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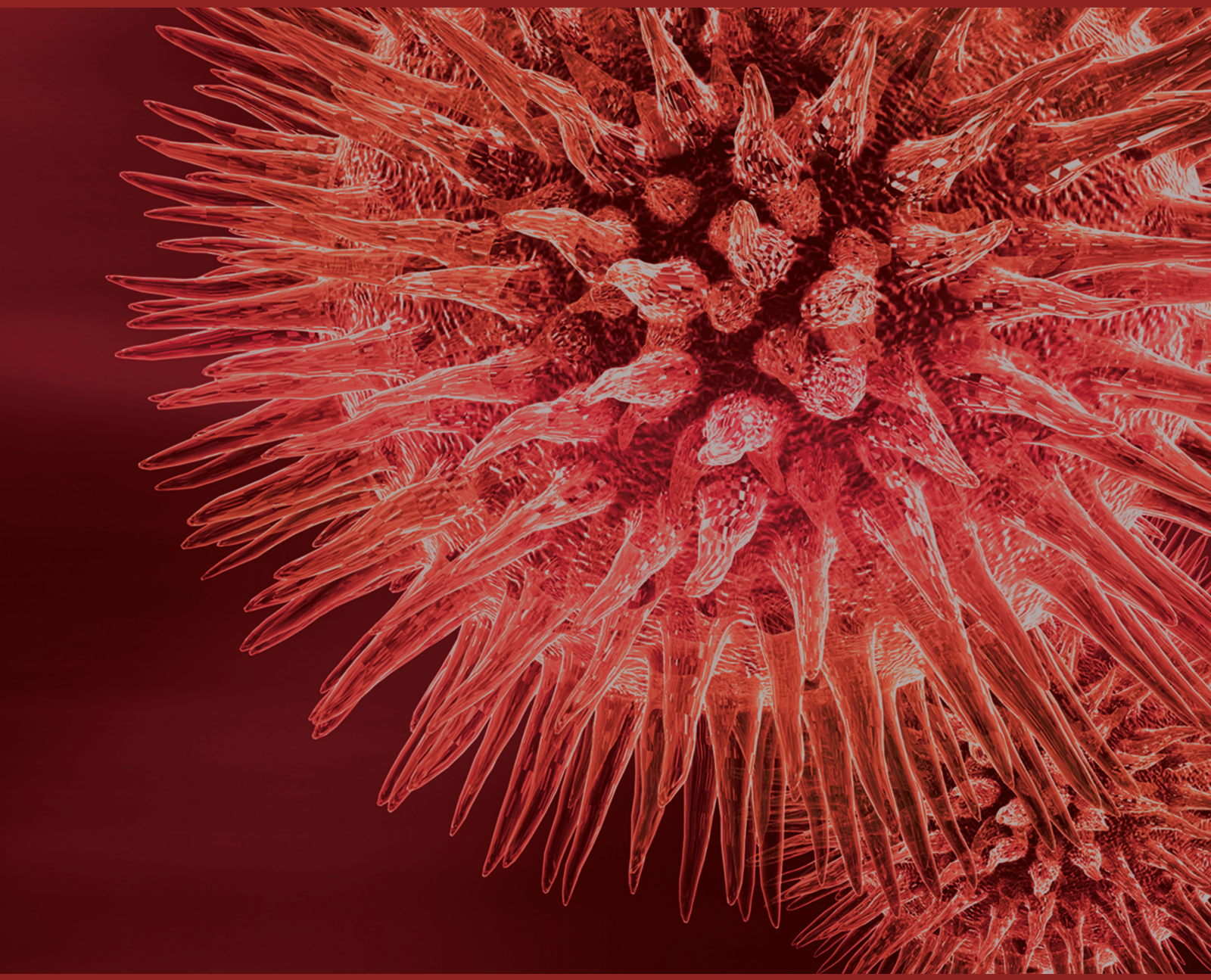
Advances in Airway Management and Ventilation Strategies in Emergency Medicine

Guest Editors: Tomasz Gaszynski, Kamil Toker, Massimiliano Carassiti, Athanasios Chalkias, and Jestin N. Carlson



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Contents

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Editorial

Advances in Airway Management and Ventilation Strategies in Emergency Medicine

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Effective management of the airway is a priority in resuscitation efforts and a central issue in emergency medicine for providing ventilation and oxygenation in critically ill patients. Compared to the controlled conditions of the operating theatre, airway management in the emergency department is more difficult than in other circumstances; the patient may be in respiratory distress, desaturating, or may have a compromised airway. In addition, sedation may have a profound effect on hemodynamically unstable patients, who may become severely hypotensive and rapidly deteriorated, while preparation of the patient, environment, and equipment is often challenging [1, 2].

This special issue is published with the intent of serving as a procedure manual for disseminating advances in airway management and ventilation strategies to all providers who are involved in emergency care. This issue highlights the explosive growth of video laryngoscopy which is rapidly becoming first-line for both in- and out-of-hospital airway management.

In this issue, S. Fujiwara et al. compare the utility of the Pentax-AWS Airwayscope (AWS) with the GlideScope (GS) during chest compressions on an infant manikin. They report that the AWS performs better than the GS for endotracheal intubation during ongoing cardiopulmonary resuscitation (CPR).

S. Lee et al. compare intubation performances among Pentax-AWS (AWS), GlideScope (GVL), and Macintosh laryngoscope (MCL) during mechanical chest compression in 15° and 30° left lateral tilt, simulating maternal cardiopulmonary resuscitation. Their study indicates AWS as an appropriate laryngoscope for airway management of pregnant women in lateral tilt.

P. Schoettker and J. Corniche assess the quality and speed of intubation between the Airtraq with its new iPhone AirView app and the King Vision in a manikin study. They report that the Airtraq-AirView allows faster identification of the landmarks and intubation in a difficult airway manikin, highlighting the need for further research. Also, H. Y. Choi et al. acknowledge the importance of early airway management in severely ill patients by investigating the efficacy of face-to-face intubation in four different types of laryngoscopes. In this study, Pentax Airway Scope and Macintosh were the most favorable laryngoscopes in face-to-face intubation.

In an extensive review, M. Barak et al. discuss the complexity and difficulties of securing the airway of patients with maxillofacial trauma and present their approach for airway management of such patients. Despite the recent advances in emergency airway management techniques, healthcare personnel may still face the "cannot ventilate, cannot intubate" scenario in which the specialized equipment

may be invaluable. In this context, T. Doi et al. investigated the influence of upper airway resistance (UAR) during transtracheal jet ventilation by comparing a manual jet ventilator (MJV) and the oxygen flush device of the anesthetic machine (AM). In their model, the influence of choked flow from the Venturi effect was minimal under all UAR settings with the MJV, but the AM could not deliver sufficient flow.

J. N. Carlson et al. perform a proof of concept study to determine if portable motion technology could identify the motion components of endotracheal intubation between novice and experienced providers using inertial measurement units (IMUs) to record the movements during endotracheal intubation. They conclude that portable IMUs can be used to detect differences in movement patterns between novice and experienced providers, suggesting their value in educational efforts.

Field intubation is a complex process and time to intubation, number of attempts, and hypoxia have all been shown to correlate with increases in morbidity and mortality. B. Boehringer et al. investigate the "Impact of Video Laryngoscopy on Advanced Airway Management by Critical Care Transport Paramedics and Nurses Using the CMAC Pocket Monitor" in field intubation. They report that the CMAC video laryngoscope improves success rates in airway management, indicating that video laryngoscopes may be crucial in out-of-hospital airway management.

As many challenges are augmented in the acute setting, emergency providers must be skilled with airway management [3]. Advances in airway management technology have helped to improve many aspects of emergency airway management; however, expertise alone cannot make up for the lack of the right equipment or adequate understanding of new technologies. Conversely, these new technologies do not obviate the need for a solid foundation in airway management techniques. Up to 4% of patients who undergo emergent intubation suffer a cardiac arrest [4], indicating that a more complete understanding of the interaction between clinical experience and technological advances is needed to increase the effectiveness and improve the safety of patients undergoing emergency airway management. This special issue helps to expand our knowledge of this intersection within emergency airway management.

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References

[1] T. M. Cook, N. Woodall, J. Harper, and J. Benger, "Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments," *British Journal of Anaesthesia*, vol. 106, no. 5, pp. 632–642, 2011.

[2] A. N. Thomas and B. A. McGrath, "Patient safety incidents associated with airway devices in critical care: a review of reports to the UK National Patient Safety Agency," *Anaesthesia*, vol. 64, no. 4, pp. 358–365, 2009.

[3] J. L. Apfelbaum, C. A. Hagberg, R. A. Caplan et al., "Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway," *Anesthesiology*, vol. 118, no. 2, pp. 251–270, 2013.

[4] A. C. Heffner, D. S. Swords, M. N. Neale, and A. E. Jones, "Incidence and factors associated with cardiac arrest complicating emergency airway management," *Resuscitation*, vol. 84, no. 11, pp. 1500–1504, 2013.

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Research Article

Impact of Video Laryngoscopy on Advanced Airway Management by Critical Care Transport Paramedics and Nurses Using the CMAC Pocket Monitor

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Accurate endotracheal intubation for patients in extremis or at risk of physiologic decompensation is the gold standard for emergency medicine. Field intubation is a complex process and time to intubation, number of attempts, and hypoxia have all been shown to correlate with increases in morbidity and mortality. Expanding laryngoscope technology which incorporates active video, in addition to direct laryngoscopy, offers providers improved and varied tools to employ in management of the advanced airway. Over a nine-year period a helicopter emergency medical services team, comprised of a flight paramedic and flight nurse, intended to intubate 790 patients. Comparative data analysis was performed and demonstrated that the introduction of the CMAC video laryngoscope improved nearly every measure of success in airway management. Overall intubation success increased from 94.9% to 99.0%, first pass success rates increased from 75.4% to 94.9%, combined first and second pass success rates increased from 89.2% to 97.4%, and mean number of intubation attempts decreased from 1.33 to 1.08.

1. Introduction

Prehospital advanced airway management by paramedics and nurses has become an increasingly relevant and debated topic. Research has persistently demonstrated that failure rates of prehospital transport personnel are far higher and fraught with more complications compared to those of in-hospital personnel or physician based helicopter EMS (HEMS) colleagues [1, 2]. In cases such as cardiac arrest, recently published data is beginning to show that management with supraglottic airways or a bag-valve mask may be effective, especially in cases where immediate airway protection by endotracheal tube (ETT) is unlikely or apt to be accompanied by adverse events [3–6].

The North American HEMS crew configuration of a nurse and paramedic is atypical when compared with the international air medical industry. Research shows that critical care flight crews in this configuration manage the airway more successfully than their ground counterparts [7] and often quite similar to that of their physician colleagues who document ETT successes of between 95% and 99.2% [8, 9]. While there is a clear correlation between successful airway management and volume of exposure, the impact of aggressive education and QI processes remain unclear [10]. Furthermore rapid sequence induction protocols appear to improve first pass success of prehospital providers [10–16], as does video laryngoscopy, especially with respect to difficult airways [17, 18]. Video laryngoscopy has demonstrated shorter entry to POGO (percentage of glottic opening) and entry to tube times, improved glottic view, and lower incidence of esophageal ETT placement [19–22].

The gold standard for successful airway management continues to be the ability to insert an ETT on the first attempt with minimal or no adverse sequela such as hypoxia

or hypotension. It has been shown that adverse events and failure rates increase with repeat attempts at intubation [23–25] and occur more quickly between the first and second attempts. In fact, a single repeat intubation attempt increases the risk of experiencing an adverse event from 14% to 47% [23].

The intent of this retrospective chart review and analysis was to determine the impact of adding video laryngoscopy on markers related to effective prehospital airway management by a North American critical care transport team. Primary clinical indicators were first pass success, combined first and second pass success, ultimate method of securing the airway, and need for rescue airways such as supraglottic devices and cricothyrotomy.

2. Methods

This was a retrospective chart review of intubations performed by critical care flight paramedics and nurses from 2006 through the third quarter of 2014. Intubation attempts were defined as laryngoscopy with intent to place an advanced airway. For example, if laryngoscopy was aborted and a device would have been placed had a view been possible, this was considered an attempt.

Descriptive data was evaluated at 99% confidence intervals (except where noted) and chi square testing using Fisher's exact test was completed for significance. Raw data is shown in the tables.

Due to the retrospective, quality improvement nature of the data collection the local IRB Committee deemed that this paper did not require approval.

3. Setting

Advanced airway management is done by flight practitioners in a nurse/medic configuration employed at a moderately sized critical care transport organization in the northeast of the United States. The company currently operates two Agusta 109E rotor wing aircraft that offer primary coverage for over 33,000 square miles and 274 first response agencies and interfacility transport services for 38, mostly rural, hospitals. Call volume averages have steadily risen and currently top 1600 each year with approximately 23% scene and 77% interfacility missions though advanced airway encounters are seen more often in scene responses, 58% versus 42%, respectively.

The flight team staff includes both paramedics and nurses who are chosen based upon prior relevant critical care experience. Once selected, all staff receives the same crew member orientation and advanced airway preparation. Prior to autonomous performance on missions crew members must complete a comprehensive advanced airway management education. It minimally includes ten operating room and in situ intubations, an advanced airway skills lab, and quarterly, service-wide QI meetings. Upon completion of orientation, crews are mandated to complete at least two live intubations on adults and one pediatric intubation, which may be performed on a manikin, each quarter. Yearly education requires revisiting the airway lab for updates on advanced airway management which includes surgical airway review and other advanced ventilatory skills. All crew members receive peer to peer and medical director chart review after each flight. Feedback includes medication management of the advanced airway during and after intubation, troubleshooting techniques, and overall success and performance. Rapid sequence intubation (RSI) has been protocolized for the flight practitioners and includes the most current practices in medication administration, adjunct and rescue devices, and general airway management techniques which all may be used during advanced airway management at the discretion of the crew. During the study window there were no significant changes in crew configuration or training.

