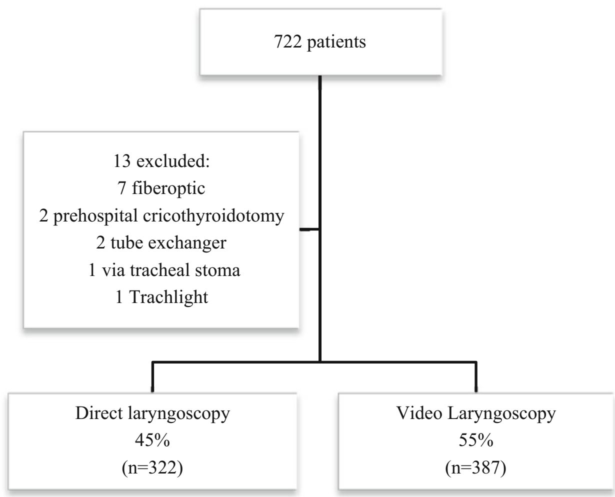

Fig. 1 Patient enrollment

device. Secondary endpoints included success on first attempt, CL view, complications, and reasons for intubation failure on first attempt. Subgroup analyses were performed based on DAPs, mechanism of injury, and operator experience level. Multivariate analysis was performed to identify risk factors for intubation failure out of all attempts that were performed with the initial device.

An attempt was defined as insertion of the laryngoscope into the patient's mouth, regardless of whether there was an attempt to pass an ETT. First pass success was defined as successful intubation on a single laryngoscopic insertion. Overall success was defined as successful intubation with the initial device selected, regardless of the number of attempts. The three methods of intubation included rapid sequence intubation (RSI) with the use of a paralytic agent, oral intubation with sedation only (no paralytic used), and oral intubation without the use of any medications. To examine differences between groups, we used Chi-square testing for categorical variables and the Student t test for continuous variables. Mann–Whitney U testing was used to examine non-parametric data. To analyze our data, we used STATA version 12. A P value less than 0.05 was considered statistically significant.

Results

A total of 722 trauma patients were intubated in our ED during our study period and met inclusion criteria. We excluded 13 patients for the following reasons; 7 underwent fiberoptic intubations; 2 patients underwent prehospital cricothyroidotomy; another 2 were intubated using a tube exchanger; 1 underwent a TrachLight^{TM} intubation; and one patient had a tracheal stoma and an endotracheal tube was therefore placed percutaneously (Fig. 1).

Table 2 Demographics and injury characteristics

	DL ($n = 322$)	VL ($n = 387$)	P value
Age, mean ± SD	37 ± 21.9	39 ± 19	0.21
Male (%)	75	77	0.45
Blunt mechanism (%)	81	83	0.43
SBP <90 mmHg (%)	10	15	0.02
GCS ≤8 (%)	45	52	0.09
ISS, median (IQR)	20.5 (9–29)	24 (10–31)	0.01
Head AIS, median (IQR)[a]	4 (3-5)	4 (3–5)	0.47
Face AIS, median (IQR)[b]	2 (1–2.5)	2 (1–3)	0.19
DAP, mean ± SD	1.6 ± 1.4	2.1 ± 1.4	<0.001
C-spine immobilization (%)	61	74	<0.001
Indication for intubation (%)			0.98
Airway control	70.2	70.8	
Respiratory failure	6.2	6.2	
Patient control	14	12.7	
Cardiac arrest	8.7	9.3	
Hypoxia	0.9	1.0	
Reason for device selection (%)			<0.001
Standard airway	95	20.4	
Difficult airway	4.1	63.8	
Education	0.9	15.8	
PGY level of intubator, median (IQR)	2 (1)	2 (1)	0.24
RSI (%)	87	85	0.11

AIS abbreviated Injury score, *DAP* difficult airway predictor, *DL* direct laryngoscopy, *VL* video laryngoscopy, *GCS* glasgow coma scale, *ISS* injury severity score, *RSI* rapid sequence intubation, *SBP* systolic blood pressure, *SD* standard deviation, *PGY* postgraduate year, *IQR* interquartile range

[a] Number of patients with reported AIS of the head: DL = 195, VL = 270

[b] Number of patients with reported AIS of the face DL = 88, VL = 115

Our final study group consisted of 709 patients who underwent either DL ($n = 322$, 45 %) or VL ($n = 387$, 55 %) (Table 2). There was no difference in age, gender, or mechanism between the two groups. VL patients were more severely injured (median Injury Severity Score [ISS], 24 (10–31)) than DL patients (median ISS, 20.5 (9–29), $P = 0.01$). Patients who were chosen to be intubated with VL presented with more DAPs and their C-spine was more often immobilized. Indications for intubation were the same in both groups. The median postgraduate year (PGY) level of the intubator did not differ between groups. RSI was used in most patients ($n = 610$, 86 %), followed by oral intubation with sedation only ($n = 92$, 13 %) and then by oral intubation without the use of any medications ($n = 7$, 1 %).

Table 3 Cormack–Lehane views

CL grade (%)	DL ($n = 322$)	VL ($n = 387$)	P value
Grade I	51.9	74.9	
Grade II	32	16.7	<0.001
Grade III	13	5.5	
Grade IV	3.1	2.9	

CL Cormack–Lehane view, *DL* direct laryngoscopy, *VL* video laryngoscopy

When a DL was used, the reason for that device being chosen was as follows: standard airway (92.6 %), prediction of a difficult airway (5.5 %), and educational purposes (1.9 %). VL was mainly used when a difficult airway was predicted (63.8 %), followed by standard airway (20.4 %), and educational purposes (15.8 %). Bougies were used more frequently in patients who underwent DL (2.5 %) than in those undergoing VL (0.5 %) ($P = 0.03$). VL achieved a better laryngoscopic view than DL in the majority of cases (Table 3).

As shown in Table 4, first pass success did not differ in both groups (76 % for VL and 71 % for DL, $P = 0.17$). VL had higher rates of overall success (83 % for DL and 88 % for VL, $P = 0.05$). VL success rate was also significantly higher than DL when C-spine immobilization was required (87 vs. 80.0 %, $P = 0.03$). Both groups required similar intubation attempts to achieve overall success. Patients who failed intubation with the initial device ($n = 101$, 16.6 %) required a different device to achieve successful intubation in 54 % of cases. The success of DL when used as a second choice was 94.6 %, whereas VL succeeded in 85.7 % of cases.

In terms of complications, DL was associated with twice as many esophageal intubations, although it was not statistically significant. (Table 5) Desaturations less than 90 % were observed in 15 % of VL intubations compared to 9 % of DL intubations. Inability to visualize the vocal cords caused the majority of DL intubation failures, whereas a significant portion of the VL failures was caused by the inability to direct the ET tube (Table 6).

On multivariate regression analysis DL had two times higher odds of failing intubation compared to VL, after controlling for male gender, presence of shock, head and face injury severity scores, DAPs, and intubator experience. Blood in the oropharynx and a small mandible were also independent factors for failed initial intubation. (Table 7).