Until early 2013, direct laryngoscopy was the routine approach used to visualize the vocal cords when securing an advanced airway. Rarely did crews encounter a video laryngoscope of any type at sending facilities. In 2013 the program placed the Karl Storz CMAC Pocket Monitor Video Laryngoscope into service as the primary visualization device. The CMAC was chosen because, unlike many other video laryngoscopes, its shape most closely mimics a traditional Macintosh blade allowing for either a direct or video view, allowing crews to maintain a technique similar to that of traditional laryngoscopy. Standard Macintosh blades sizes 2 and 4 were placed on each aircraft. Intermediate sizes were not chosen due to cost constraints and as such a full set of traditional laryngoscopy devices continue to be carried.

4. Selection of Participants

All patients requiring intubation by flight crews from 2006 through the third quarter of 2014 were included. No distinction was made between ground and flight missions. If the patient expired during a flight crew interaction, and an attempt was made to secure the airway, the experience was included in the study. Both RSI and non-RSI cases were included in the data analysis.

5. Data Collection

Data collection, as part of a robust quality improvement process, has been through thorough review of electronic patient care records. Each patient care record was reviewed for quality markers and patient deterioration. All encounters requiring airway and ventilatory support greater than free flow oxygen were separately screened for decision to intubate based on physiologic markers. Excel spreadsheets were used for primary analysis and to organize data.

6. Results

Total mission volume (ground and air transport) during the study period was 12,361 with 790 advanced airway encounters (6.4%). Two airway encounters were not included in the data review as the GlideScope was used. Initial data analysis showed a gender breakdown of 69% male and 31% female encounters, 60% trauma and 40% medical patients, and 94.3% adult (>13 years of age), 2.8% pediatric (< or = 13,

Table 1: General summary of airway encounter data.

Age	
Adult (>13)	743 (94.30)
Pediatric (<14, >1)	22 (2.8%)
Infant (<1)	11 (1.4%)
Unknown	12 (1.5%)
Sex	
Male	544 (69.4%)
Female	241 (30.5%)
Not documented	3 (0.38%)
Interfacility	331 (42.0%)
Scene	457 (57.97%)
Trauma	473 (60%)
Medical	315 (40%)

*Two GlideScope encounters are not included.

>1 year of age), and 1.4% infant patients (<1 year of age). 1.5% had no age recorded ($n = 12$). See Table 1.

6.1. Successful Endotracheal Intubations by Flight Crew. After the implementation of the CMAC, overall endotracheal intubation success by a critical care transport practitioner increased from 94.9% to 99.0% (significant at CI 95%, chi square = 6.13, Fisher's exact test $P = 0.011$), first pass success rates increased from 75.4% to 94.9% (significant at CI 99%, chi square = 35.12, Fisher's exact test $P < 0.0001$), combined first and second pass success rates increased from 89.2% to 97.4% (significant at CI 99%, chi square = 12.44, Fisher's exact test $P = 0.0002$), and the success to total attempts ratio increased from 71.4% to 91.9% (significant at CI 99%, chi square = 38.05, Fisher's exact test $P < 0.0001$). See Figure 1. While overall and first attempt success adequately reflect a system's exemplary performance, the success to attempt ratio specifically illuminates what is happening in other cases where there was no success, or more than one attempt was required. An alternative view of the success to total attempts ratio would be that, respectively, one extra attempt was required in 3.5 patients, with improvement to one extra attempt in 11 patients. Mean number of intubation attempts for all airway encounters, successful or unsuccessful, decreased from 1.33 ($n = 593$) with direct laryngoscopy to 1.08 ($n = 195$) when using the CMAC. The reduction was statistically significant using a two-tailed t-test (CI 95%, $t = 6.21$, DF 578.12, $P < 0.0001$). There were no attempts to use video laryngoscopy after failed direct laryngoscopy.

6.2. Unsuccessful Intubations by Flight Crew and Outlying Events. In flight intubation occurred in only two instances and both were successful (0.25%).

For patients unable to be intubated with an ETT, supraglottic devices (LMA or King Airways) were placed in 19 cases after direct laryngoscopy (3.2%) and in 1 instance after video laryngoscopy with the CMAC (0.5%). The reduction in supraglottic device use is significant (CI 95%, chi square = 4.297, Fisher's exact test $P = 0.036$).

Table 2: Summary of advanced airway encounters.

	Direct laryngoscopy	CMAC
Total encounters ($n = 790$) *2 GlideScope encounters not included	593	195
Total attempts	789	210
Ultimate ETT success	563	193
Mean attempts	1.33	1.08
First pass success	447	185
First and second pass	529	190
Supraglottic device use	19	1
Other providers secured	7	0
Patient pronounced after 1 attempt (failed ETI)	2	0
Cricothyrotomy	2	1

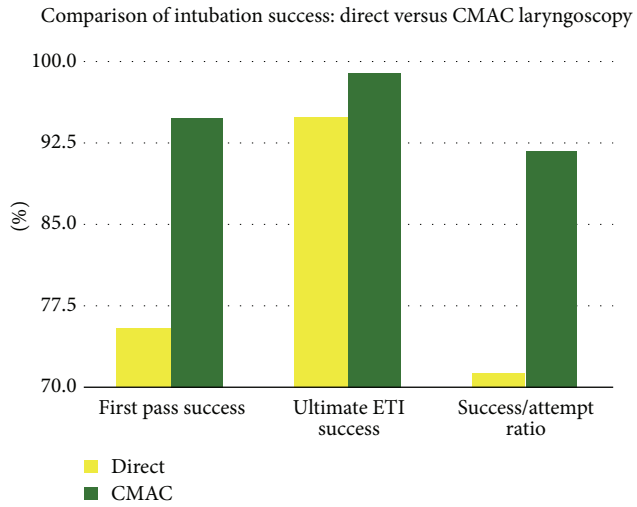

Figure 1: Comparison of intubation success using data from Table 2.

Other providers (CRNA, MD, and on-scene paramedic) secured the airway after initial attempted management by flight crews in 7 cases status after direct laryngoscopy (1.2%) and in 0 cases after video laryngoscopy (0%) which was not significant (CI 95%, chi square = 2.323, Fisher's exact test = 0.2028). Cricothyrotomy was required in two cases of failed direct laryngoscopy (0.3%, both were performed by flight crew) and in one case after failed video laryngoscopy (0.5%, performed by hospital surgeon). The use of cricothyrotomy was not statistically significant (CI 95%, chi square = 0.119, Fisher's exact test $P = 0.574$). See Table 2 for complete results.

7. Discussion

Air medical providers are consistently called for the most critically unstable patients in prehospital and rural primary hospital care. As such, their training must reflect an attempted mastery of the requisite skills, but more importantly, they must maintain a procedural proficiency necessary to care for patients in an extremely dynamic environment. Airway

management is one of these required skills. In recent years prehospital personnel, who have historically seen advanced airway management as part of their standard skill set, have come under increased scrutiny due to worse outcomes when compared with physician counterparts [26]. A 2014 Dutch report lists nonflight trained paramedic first pass success rates at just over 46% [1]. Other reports are equally concerning. Time spent securing the airway, often while neglecting other important tasks, failed attempts, and adverse outcomes have each caused programs, regions, and countries to reevaluate policies around advanced airway management. Often this has left agencies with no other choice than to adopt basic life support level airway management skills, often in the form of blind insertion devices. Skills proficiency and retraining are typically easier and more quickly achieved with these devices. This seems especially prudent in settings where advanced airway management is a rarely practiced skill. Understanding these dynamics is crucial in picking the most appropriate approach to airway management.

Despite an unchanging approach to the process of airway management over the nine-year study period, this agency demonstrated dramatic increases in successful airway management after the implementation of the CMAC video laryngoscope. Improvements were seen in all primary measures of advanced airway success: ultimate endotracheal intubation success, first pass success, combined first and second pass success, success to total attempt ratios, mean attempts, and incidence of supraglottic device use. Historically this critical care transport team demonstrated ultimate endotracheal intubation and first pass success at 94.9% and 76.6%, respectively, which is similar to other internationally reported figures for flight practitioners in the US [11]. Current success and first pass success rates with the CMAC have improved to 99% and 94.9%, respectively. When compared to our historic data prior to the use of the CMAC previous studies have shown higher mean attempts with direct laryngoscopy. The use of video laryngoscopy, however, seems to decrease mean intubation attempts in all patient encounters [27].

In comparison, European critical care teams, whether ground or air based, are more commonly led by a physician and in many cases a physician is required to be present during an intubation attempt. Ultimate intubation success by European physicians is most commonly reported to be between 96 and 99% [1, 8, 28, 29] but as low as 88% [30]. Physician first pass success tends to hover near 85% [1, 31] with a low percentage of 68% [29]. In most cases these reports are at minimum equal to, or worse than, the findings in our data review. This retrospective chart review demonstrates that a US based air ambulance staffed with critical care nurses and paramedics is able to achieve similar, if not better, rates of first pass and overall intubation success with the assistance of video laryngoscopy, in this case the CMAC.

8. Limitations

While our data suggests that the CMAC may have an impressive impact on intubation success, the review certainly has limitations. Some of these are inherent to retrospective reviews and others specific to the human bias in documentation and data collection. Without in situ video documentation of an airway encounter, one can never be certain how many attempts were actually needed to secure an airway, how long it took, or what view was actually obtained. Furthermore defining what counts as an attempt can be equally challenging as some providers may only count attempts at actually placing an endotracheal tube and not the "first look." Strict defining guidelines typically include any instance when a provider places the laryngoscope blade into a patient's mouth but, again, this is hard to ascertain without an independent observer being present or video recording of an encounter that can be independently reviewed at a later date. Our currently reviewed data also fails to include adverse events such as hypotension and hypoxia as these points were not part of historic data collection or the QI process. Other potentially confounding variables that were not taken into account were the induction medications, or lack thereof, and the use of adjuncts such as an introducer.

9. Conclusions

Expanding video laryngoscope technology is offering providers new tools to employ in the management of advanced airways. Options have become more compact and less cost prohibitive for prehospital programs. The body of data to support their use is growing and is supported by this program's experience with the CMAC. While certainly only a piece of the complex puzzle in advanced airway management, clinical markers were significantly improved after its implementation. A robust training program, both initial and ongoing, a routine QI process, and RSI protocols are likely crucial contributors to success in advanced airway management.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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References

[1] J. Peters, B. van Wageningen, I. Hendriks et al., "First-pass intubation success rate during rapid sequence induction of prehospital anaesthesia by physicians versus paramedics," *European Journal of Emergency Medicine*, 2014.

[2] D. P. Davis, J. Peay, J. A. Serrano et al., "The impact of aeromedical response to patients with moderate to severe traumatic brain injury," *Annals of Emergency Medicine*, vol. 46, no. 2, pp. 115–122, 2005.

[3] R. M. Lyon, J. D. Ferris, D. M. Young, D. W. McKeown, A. J. Oglesby, and C. Robertson, "Field intubation of cardiac arrest patients: a dying art?" *Emergency Medicine Journal*, vol. 27, no. 4, pp. 321–323, 2010.

[4] J. V. Nable, B. J. Lawner, and C. T. Stephens, "Airway management in cardiac arrest," *Emergency Medicine Clinics of North America*, vol. 30, no. 1, pp. 77–90, 2012.

[5] K. Hasegawa, A. Hiraide, Y. Chang, and D. F. M. Brown, "Association of prehospital advanced airway management with neurologic outcome and survival in patients with out-of-hospital cardiac arrest," *The Journal of the American Medical Association*, vol. 309, no. 3, pp. 257–266, 2013.

[6] T. Henlin, P. Michalek, T. Tyll, J. D. Hinds, and M. Dobias, "Oxygenation, ventilation, and airway management in out-of-hospital cardiac arrest: a review," *BioMed Research International*, vol. 2014, Article ID 376871, 11 pages, 2014.

[7] M. W. Hubble, L. Brown, D. A. Wilfong, A. Hertelendy, R. W. Benner, and M. E. Richards, "A meta-analysis of prehospital airway control techniques part I: orotracheal and nasotracheal intubation success rates," *Prehospital Emergency Care*, vol. 14, no. 3, pp. 377–401, 2010.

[8] M. le Cong, "Flying doctor emergency airway registry: a 3-year, prospective, observational study of endotracheal intubation by the Queensland Section of the Royal Flying Doctor Service of Australia," *Emergency Medicine Journal*, vol. 29, no. 3, 2010.

[9] S. J. M. Sollid, H. M. Lossius, and E. Søreide, "Pre-hospital intubation by anaesthesiologists in patients with severe trauma: An audit of a Norwegian helicopter emergency medical service," *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, vol. 18, no. 1, article 30, 2010.

[10] C. A. Brown III, K. Cox, S. Hurwitz, and R. M. Walls, "4,871 emergency airway encounters by air medical providers: a report of the air transport emergency airway management (NEAR VI:'A-TEAM') project," *The Western Journal of Emergency Medicine*, vol. 15, no. 2, pp. 188–193, 2014.

[11] L. Lowe, K. Sagehorn, and R. Madsen, "The effect of a rapid sequence induction protocol on intubation success rate in an air medical program," *Air Medical Journal*, vol. 17, no. 3, pp. 101–104, 1998.

[12] W. D. Rose, L. D. Anderson, and S. A. Edmond, "Analysis of intubations: before and after establishment of a rapid sequence intubation protocol for air medical use," *Air Medical Journal*, vol. 13, no. 11-12, pp. 475–478, 1994.

[13] R. F. Sing, M. F. Rotondo, D. H. Zonies et al., "Rapid sequence induction for intubation by an aeromedical transport team: a critical analysis," *American Journal of Emergency Medicine*, vol. 16, no. 6, pp. 598–602, 1998.

[14] M. Murphy-Macabobby, W. J. Marshall, C. Schneider, and D. Dries, "Neuromuscular blockade in aeromedical airway management," *Annals of Emergency Medicine*, vol. 21, no. 6, pp. 664–668, 1992.

[15] O. J. Ma, R. B. Atchley, T. Hatley, M. Green, J. Young, and W. Brady, "Intubation success rates improve for an air medical program after implementing the use of neuromuscular blocking agents," *American Journal of Emergency Medicine*, vol. 16, no. 2, pp. 125–127, 1998.

[16] B. J. Zink and R. F. Maio, "Out-of-hospital endotracheal intubation in traumatic brain injury: outcomes research provides us with an unexpected outcome," *Annals of Emergency Medicine*, vol. 44, no. 5, pp. 451–453, 2004.

[17] M. F. Struck, M. Wittrock, and A. Nowak, "Prehospital Glidescope video laryngoscopy for difficult airway management in a helicopter rescue program with anaesthetists," *European Journal of Emergency Medicine*, vol. 18, no. 5, pp. 282–284, 2011.

[18] M. F. Aziz, D. Healy, S. Kheterpal, R. F. Fu, D. Dillman, and A. M. Brambrink, "Routine clinical practice effectiveness of the glidescope in difficult airway management: an analysis of 2,004 glidescope intubations, complications, and failures from two institutions," *Anesthesiology*, vol. 114, no. 1, pp. 34–41, 2011.

[19] J. N. Carlson, J. Quintero, F. X. Guyette, C. W. Callaway, and J. J. Menegazzi, "Variables associated with successful intubation attempts using video laryngoscopy: a preliminary report in a helicopter emergency medical service," *Prehospital Emergency Care*, vol. 16, no. 2, pp. 293–298, 2012.

[20] J. C. Sakles, "VL vs. DL for emergency room intubation," in *Proceedings of the SAEM Annual Meeting*, Philadelphia, Pa, USA, September 2013, http://www.airwayworld.com/wp-content/uploads/2013/09/Sakles-DL-vs.-VL-Debate-SAM-2013-FINAL.pdf.

[21] J. C. Sakles, J. Mosier, S. Chiu, M. Cosentino, and L. Kalin, "A comparison of the C-MAC video laryngoscope to the macintosh direct laryngoscope for intubation in the emergency department," *Annals of Emergency Medicine*, vol. 60, no. 6, pp. 739–748, 2012.

[22] V. Lakticova, S. J. Koenig, M. Narasimhan, and P. H. Mayo, "Video laryngoscopy is associated with increased first pass success and decreased rate of esophageal intubations during urgent endotracheal intubation in a medical intensive care unit when compared to direct laryngoscopy," *Journal of Intensive Care Medicine*, vol. 30, no. 1, pp. 44–48, 2014.

[23] J. C. Sakles, S. Chiu, J. Mosier, C. Walker, and U. Stolz, "The importance of first pass success when performing orotracheal intubation in the emergency department," *Academic Emergency Medicine*, vol. 20, no. 1, pp. 71–78, 2013.

[24] T. C. Mort, "Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts," *Anesthesia and Analgesia*, vol. 99, no. 2, pp. 607–613, 2004.

[25] T. Goto, K. Gibo, Y. Hagiwara et al., "Multiple failed intubation attempts are associated with decreased success rates on the first rescue intubation in the emergency department: a retrospective analysis of multicentre observational data," *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, vol. 23, no. 1, article 5, 2015.

[26] A. Timmermann, S. G. Russo, and M. W. Hollmann, "Paramedic versus emergency physician emergency medical service: role of the anaesthesiologist and the European versus the Anglo-American concept," *Current Opinion in Anaesthesiology*, vol. 21, no. 2, pp. 222–227, 2008.

[27] M. A. Wayne and M. McDonnell, "Comparison of traditional versus video laryngoscopy in out-of-hospital tracheal intubation," *Prehospital Emergency Care*, vol. 14, no. 2, pp. 278–282, 2010.

[28] H. M. Lossius, J. Røislien, and D. J. Lockey, "Patient safety in pre-hospital emergency tracheal intubation: a comprehensive meta-analysis of the intubation success rates of EMS providers," *Critical Care*, vol. 16, no. 1, article R24, 2012.

[29] F. Adnet, N. J. Jouriles, P. Le Toumelin et al., "Survey of out-of-hospital emergency intubations in the French prehospital medical system: A multicenter study," *Annals of Emergency Medicine*, vol. 32, no. 4, pp. 454–460, 1998.

[30] C. Slagt, A. Zondervan, P. Patka, and J. J. de Lange, "A retrospective analysis of the intubations performed during 5 years of helicopter emergency medical service in Amsterdam," *Air Medical Journal*, vol. 23, no. 5, pp. 36–37, 2004.

[31] J. Von Vopelius-Feldt and J. R. Benger, "Prehospital anaesthesia by a physician and paramedic critical care team in Southwest England," *European Journal of Emergency Medicine*, vol. 20, no. 6, pp. 382–386, 2013.

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Research Article

A Randomized Comparison Simulating Face to Face Endotracheal Intubation of Pentax Airway Scope, C-MAC Video Laryngoscope, Glidescope Video Laryngoscope, and Macintosh Laryngoscope

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Objectives. Early airway management is very important for severely ill patients. This study aimed to investigate the efficacy of face to face intubation in four different types of laryngoscopes (Macintosh laryngoscope, Pentax airway scope (AWS), Glidescope video laryngoscope (GVL), and C-MAC video laryngoscope (C-MAC)). *Method*. Ninety-five nurses and emergency medical technicians were trained to use the AWS, C-MAC, GVL and Macintosh laryngoscope with standard airway trainer manikin and face to face intubation. We compared VCET (vocal cord exposure time), tube pass time, 1st ventilation time, VCET to tube pass time, tube pass time to 1st ventilation time, and POGO (percentage of glottis opening) score. In addition, we compared success rate according to the number of attempts and complications. *Result*. VCET was similar among all laryngoscopes and POGO score was higher in AWS. AWS and Macintosh blade were faster than GVL and C-MAC in total intubation time. Face to face intubation success rate was lower in GVL than other laryngoscopes. *Conclusion*. AWS and Macintosh were favorable laryngoscopes in face to face intubation. GVL had disadvantage performing face to face intubation.

1. Introduction

Intubation is one of the most important procedures attributing prognosis in severely ill patients [1]. Endotracheal intubation success rates are variable depending on airway structure, patient's clinical status, practitioner's skills, and so forth [2, 3]. The video laryngoscopes, recently and widely used, are good substitutes for conventional direct laryngoscope in difficult airway management [4]. They mount camera lens at the tip of laryngoscope and more curved blade, so that intubation can be performed safely and comfortably with clear and wide internal field of vision [5]. Many emergency physicians are concerned about the feasibility of urgent airway management in limited space in means of transporting patients such as ambulances or helicopters in cases of traffic delays, patients' rapid deterioration of mental state, or entrapped

trauma casualties [6]. In prehospital environment in which patients are on the ground or entrapped in vehicles, it is difficult to perform conventional intubation [7–9]. For decades, conventional tracheal intubation was performed at upper side of patient's head. However, mostly, in entrapped patients with restricted position, there is not enough space on patient's head side for tracheal intubation [1]. For this situation, we can try face to face intubation; in other words, inverse intubation can be performed with the provider's face at the same level as the patient's face. There is no needed for another space on patient's head side for tracheal intubation in face to face intubation. Therefore, it can be a very useful method for performing tracheal intubation in restricted position [10]. But it is different from conventional tracheal intubation in the position in which the glottis is viewed and the manipulation of the tube due to the reversely progressing direction. Similarly, since face to face intubation with video laryngoscope differs from conventional intubation, untrained practitioner may feel difficulty performing it.

As described above, face to face intubation will be a good substitute for conventional endotracheal intubation for patients who need urgent endotracheal intubation immediately in limited space [11].

In this study, after teaching the face to face intubation using conventional laryngoscope and video laryngoscopes in manikin model, we analyzed the success rate, time spent, and complications caused by intubation procedure.

2. Methods

The Institutional Review Board at Hallym University Kangnam Sacred Heart Hospital approved this study. IRB number was 2014-11-153.

2.1. Subject. Ninety-five nurses and emergency medical technicians (EMT) participated in a 2-day long airway management education program in Gyeonggi-do fire service academy, South Korea. They were divided into 4 groups and each group was trained in consecutive order.

2.2. Study Design. Instructors gave lectures during 2 hours about endotracheal intubation and airway managements. The lecture session was followed by practice session. They were divided into 4 groups. Each group took 4 different 50-minute long practices which include endotracheal intubation using Macintosh blade and video laryngoscopes and face to face intubation. It took 4 hours in total.

After the practice session, the subjects were divided into four groups and each group took checklist for the test for tracheal intubation. Four groups were divided by kinds of laryngoscopes, direct laryngoscope (Macintosh blade, #4), Pentax airway scope (AWS, Hoya, Tokyo, Japan), C-MAC video laryngoscope pocket with standard #3 blade model (C-MAC, Karl Storz Endoscopy, Tuttlingen, Germany), and Glidescope video laryngoscope with standard #3 blade model (GVL, Verathon Medical Inc., Bothell, WA). And we used Laerdal airway management trainer (Laerdal, Medical Corporation, Stavanger, Norway) which is as widely used manikin for training of airway management.

Instructors checked and recorded POGO (percentage of glottis opening) and times when glottis was visible and when endotracheal tube passed vocal cord. They also checked chest rising of manikin, which was recorded as 1st ventilation, using tube ballooning and ventilation with bag-valve mask.

All the tests were performed in separated space. Before test, every subject received random test sequence table. Test sequence of laryngoscope types were determined by random sample.

2.3. Statistical Analysis. Statistical analysis was carried out with the 22.0 version of the SPSS program for windows (SPSS Inc., Chicago, IL, USA). Data was presented as mean ± standard deviation (SD). In previous study, total intubation time for face to face intubation was 21.6 ± 10.1 seconds [10]. To detect 20% difference in total intubation time with a power of 0.9 and $\alpha = 0.05$, we estimate that 75 subjects would be adequate considering a 20% drop rate. We used Shapiro-Wilk test for verifying normal distribution and Wilcoxon signed rank test for verifying the result which is not according to normal distribution. A significant difference was considered when P value was less than 0.05. For comparison in correlation of multiple variables, we used Friedman test and applied Bonferroni's method for Post hoc analysis.

3. Result

95 subjects participated in this study but we excluded 9 subjects due to informational errors such as missing data on evaluation form. So, 86 subjects were enrolled in this study. They consisted of 54 men (62.8%) and 32 women (37.2%) and were classified into 17 nurses (19.8%), 68 1st level EMT (emergency medical technicians) (79.0%), and 1 2nd level EMT (1.2%). 1st level EMT was licensed to college graduates of emergency medical technology; otherwise, 2nd level EMT was licensed by passing written and practical test for emergency situations. In South Korea, most of healthcare providers in the field consisted of 1st level EMT, 2nd level EMT, and nurses. Mean age of subjects was 28.3 years old; mean career as healthcare provider was 3.6 years. Most of them (83 of 86) experienced intubation less than 3 times. In addition, they never experienced intubation using video laryngoscopes and face to face intubation (Table 1). We described the result divided into VCET (vocal cord exposure time), POGO (percentage of glottis opening) score, tube pass time and 1st ventilation time. In addition, we calculated spent time from VCET to tube pass time and from tube pass time to 1st ventilation time. We limited subject's data in case of successful endotracheal intubation achieved only in 1st attempt. We compared the success rate with the number of attempts and regarded a failure in case of not achieving endotracheal intubation within 1 minute because we assumed the emergency situation in which subjects must achieve face to face intubation in spite of very narrow space; in other words, they cannot wait for conventional intubation and needed more space [6, 12]. Finally, we described complication by kinds of laryngoscope.

Table 1: Demographic characteristics of subjects ($n = 86$).

Characteristics	Data
Sex (n, percent)	Male (54, 62.8%)
Age (years, range)	28.3 (21–40)
Work experience as healthcare provider (years)	3.6
0 (n, percent)	27 (31.4%)
to 5 years	36 (41.9%)
>5 years	23 (26.7%)
License	
Nurse	17 (19.8%)
1st level EMT	67 (77.9%)
2nd level EMT	1 (1.2%)
Intubation experience	
MCL <3 (times)	83 (96.5%)
Video laryngoscope <3 (times)	86 (100%)
Face to face intubation <1	86 (100%)

EMT: emergency medical technician; MCL: Macintosh laryngoscope.

3.1. VCET. Vocal cord exposure time (VCET) means the time taken by the subject to hold a handle of laryngoscope to find a vocal cord opening. In Macintosh blade, the VCET was 7.8 ± 3.3 seconds and it was faster than other video laryngoscopes, in AWS 10.9 ± 7.8, in GVL 8.4 ± 4.9, and in C-MAC 8.4 ± 4.6. But, no significant difference showed among laryngoscopes ($P = 0.199$ in Friedman test) (Table 2).