Table 4 Success of DL and VL, by subgroup

Intubation success (%)	DL ($n = 322$)	VL ($n = 387$)	P Value
First pass success	71	76	0.17
Overall success	83	88	0.05
Intubation attempts, mean ± SD	1.5 ± 1.1	1.3 ± 0.7	0.07
Overall Success by Subgroups			
DAP			
C-spine immobilization ($n = 483$)	80	87	0.03
Blood in airway ($n = 281$)	78	82	0.38
Vomit in airway ($n = 85$)	79	89	0.21
Short neck ($n = 69$)	68	83	0.15
Small mandible ($n = 25$)	40	67	0.19
Obesity ($n = 74$)	74	81	0.46
Airway edema ($n = 37$)	56	79	0.18
Facial trauma ($n = 220$)	86	87	0.74
Large tongue ($n = 66$)	62	84	0.045
DAP ≥3 ($n = 230$)	75	81	0.26
Blunt mechanism ($n = 582$)	82	88	0.08
Hypotension ($n = 93$)	78	88	0.18
GCS ≤8 ($n = 346$)	84	83	0.89
Head AIS ≥3 ($n = 387$)	83	88	0.08
Face AIS ≥3 ($n = 51$)	83	90	0.12
Experience level			
MS 4 ($n = 4$)	67	100	0.51
Paramedic ($n = 3$)	100	100	N/A
PGY1 ($n = 112$)	82	96	0.63
PGY2 ($n = 267$)	88	94	0.09
PGY3 ($n = 312$)	85	88	0.39
PGY4 ($n = 2$)	–	100	0.16
Attending ($n = 9$)	67	100	0.26

C-spine cervical spine, *DAP* difficult airway predictor, *DL* direct laryngoscopy, *VL* video laryngoscopy, *PGY* postgraduate year, *MS* medical student, *GCS* glasgow coma scale, *SD* standard deviation

Table 5 Complications, by device

Complications (%)	DL ($n = 267$)	VL ($n = 341$)	P value
Esophageal intubation	3.0	1.8	0.3
Mainstem intubation	4.1	2.6	0.3
Aspiration	1.1	1.5	0.7
Desaturation	9.4	14.1	0.08
Total	17.6	20	0.2

Desaturation saturations less than 90 %, *DL* direct laryngoscopy, *VL* video laryngoscopy

[a] In these 608 patients, only one device was used

Discussion

In this study, overall successful tracheal intubation rates were higher for VL compared to DL. After controlling for several factors, DL was associated with higher intubation failure rates compared to VL. Several reports in the literature on patients with DAPs have shown that VL offers better visualization of the glottis [6–8, 11, 13, 15].

Table 6 Reasons for intubation failure on first attempt

Intubation failure (%)	DL ($n = 85$)	VL ($n = 87$)	*P* value
Inability to visualize cords	64.7	46	
Failure to direct the ET tube	21.2	40.2	
Esophageal intubation	10.6	6.9	0.05
Equipment failure	2.4	4.6	
Other[a]	1.2	2.3	

DL direct laryngoscopy, *VL* video laryngoscopy, *ET* endotracheal

[a] Increased secretions, inexperience with the video laryngoscope

Table 7 Multivariate analysis for intubation failure

	Odds ratio	95 % Confidence interval	*P* value
DL vs. VL	1.82	1.15–2.86	0.01
Blood in airway	2.26	1.41–3.92	0.002
Short mandible	5.9	2.29–15.2	<0.001

Variables in multivariate regression model: age, gender, presence of head injury, presence of facial injury, difficult airway predictors, experience level of intubator

DL direct laryngoscopy, *VL* video laryngoscopy

According to those reports, time and ease of intubation differed among various VL devices and studies. However, those reports were severely limited by their sole focus on manikins and by the different skill levels of their intubators.

In the initial stages of assessing a trauma patient, airway management is always considered to be of paramount importance. Its key significance is backed by the current Advanced Trauma Life Support (ATLS) guidelines [16]. Securing the airway can be challenging in trauma patients., who may have facial injuries, cervical fractures or cervical collars in place, full stomachs with the consequent risk for aspiration, secretions, or blood in their airway. This, in addition to the urgency of the trauma setting can make securing the airway more difficult and risky than an elective intubation [17–19]. All of these factors likely contribute to the rate of success for intubation being lower than in elective circumstances.