3.2. POGO Score. Percentage of glottis opening (POGO) score defined a certain extent of visualized vocal cord after insertion of laryngoscope to oral cavity. If we can watch whole vocal cord, we mark it 100%, and if we cannot find vocal cord, we mark it 0%. In Macintosh blade (53.6 ± 22.3%), POGO score was lower than all kinds of laryngoscopes that we used and showed significant difference. Compared to Macintosh blade, POGO score in AWS was 81.7 ± 18.3% ($P = 0.000$), in GVL was 65.4 ± 25.0% ($P = 0.000$), and in C-MAC was 72.9 ± 20.8% ($P = 0.000$). In comparison of video laryngoscopes, AWS showed higher POGO score than GVL ($P = 0.000$) and C-MAC ($P = 0.002$), but there was no significant difference between GVL and C-MAC ($P = 0.188$) (Tables 2 and 3).

3.3. Tube Pass Time. Tube pass time means time spent by subjects to grasp a handle of blade passing the vocal cord by endotracheal tube. Macintosh blade (18.7 ± 7.3 sec) was faster than GVL (26.8 ± 10.0 sec, $P = 0.001$) and C-MAC (22.8 ± 10.2 sec, $P = 0.000$) and showed no difference with AWS (19.6 ± 9.5 sec, $P = 0.608$). In comparison among video laryngoscopes, AWS was faster than GVL ($P = 0.005$) but there were no differences between AWS and C-MAC and GVL and C-MAC ($P = 0.011$, $P = 0.108$) (Tables 2 and 3).

3.4. 1st Ventilation Time. 1st ventilation time means time spent from holding a handle of laryngoscope and passing the vocal cord by endotracheal tube to give 1st ventilation via inserted endotracheal tube. It also means total intubation time. There were no differences between Macintosh blade (28.4 ± 7.7 sec) and AWS (29.6 ± 10.9 sec) and GVL (39.2 ± 9.7 sec) and C-MAC (35.2 ± 10.4 sec) ($P = 0.530$, $P = 0.207$). However, Macintosh blade was faster than GVL ($P = 0.000$) and C-MAC ($P = 0.000$); AWS was also faster than GVL ($P = 0.003$) and C-MAC ($P = 0.000$) (Tables 2 and 3).

3.5. VCET to Time of Endotracheal Tube Passing Vocal Cord (Tube Pass Time). It means time spent from vocal cord exposure to passing the endotracheal tube. Macintosh blade (10.9 ± 5.9) and AWS (10.4 ± 10.9) showed similar result, and there is no significant difference ($P = 0.028$). In GVL (22.8 ± 27.1) and C-MAC (17.1 ± 14.3), they needed more time from vocal cord exposure to endotracheal tube passing via vocal cord compared to Macintosh blade and AWS, individually (Macintosh versus GVL, $P = 0.003$; Macintosh versus C-MAC, $P = 0.001$; AWS versus GVL, $P = 0.001$; AWS versus C-MAC, $P = 0.000$). No significant difference showed between GVL and C-MAC ($P = 0.161$) (Tables 2 and 3).

3.6. Time of Endotracheal Tube Passing Vocal Cord (Tube Pass Time) to 1st Ventilation Time. 9.6 ± 3.9 seconds are needed from tube passing to 1st ventilation in Macintosh blade, and that, in AWS, was 9.8 ± 3.7 seconds. In GVL and C-MAC, the results were 10.6 ± 9.7 seconds and 12.2 ± 4.5 seconds. In comparison with Macintosh blade, AWS ($P = 0.860$) and GVL ($P = 0.060$) did not show significant difference, but C-MAC ($P = 0.000$) was meaningfully slower than Macintosh blade. AWS was faster than C-MAC with significant difference ($P = 0.000$), but there was no difference with GVL ($P = 0.171$). No significant difference was found between GVL and C-MAC ($P = 0.165$) (Tables 2 and 3).

3.7. Endotracheal Intubation Success Rate according to the Number of Attempts. 86 subjects performed face to face intubation using laryngoscopes; we determined a failure in which subjects did not achieve endotracheal intubation within 1 minute or accomplished esophageal intubation. In Macintosh blade, 72 subjects (83.7%) achieved successful endotracheal intubation in first attempt and 85 (98.8%) succeeded in second attempt. At third attempt, all subject (100%) succeeded in endotracheal intubation. 71 subjects (82.5%) succeeded in endotracheal intubation in first attempt using AWS. In second attempt, 84 (97.6%) achieved successful endotracheal intubation; 85 (98.8%) succeeded in third attempt; all subject (100%) succeeded in fourth attempt. In GVL, 37 subjects (43.0%) succeeded in endotracheal intubation at first attempt, and 62 (72.0%) succeeded in second attempt. 70 subjects (81.3%) succeeded in third attempt, and 73 (84.8%) in the fourth. 13 subjects (15.2%) did not achieve successful intubation during four attempts. 74 subjects (86.0%) succeeded in endotracheal intubation in first attempt using GVL, 83 subjects (96.5%) in second attempt, and 85 (98.8%) in third attempt. 1 subject (1.2%) failed in endotracheal intubation during four attempts (Figure 1, Table 4).

3.8. Complication. We examined complications of face to face intubation during procedure for tooth injury and esophageal

Table 2: Comparison of intubation time (sec) and POGO (%) according to laryngoscopes (mean ± SD).

	MCL	AWS	GVL	C-MAC	*P* value
VCET (sec)	7.8 ± 3.3	10.9 ± 7.8	8.4 ± 4.9	8.4 ± 4.6	0.199
POGO (%)	53.6 ± 22.3	81.7 ± 18.3	65.4 ± 25.0	72.9 ± 20.8	0.000
Tube pass time (sec)	18.7 ± 7.3	19.6 ± 9.5	26.8 ± 10.0	22.8 ± 10.2	0.001
1st ventilation time (sec)	28.4 ± 7.7	29.6 ± 10.9	39.2 ± 9.7	35.2 ± 10.4	0.000
VCET to tube pass time (sec)	10.9 ± 5.9	10.4 ± 10.9	22.8 ± 27.1	17.1 ± 14.3	0.000
Tube pass time to 1st ventilation time (sec)	9.6 ± 3.9	9.8 ± 3.7	10.6 ± 9.7	12.2 ± 4.5	0.000

* *P* value < 0.05 is level of statistical significance according to Friedman test.
MCL: Macintosh laryngoscope; AWS: Pentax airway scope; GVL: Glidescope video laryngoscope; C-MAC: C-MAC video laryngoscope.

Table 3: Statistical significance (*P* value) among laryngoscopes for intubation time (sec) and POGO (%).

	MCL versus AWS (*P* value)	MCL versus GVL (*P* value)	MCL versus C-MAC (*P* value)	AWS versus GVL (*P* value)	AWS versus C-MAC (*P* value)	GVL versus C-MAC (*P* value)
VCET	0.008	0.038	0.217	0.756	0.090	0.220
POGO	0.000*	0.000*	0.000*	0.000*	0.002*	0.188
Tube pass time	0.608	0.001*	0.000*	0.005*	0.011	0.108
1st ventilation time	0.530	0.000*	0.000*	0.003*	0.000*	0.207
VCET to tube pass time	0.028	0.003*	0.001*	0.001*	0.000*	0.161
Tube pass time to 1st ventilation time	0.860	0.060	0.000*	0.171	0.000*	0.165

* *P* value < 0.008 is level of statistical significance according to Bonferroni's method.
MCL: Macintosh laryngoscope; AWS: Pentax airway scope; GVL: Glidescope video laryngoscope; C-MAC: C-MAC video laryngoscope.

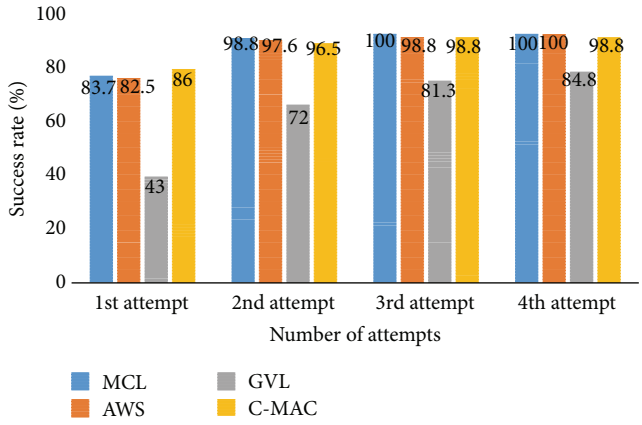

Figure 1: Endotracheal intubation success rate according to the number of attempts. Glidescope video laryngoscope (GVL) showed lower success rate compared with other laryngoscopes in all of attempts. MCL: Macintosh laryngoscope; AWS: Pentax airway scope; GVL: Glidescope video laryngoscope; C-MAC: C-MAC video laryngoscope.

intubation. We included all attempts of endotracheal intubation. Tooth injury was considered when tester heard tooth click. The number of tooth injuries in Macintosh blade was one, in AWS and GVL five, and, else, in C-MAC three. One esophageal intubation occurred in Macintosh blade, and no esophageal intubation occurred in video laryngoscopes.

4. Discussion

Endotracheal intubation is very important procedure in emergency department for severely ill patients [13, 14]. In conventional intubation, operator sets a location at the upper side of patient's head, grasps a laryngoscope with left hand, and inserts endotracheal tube by right hand. For better visualization, operator shift patient's tongue to left using blade. Lots of new techniques and machines are introduced for easy successful intubation, but, until recently, conventional intubation is the most commonly used method for airway management. Video laryngoscopes, for difficult airway, consist of a laryngoscope with a light source and a camera in distal blade. In contrast to conventional blade having about 15′-visual field, video laryngoscopes make wider visual angle because of the camera on distal blade [4]. In special situation, such as, in ambulance or helicopter, occasionally, there is no space at patient's upper side for conventional intubation, So operator has to intubate on lateral or frontal side of patient [9]. In contrast to conventional laryngoscopy, the practitioner holds the handle of the laryngoscope in his right hand with the top of the blade in the upright position. After the opening of patient's airways, the top of the laryngoscope's curved blade will be in place in the left part of the patient's mouth [10].

We examined this study to investigate whether video laryngoscopes are helpful in special situation like being entrapped in car or permitted narrow space and whether video laryngoscopes are more useful than conventional

Table 4: Success rate according to the number of attempts.

	MCL	AWS	GVL	CMAC
Success at 1st attempt	72 (83.7%)	71 (82.5%)	37 (43.0%)	74 (86.0%)
Success at 2nd attempt	13 (15.1%) (85, 98.8%)	13 (15.1%) (84, 97.6%)	25 (29.0%) (62, 72.0%)	9 (10.4%) (83, 96.5%)
Success at 3rd attempt	1 (1.1%) (86, 100%)	1 (1.1%) (85, 98.8%)	8 (9.3%) (70, 81.3%)	2 (2.3%) (85, 98.8%)
Success at 4th attempt	0	1 (1.1%) (86, 100%)	3 (3.4%) (73, 84.8%)	0
Failure at 4th attempt	0	0	13 (15.1%)	1 (1.1%)

MCL: Macintosh laryngoscope; AWS: Pentax airway scope; GVL: Glidescope video laryngoscope; C-MAC: C-MAC video laryngoscope.

intubation set (Macintosh blade). We choose several video laryngoscopes: AWS which has endotracheal tube-guiding groove channel in distal blade (P blade), GVL with difficult blade for difficult airway that has elliptically tapered blade shape rising to distal, and C-MAC with conventional blade which has the same blade angle compared with Macintosh blade [4].

We discussed the course of face to face intubation categorized as VCET, POGO score, VCET to tube pass time, tube pass time to 1st ventilation time, success rate by number of attempts and complications.

4.1. Face to Face Intubation versus Supraglottic Airway Devices Insertion. In previous simulation study, supraglottic airway devices (SAD) are faster than Macintosh laryngoscope in entrapped situation [15]. Hence, SAD insertion can be considered to be more useful method compared with endotracheal intubation. However, in cases of lung injuries or massive bleeding or vomitus in oral cavity, SAD alone is not enough to secure airway. In these cases, endotracheal intubation is preferred to SAD insertion for providing high oxygen concentration [16].

In case of severe injury with restricted position, face to face intubation is a reasonable choice.

4.2. Vocal Cord Exposure Time (VCET). No significant difference was detected among all laryngoscopes ($P = 0.199$). Macintosh blade had advantage of easy insertion to oral cavity because it had smaller blade than other video laryngoscopes due to its simplicity; however, video laryngoscopes had camera at the mount of blade tip, so subjects easily detected vocal cord so long as blade of video laryngoscope was inserted in oral cavity.

4.3. POGO (Percentage of Glottis Opening) Score. Macintosh blade showed lower POGO score than all laryngoscopes, in AWS ($P = 0.000$) and GVL ($P = 0.000$) and C-MAC ($P = 0.000$). In comparison among video laryngoscopes, AWS showed higher POGO than GVL ($P = 0.000$) and C-MAC ($P = 0.002$). GVL with C-MAC did not show significant difference ($P = 0.016$, $P = 0.022$). Video laryngoscopes were made for difficult airway management and gave us advanced vision compared to Macintosh blade [17]. In case of face to face intubation, similar to conventional intubation, the visual field is wider and POGO is higher in video laryngoscopes than Macintosh blade. GVL with difficult blade had more curved angle than other blades, so it was difficult to expose vocal cord in face to face intubation performing on opposite side of conventional intubation.

4.4. VCET to Tube Pass Time. VCET to tube pass time means spending time from vocal cord exposure to pass it. Between Macintosh blade and AWS, there was no significant difference ($P = 0.028$). Macintosh was faster than GVL ($P = 0.003$) and C-MAC ($P = 0.001$). Among video laryngoscopes, AWS was faster than GVL and C-MAC ($P = 0.001$, $P = 0.000$). There was no significant difference between GVL and C-MAC ($P = 0.161$).

It may be due to eye-hand discordance. In case of face to face intubation using Macintosh blade, operator sets location on upper side of patient's head, checks vocal cord with the naked eye, and inserts endotracheal tube to vocal cord. On the other hand, operator with video laryngoscopes will be watching monitor showing view from end of video laryngoscope which is in contrast angle to hand direction [18]. Operator inserts endotracheal tube to vocal cord watching screen attached to video laryngoscopes, but the direction of manipulating endotracheal tube and the location of vocal cord on screen to advanced direction of endotracheal tube is different [19, 20]. So, it is difficult to insert endotracheal tube quickly and precisely. Difficult blade of GVL has larger angle of blade for difficult airway compared to conventional blade, so it is more difficult to manipulate endotracheal tube due to more distorted up-and-down angle.

4.5. Tube Pass Time to 1st Ventilation Time. Macintosh was faster than C-MAC ($P = 0.000$) and showed no significant difference with AWS ($P = 0.860$) and with GVL ($P = 0.060$). In comparison among video laryngoscopes, AWS was faster than C-MAC ($P = 0.000$). AWS and GVL and GVL and C-MAC did not show significant difference ($P = 0.171$, $P = 0.165$).

We did not know the definite cause of why C-MAC was slower than Macintosh blade and AWS. Maybe, in face to face intubation, the monitor attached to C-MAC was inversely rotated. Most operators in this study tried rotating C-MAC monitor to its original positon taking up more time. We thought it requires further investigation about other causes.

4.6. Success Rate according to the Number of Attempts. In Macintosh blade, AWS, and C-MAC, they showed over 80% success rate in first attempt (Table 4). Otherwise, only 43% of subjects achieved successful intubation in GVL. For second attempt, 72% of subjects succeeded in GVL; the others showed over 95% success rate. After fourth trial, Macintosh and AWS showed 100% success rate; C-MAC showed 98.8%. But GVL showed only 84.8% of success rate, and 15.2% of subjects could not achieve successful face to face intubation during four times of attempts (Figure 1). GVL had difficult blade for difficult airway; in contrast to other laryngoscopes, eye-hand discordance was more severe.

4.7. Complication. One tooth injury occurred in Macintosh, five injuries in AWS, five injuries in GVL, and three injuries in C-MAC. AWS had bigger and thicker blade than others, it contributed to tooth injury. In performing intubation using GVL, as appeared by the result in which GVL showed lower successful face to face intubation rate, subjects seemed to move more in oral cavity than other laryngoscopes for successful intubation; we guessed it influenced broken tooth. Esophageal intubation occurred once only in Macintosh blade; it seemed to be meaningless.

4.8. Limitation. First, we cannot exclude learning effect of laryngoscopes. Though subjects performed face to face intubation using multiple laryngoscopes via randomized serial, subjects might be trained four times of serial face to face intubation and perform better as time goes by. Second, it is simulation study using manikin, not a patient. In this study, all manikins lay down on floor, not in sitting position. Face to face intubation is very useful in patient of entrapped car, mostly sitting. In addition, there is enough space at upper manikin's head side to perform face to face intubation compared to narrow space such as ambulance and helicopter.

It is not unusual that operator suffers poor visual field due to secretion or blood or vomitus on performing CPR in field. Sometimes, intubation was delayed for cleaning lens of video laryngoscopes. However, in case of Macintosh blade, securing visual field was faster because direct suction was possible in insertion state of Macintosh blade. So the result could not adapt to patients exactly. Third, subjects had no experience of face to face intubation, but they took lots of lectures about airway management using manikin. So they have familiarity of intubation using manikin study compared to someone who has no prior education.

Fourth, we simulated this study and assumed an emergency situation in which the victim needed emergent face to face intubation in limited study; we determined that the failure time of intubation was 1 minute. We thought it might be a cause of low success rate in first intubation attempt using GVL. We compared spent time only in success cases at first time attempt of all kinds of laryngoscopes. So, we guessed that GVL took a long time for face to face intubation compared to our result. Next study, if that is possible, it will give the opportunity for successful intubation without limited time and it will be more correct in comparison to intubation time among laryngoscopes.

5. Conclusion

In limited space and restricted position with emergent situation, face to face intubation is a useful substitute for conventional intubation. However, its success rate is different due to multiple causes, for example, eye-hand discordance. Macintosh blade and AWS showed significantly faster intubation time than GVL and C-MAC, in face to face intubation.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Authors' Contribution

Hyun Young Choi and Young Min Oh contributed equally to this study.

References

[1] P. Schober, R. Krage, D. van Groeningen, S. A. Loer, and L. A. Schwarte, "Inverse intubation in entrapped trauma casualties: a simulator based, randomised cross-over comparison of direct, indirect and video laryngoscopy," *Emergency Medicine Journal*, vol. 31, pp. 959–963, 2014.

[2] M. Gellerfors, A. Larsson, C. H. Svensén, and D. Gryth, "Use of the airtraq device for airway management in the prehospital setting—a retrospective study," *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, vol. 22, no. 1, article 10, 2014.

[3] H. Al-Thani, A. El-Menyar, and R. Latifi, "Prehospital versus emergency room intubation of trauma patients in Qatar: a-2-year observational study," *North American Journal of Medical Sciences*, vol. 6, no. 1, pp. 12–18, 2014.

[4] A. Kilicaslan, A. Topal, A. Tavlan, A. Erol, and S. Otelcioglu, "Effectiveness of the C-MAC video laryngoscope in the management of unexpected failed intubations," *Brazilian Journal of Anesthesiology*, vol. 64, no. 1, pp. 62–65, 2014.

[5] A. M. Burnett, R. J. Frascone, S. S. Wewerka et al., "Comparison of success rates between two video laryngoscope systems used in a prehospital clinical trial," *Prehospital Emergency Care*, vol. 18, no. 2, pp. 231–238, 2014.

[6] K. B. Wong, C. T. Lui, W. Y. W. Chan, T. L. Lau, S. Y. H. Tang, and K. L. Tsui, "Comparison of different intubation techniques performed inside a moving ambulance: a manikin study," *Hong Kong Medical Journal*, vol. 20, no. 4, pp. 304–312, 2014.

[7] N. Komasawa, R. Ueki, M. Itani, H. Nomura, S.-I. Nishi, and Y. Kaminoh, "Evaluation of tracheal intubation in several positions by the Pentax-AWS Airway Scope: a manikin study," *Journal of Anesthesia*, vol. 24, no. 6, pp. 908–912, 2010.

[8] T. Asai, "Tracheal intubation with restricted access: a randomised comparison of the Pentax-Airway Scope and Macintosh laryngoscope in a manikin," *Anaesthesia*, vol. 64, no. 10, pp. 1114–1117, 2009.

[9] E. Gaszynska, P. Samsel, M. Stankiewicz-Rudnicki, A. Wieczorek, and T. Gaszynski, "Intubation by paramedics using the ILMA or AirTraq, KingVision, and Macintosh laryngoscopes in vehicle-entrapped patients: a manikin study," *European Journal of Emergency Medicine*, vol. 21, no. 1, pp. 61–64, 2014.

[10] K. J. Robinson, K. Donaghy, and R. Katz, "Inverse intubation in air medical transport," *Air Medical Journal*, vol. 23, no. 1, pp. 40–43, 2004.

[11] R. Amathieu, J. Sudrial, W. Abdi et al., "Simulating face-to-face tracheal intubation of a trapped patient: a randomized comparison of the LMA Fastrach™, the GlideScope™, and the Airtraq™ laryngoscope," *British Journal of Anaesthesia*, vol. 108, no. 1, pp. 140–145, 2012.

[12] M. Tuma, A. El-Menyar, H. Abdelrahman et al., "Prehospital intubation in patients with isolated severe traumatic brain injury: a 4-Year Observational study," *Critical Care Research and Practice*, vol. 2014, Article ID 135986, 6 pages, 2014.

[13] D. Venezia, A. Wackett, A. Remedios, and V. Tarsia, "Comparison of sitting face-to-face intubation (two-person technique) with standard oral-tracheal intubation in novices: a Mannequin Study," *Journal of Emergency Medicine*, vol. 43, no. 6, pp. 1188–1195, 2012.

[14] S. Sobuwa, H. B. Hartzenberg, H. Geduld, and C. Uys, "Outcomes following prehospital airway management in severe traumatic brain injury," *South African Medical Journal*, vol. 103, no. 9, pp. 644–646, 2013.

[15] W. A. Wetsch, A. Schneider, R. Schier, O. Spelten, M. Hellmich, and J. Hinkelbein, "In a difficult access scenario, supraglottic airway devices improve success and time to ventilation," *European Journal of Emergency Medicine*, 2015.

[16] J. Mayglothling, T. M. Duane, M. Gibbs et al., "Emergency tracheal intubation immediately following traumatic injury: an eastern association for the surgery of trauma practice management guideline," *The Journal of Trauma and Acute Care Surgery*, vol. 73, no. 5, pp. S333–S340, 2012.

[17] T. Arima, O. Nagata, T. Miura et al., "Comparative analysis of airway scope and Macintosh laryngoscope for intubation primarily for cardiac arrest in prehospital setting," *The American Journal of Emergency Medicine*, vol. 32, no. 1, pp. 40–43, 2014.

[18] S. Rentsch and M. K. Rand, "Eye-hand coordination during visuomotor adaptation with different rotation angles," *PLoS ONE*, vol. 9, no. 10, Article ID e109819, 2014.

[19] P. Breedveld and M. Wentink, "Eye-hand coordination in laparoscopy—an overview of experiments and supporting aids," *Minimally Invasive Therapy & Allied Technologies*, vol. 10, no. 3, pp. 155–162, 2001.

[20] K. Maruyama, S. Tsukamoto, S. Ohno et al., "Effect of cardiopulmonary resuscitation on intubation using a Macintosh laryngoscope, the AirWay Scope, and the gum elastic bougie: a Manikin Study," *Resuscitation*, vol. 81, no. 8, pp. 1014–1018, 2010.

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Review Article

Airway Management of the Patient with Maxillofacial Trauma: Review of the Literature and Suggested Clinical Approach

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According to the Advanced Trauma Life Support recommendations for managing patients with life-threatening injuries, securing the airway is the first task of a primary caregiver. Airway management of patients with maxillofacial trauma is complex and crucial because it can dictate a patient's survival. Securing the airway of patients with maxillofacial trauma is often extremely difficult because the trauma involves the patient's airway and their breathing is compromised. In these patients, mask ventilation and endotracheal intubation are anticipated to be difficult. Additionally, some of these patients may not yet have been cleared of a cervical spine injury, and all are regarded as having a full stomach and having an increased risk of regurgitation and pulmonary aspiration. The requirements of the intended maxillofacial operation may often preclude the use of an oral intubation tube, and alternative methods for securing the airway should be considered before the start of the surgery. In order to improve the clinical outcome of patients with maxillofacial trauma, cooperation between maxillofacial surgeons, anesthesiologists, and trauma specialists is needed. In this review, we discuss the complexity and difficulties of securing the airway of patients with maxillofacial trauma and present our approach for airway management of such patients.

1. Introduction

The patient with maxillofacial trauma presents serious challenges for the physician because airway management in these patients can be complicated by their injury. The first challenge is to secure the airway for sufficient and effective breathing and/or ventilation. When planning to secure the airway, the physician has to consider several aspects: (a) the nature of the trauma and its effect on the airways, (b) potential difficulties in mask ventilation or endotracheal intubation, (c) possible trauma of the cervical spine, (d) the risk of regurgitation and aspiration of gastric contents, (e) significant bleeding that precludes view of airway anatomy and may cause circulatory deterioration, and (f) the type of maxillofacial operation that is to be done and whether the oral cavity needs to be empty for performing the procedure and closed with maxilla-mandibular fixation (MMF) at the end of surgery. The time available for deciding on and then performing the optimal method in order to secure the airway under a particular set of circumstances is often short because the patient's condition can deteriorate quickly.

In this review we will describe and discuss the various stages of airway management of the patient with maxillofacial trauma and how each stage contributes to comprehensive, safe, and practical airway management of these patients.

2. Maxillofacial Trauma and Airway Injuries

Safe and optimal airway management of the patient with maxillofacial trauma requires appreciation of the nature of the trauma. There are several maxillofacial injuries that

require immediate treatment, especially in acute upper airway compromise and/or when profuse hemorrhage occurs. According to Hutchison et al. [1], there are six specific situations associated with maxillofacial trauma, which can adversely affect the airway.

(1) Posteroinferior displacement of a fractured maxilla parallel to the inclined plane of the base of the skull may block the nasopharyngeal airway.

(2) A bilateral fracture of the anterior mandible may cause the fractured symphysis and the tongue to slide posteriorly and block the oropharynx in the supine patient.

(3) Fractured or exfoliated teeth, bone fragments, vomitus, blood, and secretions as well as foreign bodies, such as dentures, debris, and shrapnel, may block the airway anywhere along the oropharynx and larynx.

(4) Hemorrhage from distinct vessels in open wounds or severe nasal bleeding from complex blood supply of the nose may also contribute to airway obstruction.

(5) Soft tissue swelling and edema which result from trauma of the head and neck may cause delayed airway compromise.

(6) Trauma of the larynx and trachea may cause swelling and displacement of structures, such as the epiglottis, arytenoid cartilages, and vocal cords, thereby increasing the risk of cervical airway obstruction.