VL was superior to DL when patients presented with difficult airway predictors, severe facial or head injury but reached only statistical significance in patients with C-spine immobilization. After adjusting for those factors, VL was superior to DL in terms of overall success. A recent randomized controlled study focused on the effect of VL and DL on trauma mortality [19]. In this report, first pass success was similar between the two devices but intubation duration was significantly longer for the VL group. Our study did not capture intubation duration, but there was a trend toward more frequent desaturations with the VL group, which may have resulted from more prolonged intubation times. Higher mortality was observed in the VL group who presented with severe head injury and was attributed to prolonged intubation times. However, intubation times between survivors and non-survivors were similar. Lastly, difficult airway predictors were not accounted for. This presents a significant limitation, since our study showed that those predictors can significantly impact intubation success.

Visualization of the vocal cords remains the main prerequisite for successful intubation with DL. However, in trauma patients C-spine immobilization makes it difficult to obtain a view of the glottic inlet, while maintaining the C-spine in a neutral position [20–22]. Such patients are at risk of complications, related either to unintentional C-spine motion or to repeated unsuccessful intubation attempts [23]. In contrast, VL does not require alignment of the axes; thus, movement of the C-spine is not necessary [24–28]. Our data showed that when there was cervical spine immobilization in place, the intubation rate was significantly higher with VL, compared to DL.

Several studies have compared direct laryngoscopy to video laryngoscopy in a simulated difficult airway with cervical immobilization. VL has been associated with a better view of the airway [6–10], an improved success rate [7, 9, 10, 29, 30], reduced procedural difficulty [8, 11, 29, 31–33], and faster intubation times [7, 8, 34]. Multiple studies have found a better view of the glottis with VL, but the better view is not associated with successful intubation in all patients. Our study confirmed that the laryngeal view is improved with VL devices; however, adequate visualization of the vocal cords did not determine successful intubation in all cases, where inability to advance the ET tube caused intubation failure in 40.2 % of the cases. Similarly, esophageal intubations were more frequent with DL, which can be also attributed to the worse glottic view with DL. The Cormack–Lehane grading system had been designed for direct laryngoscopy, and failure to pass the ET tube despite good visualization of the vocal cords has been reported as a reason for intubation failure in the VL group. The 60-degree angle of the GlideScope blade does not offer the straight line of view seen with DL, so the ET tube needs to be advanced around a curvature. Additionally, blood or vomit in the airway, which is frequently encountered in a trauma patient, can severely disturb the view of the glottis by causing contamination of the video camera lens. This may require removal of the VL to wipe off the lens, and thus could potentially increase the number of attempts at intubation or prolong the total intubation time. The net result could potentially be a higher incidence of oxygen desaturations, as our study showed and has been also previously described [19].

Conversely, it has recently been shown that video laryngoscopy has fewer advantages when used by experienced anesthesiologists in an experiment using an airway manikin [35]. However, most trauma centers do not have the luxury of anesthesiologists attending in every trauma activation [36], and we feel that our study more closely resembles that of the real-world situation where residents and attendings of differing levels of experience are performing the intubations.

Our study has several limitations. Selection bias may exist since our patients were not randomized to either DL or VL. The specific device used was based on attending preference, and these preferences varied among the different faculty members. However, once the device was chosen, the resident performing the procedure would not be able to predict success or failure. In addition, although we attempted to measure and account for several potential confounders (e.g., the severity of trauma, the training level of the resident), we may have omitted some important confounders. We were unable to calculate time to intubation, as we did not have dedicated research staff that was able to measure this. Although we were able to quantify the PGY level of the residents and showed that this was not a factor in success rates, we do not have data on each individual's experience level. Nor do we have data on the level of experience of the supervising attending.

The main strengths of our study are the number of patients included and the structured data form that was completed immediately after each intubation, when the details of the procedure were fresh in the mind of the intubator.

Conclusions

We conclude that VL in trauma patients is associated with higher overall success rates than DL, especially in patients with C-spine immobilization and after controlling for other difficult airway predictors. These data suggest that for patients with C-spine immobilization, VL should be the preferred method of intubation in the ED. We do not wish to suggest that DL be abandoned, as from a training perspective, expertise must be attained in this modality before video laryngoscopy can be effective; operators should be proficient at both methods of intubations, so that the appropriate technique can be selected.