A high index of suspicion, a meticulous physical examination, and close observation of the patient may assist in the early detection of such situations and facilitate proper and timely management in order to avoid future complications. Once airway management has been completed and hemorrhage is controlled at all sites, the patient should have a computerized tomography (CT) scan of the head and neck with i.v. contrast material, in order to demonstrate the vascular structures surrounding the injury sites and provide detailed information on the type and extent of the trauma, for definitive management of bone and soft tissue injuries. The imaging and the definitive maxillofacial operation may be deferred until all life- and/or organ-threatening injuries have been properly managed.

3. Early Airway Maintenance

According to the Advanced Trauma Life Support (ATLS) recommendations for managing patients who sustained life-threatening injuries, airway maintenance with cervical spine immobilization is the first priority [2]. The loss of an airway may be lethal and can occur faster than the loss of the ability to breathe or the onset of circulatory problems. Thus, life-saving intervention should begin with airway management, when required [2–4]. In fact, the most common critical care errors that contribute to the death of trauma patients are related to airway and respiratory management [5]. Airway management problems are not confined to the early stages of the "triage process" or to the resuscitation of the patient. Morbidity and mortality of in-hospital trauma patients often result from critical care errors, with airway management being the most common [5, 6]. Gruen et al. studied the causes of death of 2594 trauma patients in order to identify the error patterns which contributed to inpatient deaths [6]. They found that 16% of inpatient deaths were caused by failure to intubate or failure to secure or protect the airway.

The first action in the process of early airway management is preoxygenation, which may prolong the time interval up to hypoxemic state. Effective preoxygenation of the lungs increases oxygen content in the functional residual capacity which is the principal oxygen store during apnea. Since the time for achieving airway control before onset of dangerous levels of hypoxemia is critical, preoxygenation is crucial and is to be carried out as much as possible, using a nonrebreathing mask. In some patients preoxygenation is unfeasible due to the maxillofacial trauma itself, and hypoxemia is to be expected.

Endotracheal intubation is the gold standard procedure to secure the airway in trauma patients. It is to be performed via the oral route with a rapid sequence induction and a manual in-line stabilization maneuver, in order to decrease the risk of pulmonary aspiration and take into account a potential cervical spine (C-spine) injury [2]. However, endotracheal intubation is expected to be difficult in a maxillofacial trauma patient. The challenge in performing the intubation arises mainly from a difficulty in viewing the vocal cords using conventional direct laryngoscope. The oral cavity, pharynx, and larynx may be filled with blood, secretions, soft tissue, and bone fragments, all of which preclude a good view of the vocal cords.

Regarding mask ventilation, mask ventilation is problematical in the patient with maxillofacial trauma because the oral cavity and/or oropharynx's anatomy could be disarranged by the trauma and/or blocked by bleeding. Thus, the ventilation mask cannot be properly fitted to the face for effective mask ventilation. Furthermore, an injured airway may prevent efficient air transfer from the mask to the lungs.

In addition to the problem of anticipated difficult intubation and difficult mask ventilation, several other factors may aggravate the scenario: the risk of regurgitation and aspiration, the potential C-spine injury, the patient who is starved for air and may already be hypoxemic, could also be uncontrollable and combative, and lack of experience of the primary care provider.

3.1. Full Stomach. Like all trauma patients, the patient with maxillofacial trauma must be assumed to have a "full stomach" because digestion stops when the trauma occurred. Since such patients often bleed from the upper airway, blood is swallowed and accumulates in the stomach. Accordingly, the risk of regurgitation and aspiration is high. In order to diminish such risks, evacuating the contents of the stomach through the nasogastric tube before proceeding with airway management is recommended. However, insertion of a nasogastric tube in a confused, uncooperative, sometimes intoxicated patient who has sustained a facial injury may, by itself, trigger vomiting. In addition, it is relatively contraindicated in cases with a possible fracture of the base of skull.

Formerly it was accustomed to use Sellick's maneuver [7], in order to reduce the risk of pulmonary aspiration. The Sellick's maneuver is a technique in which the esophagus is occluded by applying pressure on the cricoid cartilage. Over the years Sellick's maneuver, which is also called cricoid pressure, has been incorporated into "rapid sequence induction" (RSI). Although Sellick's maneuver and RSI are widely used, the maneuver may significantly hamper endotracheal intubation because the laryngeal view is worsened [8, 9]. In addition, its efficacy in preventing aspiration is questionable [10], and in some cases it may lead to ruptured esophagus. Thus, the application of cricoid pressure as prophylaxes for aspiration in trauma patients is no longer indicated [11].

3.2. C-Spine Injury. A patient with a supraclavicular injury is considered to have a C-spine injury, until proven otherwise by imaging [12, 13]. Since a complete C-spine clearance may take several hours and sometimes days to achieve, the patient must be fitted with a neck collar for cervical spine immobilization. At the time of intubation, the anesthesiologist's assistant performs "in-line stabilization" in order to support the head and neck in place and prevent neck movement throughout the procedure [14]. However, several studies indicate that direct laryngoscopy and intubation are unlikely to cause clinically significant neck movements. On the other hand, "in-line stabilization" may not always immobilize the injured segments effectively. In addition, "in-line stabilization" worsens the laryngoscopic view which may, in turn, worsen the outcome in traumatic brain injury by delaying endotracheal intubation and causing hypoxia [15, 16]. Using a video laryngoscope, instead of a conventional laryngoscope with a Macintosh blade, may be beneficial for intubating patients whose neck position needs to be in a neutral position and their cervical spine requires immobilization [17–19]. Neck movements during laryngoscopy using a conventional Macintosh laryngoscope has been compared to that using the GlideScope video laryngoscope [18] and the Truview PCD laryngoscope [19]. The results of the two studies found that the number of neck movements is reduced when using the video laryngoscopes for endotracheal intubation.

3.2.1. Maxillofacial Bleeding. In patients with major maxillofacial trauma, severe uncontrolled bleeding is possible, especially in trauma that involves more than two thirds of the face, "panfacial trauma." Since the head and neck region is abundantly vascularized, severe life-threatening bleeding may occur during isolated facial trauma [20, 21]. The hemorrhage affects the patient's condition and prognosis in several ways: (a) blood in the oral cavity often excludes mask ventilation, (b) it may preclude good view of airway anatomy, thus making intubation very difficult, (c) significant hemorrhage may cause circulatory compromise that may be fatal, (d) coagulation may deteriorate due to massive blood transfusion, and (e) the surgical field conditions during bleeding are less than optimal for operating. Management of the patient includes volume replacement and local control of the bleeding with packing, ligation, or, in selected cases, arterial embolization [22, 23].

3.3. Emergency Situations. Managing the airway in an emergent situation poses additional difficulty because the time to accomplish the task is short and the patient's condition may deteriorate quickly. Both decision-taking and performance are diminished at such times. The performance of urgent or emergent intubation is associated with remarkably high complication rates, which may exceed 20% [24, 25]. These high rates are due to several factors, which include repeated intubation attempts, the need to perform direct laryngoscopy without muscle relaxation, and the lack of experience of the operator. The main complications that may occur at that time are hypoxemia, aspiration, esophageal intubation, esophageal tear, alterations in the heart rate, new onset cardiac dysrhythmias, and cardiac arrest.

3.4. Personnel Experience. In emergency situations, the care of acute trauma patients is provided by individuals who are often not experienced, the "inverse care law" [26]. The responsibility for acute airway management often falls into the hands of nonanesthesiologists [27, 28]. In their multicenter analysis of 8937 intubations in the emergency department, Walls et al. [28] reported that anesthesiologists performed only 3% of the intubations, and the remaining 97% of the intubations were performed by emergency physicians (87%) and physicians from other specialties (10%). In order to improve the clinical outcome of patients with maxillofacial trauma, we believe that the most experienced personnel in the hospital should be tasked with airway management of such patients.

4. Approach to the Airway of the Patient with Maxillofacial Trauma

4.1. Airway Evaluation and Preparation. Airway evaluation of a patient with maxillofacial trauma should be done thoroughly and as quickly as possible because the patient's airway is compromised. Additionally, the attending physicians should become familiar with all details of the trauma and identify the difficulties involved in order to choose the best approach for managing the patient's airway [29, 30]. Team work between the surgeons, the anesthesiologists, and the trauma specialists is necessary for managing the patient.

At this time we ask the following questions.

(i) Is the patient conscious? If so, the use of sedatives or analgesics should be done cautiously, if at all, because the airway can be lost following injudicious use of such drugs [31].

(ii) Is the patient breathing spontaneously? If so, preoxygenation is mandatory. There is time to arrive at the hospital and manage the airway under the best conditions, with the best equipment and by the most experienced personnel. Failed attempts at endotracheal intubation by inexperienced or nonexpert individuals could cause rapid deterioration in the patient's condition. According to the American Society of Anesthesiologists (ASA) Practice Guidelines for management of the difficult airway, spontaneous

breathing should be preserved in patients with anticipated difficult endotracheal intubation [32].

(iii) Is the patient hypoxemic? If preoxygenation is possible and effective in improving patient's oxygenation then it is to be done with a face mask. If preoxygenation is not possible then ventilation is to be pursued at that time by the caretakers, according to their capability and equipment.

(iv) What is the extent, the details, and the anatomy of the injury? Are the bony structures of the face involved? In cases of massive injuries, mask ventilation may be impossible, while injury limited to the soft tissues may enable mask ventilation [33].

(v) For quick and easy identification of factors that may predispose difficult intubation or ventilation, one may use the LEMON assessment [33, 34]. The components of this assessment are as follows: look externally to detect difficult airway predictors, such as short neck and evaluate mouth opening and thyromental distance, Mallampati class, obstruction of the upper airway that may be noticed by stridor, and neck mobility. If one or more of the components are degraded then difficulty in airway control is to be expected.

(vi) Is there a limitation of mouth opening? If so, is pain the cause of the limitation and can the mouth be opened wider after analgesia? The answers to these questions depend, among other things, on whether there is the clinical or radiological evidence of a temporomandibular joint (TMJ) injury. If the limitation of mouth opening is caused by a TMJ injury, sedation will not improve mouth opening and may even worsen the scenario.

(vii) Are there additional predictors for difficult endotracheal intubation, such as obesity? In their study of 1377 intubations in the emergency department patients, Gaither et al. identified C-spine immobility, blood or vomitus in the airway, airway edema, facial or neck injury, and obesity as predictors of difficult endotracheal intubation [35].

(viii) What are the requirements of the upcoming maxillofacial surgery? Does the oral cavity need to be completely free of any medical devices for performing the surgery?

As with all situations of difficult airway management, the staff should be notified and prepared. The patient should be transferred as quickly as possible to a dedicated location, in the emergency department or the operating rooms, where the best equipment and conditions are available for performing endotracheal intubation. That location is to be equipped with all available airway management tools, including laryngoscopes of various types and sizes, video laryngoscopes, fiber-optic devices, and surgical devices for cricothyroidotomy, according to the published guidelines' difficult airway equipment list [36]. In addition, high-flow suction unit, high pressure blood heaters and transfusers, and resuscitation equipment are to be prepared and ready when there is a call.

4.2. Airway Management Devices. There are numerous airway management devices; however, only an endotracheal tube or tracheostomy tube is considered to be definitive when applied. As stated earlier, not having an unobstructed view of the vocal cords of the patient with maxillofacial trauma is the main obstacle for performing successful endotracheal intubation in such patients. Numerous airway devices and strategies have been developed to overcome this obstacle. Some devices, such as the flexible fiber-optic bronchoscope (FOB), enable an indirect view of the vocal cords. Other devices, such as the laryngeal mask airway (LMA) or the double lumen esophageal-tracheal Combitube, can be inserted blindly and do not require view of the vocal cords by any means. Another option for endotracheal intubation of a patient with maxillofacial injury is to place an LMA and then pass an endotracheal intubation tube through the LMA. The final option is the surgical one: to establish a direct access to the trachea by performing a cricothyroidotomy or a tracheotomy.

Since this review is a limited scope review, we chose to discuss several airway devices that are beneficial in the management of the patient with a maxillofacial trauma.

4.3. Airway Devices That Enable an Indirect View of the Vocal Cords

4.3.1. The FOB. Although performing fiber-optic intubation under local anesthesia for achieving successful endotracheal intubation is one of the recommended methods in situations where airway management is difficult [32], the use of FOB is somewhat impractical in patients with maxillofacial trauma. Blood, vomitus, and secretions in the patient's airway may preclude vision by fiber-optic instruments, and accomplishing effective local anesthesia in the injured regions is difficult. Furthermore, the patient's cooperation is essential for such an approach, and this cooperation is not easy to obtain in the trauma patient.

4.3.2. The Video Laryngoscope. The video laryngoscope, such as GlideScope video laryngoscope, enables an indirect view of the epiglottis and the vocal cords [37]. The successful use of a video laryngoscope relies on a good view of the inner airway, which is precluded in the trauma patient by blood and secretions. Accordingly, the use of a video laryngoscope is not better than that of FOB. However, the video laryngoscope may be useful in selected patients with soft tissue swelling at the base of the tongue, and in those patients in whom disruption of the normal anatomy precludes locating the epiglottis.

4.4. Blindly Placed Airway Management Devices. Supraglottic airway devices (SAD), such as the LMA and its several diverse variations, are very important devices for managing the difficult airway [32]. For airway management of the trauma patient, the SAD is placed blindly in the oropharynx and its

successful placement requires minimal experience [38–40]. However, SADs do not provide a definitive airway and can be displaced when the patient with an SAD is moved and transferred. In addition, patients suffering from facial trauma often have minimal space in the mouth, which complicates the use of supraglottic airway device. This restricts the use of these devices in some cases. Thus, it is not a final airway tool for managing trauma patients, especially for trauma patient that requires maxillofacial surgery, where the oral cavity is to be empty. However, a SAD is an ideal rescue device for ventilating a patient until the definitive airway is achieved, as has been repeatedly proven in combat casualties and many other trauma victims [41–43]. When the definitive surgery is to be performed, the SAD may be replaced by an endotracheal tube [44] or, alternatively, into a tracheostomy.