References

1. Burkle CM, Zepeda FA, Bacon DR et al (2004) A historical perspective on use of the laryngoscope as a tool in anesthesiology. Anesthesiology 100:1003–1006
2. Agro F, Barzoi G, Montecchia F (2003) Tracheal intubation using a Macintosh laryngoscope or a GlideScope in 15 patients with cervical spine immobilization. Br J Anaesth 90:705–706
3. Sakles JC, Mosier JM, Chiu S et al (2012) Tracheal intubation in the emergency department: a comparison of GlideScope(R) video laryngoscopy to direct laryngoscopy in 822 intubations. J Emerg Med 42:400–405
4. Sakles JC, Patanwala AE, Mosier JM et al (2014) Comparison of video laryngoscopy to direct laryngoscopy for intubation of patients with difficult airway characteristics in the emergency department. Intern Emerg Med 9:93–98
5. Niforopoulou P, Pantazopoulos I, Demestiha T et al (2010) Video-laryngoscopes in the adult airway management: a topical review of the literature. Acta Anaesthesiol Scand 54:1050–1061
6. Kim HJ, Chung SP, Park IC et al (2008) Comparison of the GlideScope video laryngoscope and Macintosh laryngoscope in simulated tracheal intubation scenarios. Emerg Med J 25:279–282
7. Savoldelli GL, Schiffer E, Abegg C et al (2008) Comparison of the Glidescope, the McGrath, the Airtraq and the Macintosh laryngoscopes in simulated difficult airways*. Anaesthesia 63:1358–1364
8. Bair AE, Olmsted K, Brown CA 3rd et al (2010) Assessment of the storz video Macintosh laryngoscope for use in difficult airways: a human simulator study. Acad Emerg Med 17:1134–1137
9. Koh JC, Lee JS, Lee YW et al (2010) Comparison of the laryngeal view during intubation using Airtraq and Macintosh laryngoscopes in patients with cervical spine immobilization and mouth opening limitation. Korean J Anesthesiol 59:314–318
10. Zamora JE, Nolan RL, Sharan S et al (2011) Evaluation of the Bullard, GlideScope, Viewmax, and Macintosh laryngoscopes using a cadaver model to simulate the difficult airway. J Clin Anesth 23:27–34
11. Nasim S, Maharaj CH, Butt I et al (2009) Comparison of the Airtraq and Truview laryngoscopes to the Macintosh laryngoscope for use by Advanced Paramedics in easy and simulated difficult intubation in manikins. BMC Emerg Med 9:2
12. Mosier JM, Stolz U, Chiu S et al (2012) Difficult airway management in the emergency department: GlideScope videolaryngoscopy compared to direct laryngoscopy. J Emerg Med 42:629–634
13. Tan BH, Liu EH, Lim RT et al (2009) Ease of intubation with the GlideScope or Airway Scope by novice operators in simulated easy and difficult airways–a manikin study. Anaesthesia 64:187–190
14. Benjamin FJ, Boon D, French RA (2006) An evaluation of the GlideScope, a new video laryngoscope for difficult airways: a manikin study. Eur J Anaesthesiol 23:517–521
15. McElwain J, Malik MA, Harte BH et al (2010) Comparison of the C-MAC videolaryngoscope with the Macintosh, Glidescope, and Airtraq laryngoscopes in easy and difficult laryngoscopy scenarios in manikins. Anaesthesia 65:483–489
16. Kortbeek JB, Al Turki SA, Ali J et al (2008) Advanced trauma life support, 8th edition, the evidence for change. J Trauma 64:1638–1650
17. Langeron O, Birenbaum A, Amour J (2009) Airway management in trauma. Minerva Anestesiol 75:307–311
18. Stephens CT, Kahntroff S, Dutton RP (2009) The success of emergency endotracheal intubation in trauma patients: a 10-year experience at a major adult trauma referral center. Anesth Analg 109:866–872
19. Yeatts DJ, Dutton RP, Hu PF et al (2013) Effect of video laryngoscopy on trauma patient survival: a randomized controlled trial. The journal of trauma and acute care surgery 75:212–219
20. Thiboutot F, Nicole PC, Trepanier CA et al (2009) Effect of manual in-line stabilization of the cervical spine in adults on the rate of difficult orotracheal intubation by direct laryngoscopy: a randomized controlled trial. Can J Anaesth 56:412–418
21. Santoni BG, Hindman BJ, Puttlitz CM et al (2009) Manual in-line stabilization increases pressures applied by the laryngoscope

blade during direct laryngoscopy and orotracheal intubation. Anesthesiology 110:24–31
22. Aoi Y, Inagawa G, Hashimoto K et al (2011) Airway scope laryngoscopy under manual inline stabilization and cervical collar immobilization: a crossover in vivo cinefluoroscopic study. J Trauma 71:32–36
23. Mort TC (2004) Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts. Anesth Analg 99:607–613
24. Hirabayashi Y, Fujita A, Seo N et al (2008) A comparison of cervical spine movement during laryngoscopy using the Airtraq or Macintosh laryngoscopes. Anaesthesia 63:635–640
25. Maruyama K, Yamada T, Kawakami R et al (2008) Randomized cross-over comparison of cervical-spine motion with the AirWay Scope or Macintosh laryngoscope with in-line stabilization: a video-fluoroscopic study. Br J Anaesth 101:563–567
26. Maruyama K, Yamada T, Kawakami R et al (2008) Upper cervical spine movement during intubation: fluoroscopic comparison of the AirWay Scope, McCoy laryngoscope, and Macintosh laryngoscope. Br J Anaesth 100:120–124
27. Turkstra TP, Pelz DM, Jones PM (2009) Cervical spine motion: a fluoroscopic comparison of the AirTraq Laryngoscope versus the Macintosh laryngoscope. Anesthesiology 111:97–101
28. Dupanovic M, Fox H, Kovac A (2010) Management of the airway in multitrauma. Curr Opin Anaesthesiol 23:276–282
29. Malik MA, Maharaj CH, Harte BH et al (2008) Comparison of Macintosh, Truview EVO2, Glidescope, and Airwayscope laryngoscope use in patients with cervical spine immobilization. Br J Anaesth 101:723–730
30. Takahashi K, Morimura N, Sakamoto T et al (2010) Comparison of the Airway Scope and Macintosh laryngoscope with in-line cervical stabilization by the semisolid neck collar: manikin study. J Trauma 68:363–366
31. Malik MA, Subramaniam R, Churasia S et al (2009) Tracheal intubation in patients with cervical spine immobilization: a comparison of the Airwayscope, LMA CTrach, and the Macintosh laryngoscopes. Br J Anaesth 102:654–661
32. Malik MA, O'Donoghue C, Carney J et al (2009) Comparison of the Glidescope, the Pentax AWS, and the Truview EVO2 with the Macintosh laryngoscope in experienced anaesthetists: a manikin study. Br J Anaesth 102:128–134
33. Aoi Y, Inagawa G, Nakamura K et al (2010) Airway scope versus macintosh laryngoscope in patients with simulated limitation of neck movements. J Trauma 69:838–842
34. Liu EH, Goy RW, Tan BH et al (2009) Tracheal intubation with videolaryngoscopes in patients with cervical spine immobilization: a randomized trial of the Airway Scope and the GlideScope. Br J Anaesth 103:446–451
35. Wetsch WA, Spelten O, Hellmich M et al (2012) Comparison of different video laryngoscopes for emergency intubation in a standardized airway manikin with immobilized cervical spine by experienced anaesthetists. A randomized, controlled crossover trial. Resuscitation 83:740–745
36. Hardcastle TC, Goff T (2007) Trauma unit emergency doctor airway management. S Afr Med J 97:864–867