The Combitube is another airway management device that is inserted blindly into the oropharynx. In a patient with a maxillofacial trauma, the use of the Combitube may result in additional damage to the upper airway. Furthermore, insertion of Combitube can be associated with serious injury to the upper airway and digestive tract, such as esophageal laceration and perforation, tongue edema, vocal cord injury, tracheal injury, aspiration pneumonitis, and pneumomediastinum [45].

4.5. The Surgical Airway. The surgical airway is considered to be the last option in airway management; however, in patient with facial trauma sometimes it is the best solution. To be prepared well, a qualified surgeon should stand on site during conventional airway management in order to be immediately in charge. Performing a cricothyroidotomy or tracheotomy under local anesthesia is a lifesaving procedure in selected patients in the "cannot intubate, cannot ventilate" situation [32, 46–48]. Surgical creation of an airway is a safe method for securing the airway when the procedure is done by an experienced surgeon. However, this approach has its drawbacks: it carries a 6% rate of complications such as hemorrhage or pneumothorax, in an elective scenario [49]. This procedure can be difficult to perform in an urgent or emergent situation [50, 51] and procedure can occasionally be fatal [52]. When a tracheotomy is carried out under local anesthesia, it is uncomfortable or even painful for the patient, who may already experiencing severe pain and anxiety. For the operator, especially the less experienced one, it may be extremely stressful [53, 54] and, as a rule, the procedure is best performed by the team's surgeon rather than the anesthesiologist.

Of the two surgical procedures, there seems to be a propensity for doing a tracheotomy rather than a cricothyroidotomy. In their retrospective analysis of 4312 emergent airways, Dillon et al. found that only 34 patients (0.008%) required emergency surgical access, and of these 34 patients a tracheotomy was done in 24 and a cricothyroidotomy was done in 10 patients [55]. This preference may be attributed to the higher failure risk of cricothyroidotomy [56]. Although emergency surgical access is not frequently used, the surgical airway may be the route of choice when the maxillofacial trauma is extensive and the patient requires postoperative mechanical ventilation and MMF (Figure 1).

Figure 1: A patient with maxillofacial trauma being ventilated through tracheostomy.

4.6. The Conventional Direct Laryngoscopy. Direct laryngoscopy using a conventional laryngoscope is a simple and straightforward method for securing the airway of a patient and may be successful when done by an experienced operator. However, the risk of losing the airway is high, and hemodynamic side effects sometimes occur [57]. Considering the risk of a failed endotracheal intubation, direct laryngoscopy should be reserved for selected slim patients with good surface anatomy of the neck, where urgent cricothyroidotomy or tracheotomy is feasible when necessary, and an ear, nose, and throat specialist is ready to perform the surgical airway.

5. Preparing the Patient for Maxillofacial Surgery

The maxillofacial surgery is done after stabilization of the patient; the radiographic tests were performed, and all the injuries were identified. In some patients, the surgery is performed at the same time as the surgery on other injured organs. Operating on patients with a maxillofacial trauma and especially those with a severe complex comminuted panfacial fractures is quiet challenging for the surgeon. The surgeon has to perform fracture reduction, repair soft tissue injuries, and restore the occlusion. In order to facilitate optimal operating conditions and to achieve a proper pretraumatic figuration and function, the occlusion has to be maintained and checked at all times during the surgery. At the end of the surgery the mouth is to be set closed with MMF [33]. These surgical requirements preclude the use of oral endotracheal tube. In cases when MMF is not required, an oral tube may be suitable. The choice of an airway device that will be used during the operation is to be agreed upon by the surgeon who is familiar with the planned procedure, including possible intraoperative change of plan and potential postoperative complications.

Figure 2: A patient with maxillofacial trauma ventilated through a nasal endotracheal tube.

At this point, a decision needs to be made on the type of airway control which is suitable for the intended surgery. Some patients arrive to the operating room conscious and spontaneously breathing and their maxillofacial trauma is not extensive. In selected patients, nasoendotracheal intubation can be used for airway control during surgery [58] (Figure 2). However, nasoendotracheal intubation is relatively contraindicated in patients with midface fractures or fractures at the base of the skull [59].

Severely injured major trauma patients usually arrive at the operating room with one of the following airway control devices, namely, an endotracheal tube, a SAD, a cricothyroidotomy, or a tracheotomy, that were done earlier in the field or emergency room. In order to make a decision on which method to use for airway control during the surgery, we use an algorithm which we developed and based on our experience at Rambam Health Care Campus, a level I trauma center (Figure 3). For those trauma patients where a tracheostomy or a cricothyroidotomy was performed as the first line of securing the airway it is useful subsequently for the surgery and postoperative recovery period. It is recommended, however, that cricothyroidotomy will be converted to tracheotomy at this time [60]. If the patient arrived at the operating room with an oral endotracheal tube, and prolonged ventilation is expected, the oral tube is to be changed to open tracheostomy. When the patient presents with no mandibular fracture, a contraindication to nasal intubation is presented and there is no need for prolonged intubation; submental orotracheal intubation will be used as the method for securing the airway during surgery [61–63].

5.1. Submental Orotracheal Intubation for Maxillofacial Surgery. Submental orotracheal intubation was developed in order to avoid the need for tracheotomy and to permit unfettered access to the oral region. This type on intubation is done (a) in patients with comminuted fracture of the midface or the nose, where nasal intubation is contraindicated, (b) in patients who require restoration of the occlusion, and (c) in patients whose condition permits extubation at the end of surgery.

However, this type of intubation is contraindicated in patients with comminuted mandibular fractures.

5.1.1. Surgical Technique. Submental orotracheal intubation requires the use of a spiral reinforced armored endotracheal tube in order to prevent the tube from kinking during its usage. Following an orotracheal intubation, a 2 cm incision is made half way between the chin and the angel of the mandible, and a blunt dissection is performed to the oral floor. A surgical access is made through the superficial fascia, platysma, and deep fascia. The opening is positioned in the floor of the mouth. At the end of the dissection the forceps should be opened in order to create a tunnel for passing the tube without any interference. When creation of the surgical access is complete, the tube is pulled through the tunnel, using gentle rotational movements. Following this maneuver, the tube is connected to the ventilating machine and sutures are used to fix the tube's position (Figure 4).

When indicated, extubation is done through the external skin incision: the intermaxillary fixation is released, the fixation ligature of the tube should be opened, and the tube is disconnected from the machine. The tube should be pulled back into the oral cavity and reconnected to the anesthesia machine. The submental incision should be closed. At this point, the patient is ventilated through an oral endotracheal tube and extubation is accomplished as usual. There is no need to suture the intraoral incision and the skin incision is closed using the sutures that were placed at the time of intubation.

Complications from submental endotracheal intubation do occur and include bleeding, damage to the lingual nerve, and the marginal mandibular branch of the facial nerve, damage to the duct of the submandibular gland, damage to the sublingual gland, salivary fistulae, and skin infections [64, 65].

6. Postoperative Management of the Patient with Maxillofacial Trauma

The patient with a difficult airway is also at high risk for postoperative complications. Following surgery, the mucous membranes are edematous, the soft tissues are swollen, and the airway may be compressed. Neck expandability is relatively low and even a small hemorrhage in the region could result in airway compromise. The risk of airway-related complications during the perioperative period was studied by Peterson et al. [66]. They analyzed the American Society of Anesthesiologists Closed Claims database to identify the patterns of liability associated with the management of the difficult airway. They found that 12% of complications arose at extubation and 5% during recovery.

In intubated patients with maxillofacial trauma, extubation should be deferred until the edema subsides. During extubation the patient should be monitored closely and the care providers should be prepared for the possibility of

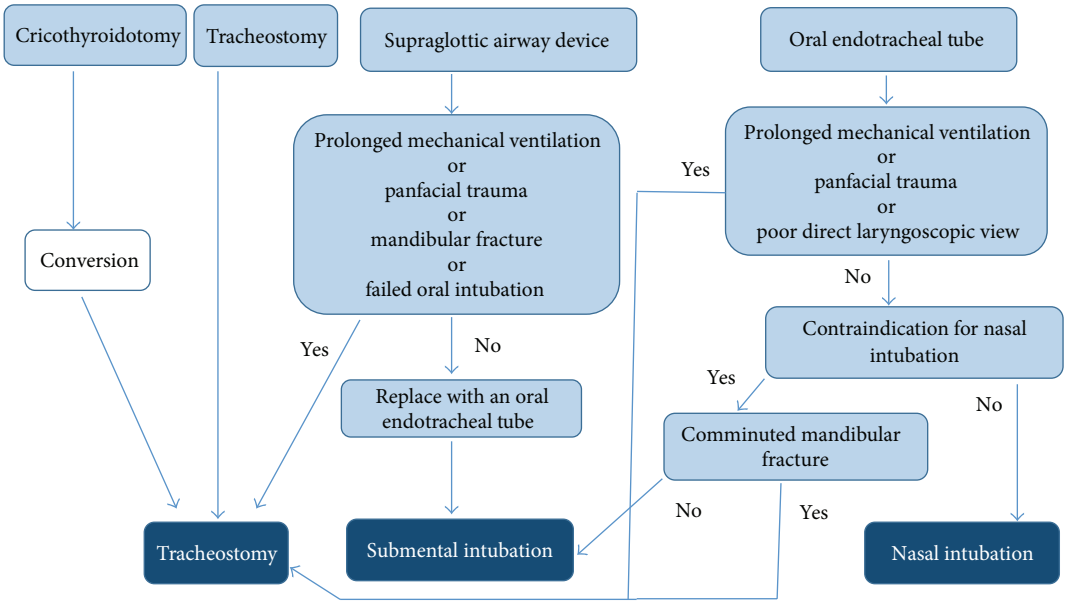

Figure 3: A decision-making algorithm for securing the airway of a patient with maxillofacial trauma during the maxillofacial surgery.

Figure 4: Submental orotracheal intubation in a patient with maxillofacial trauma.

reintubation. It is important to prevent nausea and vomiting because of the risk of gastric content aspiration [67], especially in those patients with MMF, because pulmonary aspiration is plausible. For those patients with a tracheotomy tube, the patient may be awakened and allowed to breathe spontaneously through the tracheostomy tube for a few days in order to ensure a safe recovery.

7. Conclusion

Airway management of patients with maxillofacial trauma is challenging. The clinical status and features of the trauma dictate the approach for securing the airway, and a series of steps are to be planned before airway management is initiated. Knowledge of the specific attributes of the difficult airway, expertise in the appropriate techniques for managing the difficult airway, familiarity with the various airway devices, and prompt recognition of a failed airway are necessary for optimal patient care. Skilled, open-minded personnel and a variety of advanced airway equipment are required for managing the trauma patient. Teamwork between the maxillofacial surgeon, the anesthesiologist, and the trauma expert, in which each specialist contributes his/her expert knowledge, is mandatory for better outcomes.

Conflict of Interests

The authors declare that they do not have any conflict of interests regarding the content of the paper.

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References

[1] I. Hutchison, M. Lawlor, and D. Skinner, "ABC of major trauma. Major maxillofacial injuries," *British Medical Journal*, vol. 301, no. 6752, pp. 595–599, 1990.

[2] Committee on Trauma and American College of Surgeons, *Advanced Trauma Life Support for Doctors ATLS*, American College of Surgeons, Chicago, Ill, USA, 8th edition, 2008.

[3] R. M. Walls, "Management of the difficult airway in the trauma patient," *Emergency Medicine Clinics of North America*, vol. 16, no. 1, pp. 45–61, 1998.

[4] O. Langeron, A. Birenbaum, and J. Amour, "Airway management in trauma," *Minerva Anestesiologica*, vol. 75, no. 5, pp. 307–311, 2009.

[5] A. Garcia, "Critical care issues in the early management of severe trauma," *Surgical Clinics of North America*, vol. 86, no. 6, pp. 1359–1387, 2006.

[6] R. L. Gruen, G. J. Jurkovich, L. K. McIntyre, H. M. Foy, and R. V. Maier, "Patterns of errors contributing to trauma mortality:

lessons learned from 2594 deaths," *Annals of Surgery*, vol. 244, no. 3, pp. 371–378, 2006.

[7] B. A. Sellick, "Cricoid pressure to control regurgitation of stomach contents during induction of anaesthesia," *The Lancet*, vol. 278, no. 7199, pp. 404–406, 1961.

[8] N. Haslam, L. Parker, and J. E. Duggan, "Effect of cricoid pressure on the view at laryngoscopy," *Anaesthesia*, vol. 60, no. 1, pp. 41–47, 2005.

[9] D. Y. Ellis, T. Harris, and D. Zideman, "Cricoid pressure in emergency department rapid sequence tracheal intubations: a risk-benefit analysis," *Annals of Emergency Medicine*, vol. 50, no. 6, pp. 653–665, 2007.

[10] N. Bhatia, H. Bhagat, and I. Sen, "Cricoid pressure: where do we stand?" *Journal of Anaesthesiology Clinical Pharmacology*, vol. 30, no. 1, pp. 3–6, 2014.

[11] S. K. Beckers, J. C. Brokmann, and R. Rossaint, "Airway and ventilator management in trauma patients," *Current Opinion in Critical Care*, vol. 20, no. 6, pp. 626–631, 2014.

[12] B. T. Jamal, R. Diecidue, A. Qutub, and M. Cohen, "The pattern of combined maxillofacial and cervical spine fractures," *Journal of Oral and Maxillofacial Surgery*, vol. 67, no. 3, pp. 559–562, 2009.

[13] S. A. Rahman and S. Chandrasala, "When to suspect head injury or cervical spine injury in maxillofacial trauma?" *Dental Research Journal*, vol. 11, no. 3, pp. 336–344, 2014.

[14] E. T. Crosby, "Airway management in adults after cervical spine trauma," *Anesthesiology*, vol. 104, no. 6, pp. 1293–1318, 2006.

[15] S. Manoach and L. Paladino, "Manual in-line stabilization for acute airway management of suspected cervical spine injury: historical review and current questions," *Annals of Emergency Medicine*, vol. 50, no. 3, pp. 236–245, 2007.

[16] B. G. Santoni, B. J. Hindman, C. M. Puttlitz et al., "Manual in-line stabilization increases pressures applied by the laryngoscope blade during direct laryngoscopy and orotracheal intubation," *Anesthesiology*, vol. 110, no. 1, pp. 24–31, 2009.

[17] C. Kill, J. Risse, P. Wallot, P. Seidl, T. Steinfeldt, and H. Wulf, "Videolaryngoscopy with glidescope reduces cervical spine movement in patients with unsecured cervical spine," *Journal of Emergency Medicine*, vol. 44, no. 4, pp. 750–756, 2013.

[18] A. Robitaille, S. R. Williams, M.-H. Tremblay, F. Guilbert, M. Thériault, and P. Drolet, "Cervical spine motion during tracheal intubation with manual in-line stabilization: direct laryngoscopy versus GlideScope videolaryngoscopy," *Anesthesia and Analgesia*, vol. 106, no. 3, pp. 935–941, 2008.

[19] N. Bhardwaj, K. Jain, M. Rao, and A. K. Mandal, "Assessment of cervical spine movement during laryngoscopy with Macintosh and Truview laryngoscopes," *Journal of Anaesthesiology Clinical Pharmacology*, vol. 29, no. 3, pp. 308–312, 2013.

[20] S. R. Thaller and S. L. Beal, "Maxillofacial trauma: a potentially fatal injury," *Annals of Plastic Surgery*, vol. 27, no. 3, pp. 281–283, 1991.

[21] T. Harris, S. Rice, B. Watts, and G. Davies, "The emergency control of traumatic maxillofacial haemorrhage," *European Journal of Emergency Medicine*, vol. 17, no. 4, pp. 230–233, 2010.

[22] W. H. Liu, Y. H. Chen, C. T. Hsieh, E. Y. Lin, T. T. Chung, and D. T. Ju, "Transarterial embolization in the management of life-threatening hemorrhage after maxillofacial trauma: a case report and review of literature," *The American Journal of Emergency Medicine*, vol. 26, no. 4, pp. 516.e3–516.e5, 2008.

[23] S. Khanna and A. B. Dagum, "A critical review of the literature and an evidence-based approach for life-threatening hemorrhage in maxillofacial surgery," *Annals of Plastic Surgery*, vol. 69, no. 4, pp. 474–478, 2012.

[24] T. C. Mort, "Complications of emergency tracheal intubation: immediate airway-related consequences: part II," *Journal of Intensive Care Medicine*, vol. 22, no. 4, pp. 208–215, 2007.

[25] M. W. Mechlin and W. E. Hurford, "Emergency tracheal intubation: techniques and outcomes," *Respiratory Care*, vol. 59, no. 6, pp. 881–894, 2014.

[26] J. F. Boylan and B. P. Kavanagh, "Emergency airway management: competence versus expertise?" *Anesthesiology*, vol. 109, no. 6, pp. 945–947, 2008.

[27] G. Kovacs, J. A. Law, J. Ross et al., "Acute airway management in the emergency department by non-anesthesiologists," *Canadian Journal of Anesthesia*, vol. 51, no. 2, pp. 174–180, 2004.

[28] R. M. Walls, C. A. Brown III, A. E. Bair, and D. J. Pallin, "Emergency airway management: a multi-center report of 8937 Emergency Department intubations," *Journal of Emergency Medicine*, vol. 41, no. 4, pp. 347–354, 2011.

[29] J. W. Tuckett, A. Lynham, G. A. Lee, M. Perry, and U. Harrington, "Maxillofacial trauma in the emergency department: a review," *Surgeon*, vol. 12, no. 2, pp. 106–114, 2014.

[30] J. C. Phero, M. B. Rosenberg, and J. A. Giovannitti Jr., "Adult airway evaluation in oral surgery," *Oral & Maxillofacial Surgery Clinics of North America*, vol. 25, no. 3, pp. 385–399, 2013.

[31] R. Peralta and W. E. Hurford, "Airway trauma," *International Anesthesiology Clinics*, vol. 38, no. 3, pp. 111–127, 2000.

[32] J. L. Apfelbaum, C. A. Hagberg, R. A. Caplan et al., "Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway," *Anesthesiology*, vol. 118, no. 2, pp. 251–270, 2013.

[33] C. G. Robertson and J. C. Doucet, "Helping anesthesiologists understand facial fractures," *Oral and Maxillofacial Surgery Clinics of North America*, vol. 25, no. 4, pp. 561–572, 2013.

[34] J. Mayglothling, T. M. Duane, M. Gibbs et al., "Emergency tracheal intubation immediately following traumatic injury: an eastern association for the surgery of trauma practice management guideline," *Journal of Trauma and Acute Care Surgery*, vol. 73, supplement 4, no. 5, pp. S333–S340, 2012.

[35] J. B. Gaither, D. W. Spaite, U. Stolz, J. Ennis, J. Mosier, and J. J. Sakles, "Prevalence of difficult airway predictors in cases of failed prehospital endotracheal intubation," *Journal of Emergency Medicine*, vol. 47, no. 3, pp. 294–300, 2014.

[36] P. A. Baker, B. T. Flanagan, K. B. Greenland et al., "Equipment to manage a difficult airway during anaesthesia," *Anaesthesia & Intensive Care*, vol. 39, no. 1, pp. 16–34, 2011.

[37] M. F. Aziz, D. Healy, S. Kheterpal, R. F. Fu, D. Dillman, and A. M. Brambrink, "Routine clinical practice effectiveness of the glidescope in difficult airway management: an analysis of 2,004 glidescope intubations, complications, and failures from two institutions," *Anesthesiology*, vol. 114, no. 1, pp. 34–41, 2011.

[38] R. Schalk, C. Byhahn, F. Fausel et al., "Out-of-hospital airway management by paramedics and emergency physicians using laryngeal tubes," *Resuscitation*, vol. 81, no. 3, pp. 323–326, 2010.

[39] K. Ruetzler, B. Roessler, L. Potura et al., "Performance and skill retention of intubation by paramedics using seven different airway devices-a Manikin Study," *Resuscitation*, vol. 82, no. 5, pp. 593–597, 2011.

[40] G. Goliasch, A. Ruetzler, H. Fischer, M. Frass, D. I. Sessler, and K. Ruetzler, "Evaluation of advanced airway management in absolutely inexperienced hands: a randomized manikin trial," *European Journal of Emergency Medicine*, vol. 20, no. 5, pp. 310–314, 2013.

[41] G. Grier, P. Bredmose, G. Davies, and D. Lockey, "Introduction and use of the ProSeal laryngeal mask airway as a rescue device in a pre-hospital trauma anaesthesia algorithm," *Resuscitation*, vol. 80, no. 1, pp. 138–141, 2009.

[42] R. L. Mabry and A. Frankfurt, "Advanced airway management in combat casualties by medics at the point of injury: a subgroup analysis of the reach study," *Journal of Special Operations Medicine*, vol. 11, no. 2, pp. 16–19, 2011.

[43] B. D. Adams, P. A. Cuniowski, A. Muck, and R. A. de Lorenzo, "Registry of emergency airways arriving at combat hospitals.," *The Journal of trauma*, vol. 64, no. 6, pp. 1548–1554, 2008.

[44] D. T. Wong, J. J. Yang, H. Y. Mak, and N. Jagannathan, "Use of intubation introducers through a supraglottic airway to facilitate tracheal intubation: a brief review," *Canadian Journal of Anesthesia*, vol. 59, no. 7, pp. 704–715, 2012.

[45] M.-C. Vézina, C. A. Trépanier, P. C. Nicole, and M. R. Lessard, "Complications associated with the Esophageal-Tracheal Combitube in the pre-hospital setting," *Canadian Journal of Anesthesia*, vol. 54, no. 2, pp. 124–128, 2007.

[46] D. P. Dob, H. A. McLure, and N. Soni, "Failed intubation and emergency percutaneous tracheostomy," *Anaesthesia*, vol. 53, no. 1, pp. 72–74, 1998.

[47] M. Helm, A. Gries, and T. Mutzbauer, "Surgical approach in difficult airway management," *Best Practice & Research: Clinical Anaesthesiology* , vol. 19, no. 4, pp. 623–640, 2005.

[48] A. E. Hamaekers and J. J. Henderson, "Equipment and strategies for emergency tracheal access in the adult patient," *Anaesthesia*, vol. 66, no. 2, pp. 65–80, 2011.

[49] P. A. Kearney, M. M. Griffen, J. B. Ochoa, B. R. Boulanger, B. J. Tseui, and R. M. Mentzer Jr., "A single-center 8-year experience with percutaneous dilational tracheostomy," *Annals of Surgery*, vol. 231, no. 5, pp. 701–709, 2000.

[50] H.-W. Yuen, A. H.-C. Loy, and S. Johari, "Urgent awake tracheotomy for impending airway obstruction," *Otolaryngology—Head and Neck Surgery*, vol. 136, no. 5, pp. 838–842, 2007.

[51] K. W. Altman, J. D. Waltonen, and R. C. Kern, "Urgent surgical airway intervention: a 3 year county hospital experience," *Laryngoscope*, vol. 115, no. 12, pp. 2101–2104, 2005.

[52] P. Gupta and A. Modrykamien, "Fatal case of tension pneumothorax and subcutaneous emphysema after open surgical tracheostomy," *Journal of Intensive Care Medicine*, vol. 29, no. 5, pp. 298–301, 2014.

[53] S. Cooper, "We need to cut the neck!: confronting psychological and moral distress during cricothyrotomy," *Narrative Inquiry in Bioethics*, vol. 3, no. 2, pp. E5–E9, 2013.

[54] K. B. Greenland, C. Acott, R. Segal, G. Goulding, R. H. Riley, and A. F. Merry, "Emergency surgical airway in life-threatening acute airway emergencies—why are we so reluctant to do it?" *Anaesthesia & Intensive Care*, vol. 39, no. 4, pp. 578–584, 2011.

[55] J. K. Dillon, B. Christensen, T. Fairbanks, G. Jurkovich, and K. S. Moe, "The emergent surgical airway: cricothyrotomy vs tracheotomy," *International Journal of Oral and Maxillofacial Surgery*, vol. 42, no. 2, pp. 204–208, 2013.

[56] R. L. Mabry, "An analysis of battlefield cricothyrotomy in Iraq and Afghanistan," *Journal of Special Operations Medicine*, vol. 12, no. 1, pp. 17–23, 2012.

[57] V. K. Srivastava, S. Agrawal, R. Kumar, and P. P. Misra, "Bradycardia and hypotension during laryngoscopy for intubation in maxillofacial trauma," *Saudi Journal of Anaesthesia*, vol. 6, no. 4, pp. 436–437, 2012.

[58] C. E. J. Hall and L. E. Shutt, "Nasotracheal intubation for head and neck surgery," *Anaesthesia*, vol. 58, no. 3, pp. 249–256, 2003.

[59] D. A. Muzzi, T. J. Losasso, and R. F. Cucchiara, "Complication from a nasopharyngeal airway in a patient with a basilar skull fracture," *Anesthesiology*, vol. 74, no. 2, pp. 366–368, 1991.

[60] P. Talving, J. DuBose, K. Inaba, and D. Demetriades, "Conversion of emergent cricothyrotomy to tracheotomy in trauma patients," *Archives of Surgery*, vol. 145, no. 1, pp. 87–91, 2010.

[61] A. Vashishta, S. Sharma, A. Chugh, D. Jain, N. Gupta, and U. Bihani, "Submental intubation: a useful adjunct in panfacial trauma," *National Journal of Maxillofacial Surgery*, vol. 1, no. 1, pp. 74–77, 2010.

[62] P. Schütz and H. H. Hamed, "Submental intubation versus tracheostomy in maxillofacial trauma patients," *Journal of Oral and Maxillofacial Surgery*, vol. 66, no. 7, pp. 1404–1409, 2008.

[63] B. Eisemann, M. Eisemann, M. Rizvi, M. M. Urata, and M. A. Lypka, "Defining the role for submental intubation," *Journal of Clinical Anesthesia*, vol. 26, no. 3, pp. 238–242, 2014.

[64] G. L. de Toledo, S. C. Bueno, R. A. Mesquita, and M. B. F. Amaral, "Complications from submental endotracheal intubation: a prospective study and literature review," *Dental Traumatology*, vol. 29, no. 3, pp. 197–202, 2013.

[65] G. Mittal, R. K. Mittal, S. Katyal, S. Uppal, and V. Mittal, "Airway management in maxillofacial trauma: do we really need tracheostomy/ submental intubation," *Journal of Clinical and Diagnostic Research*, vol. 8, no. 3, pp. 77–79, 2014.

[66] G. N. Peterson, K. B. Domino, R. A. Caplan, K. L. Posner, L. A. Lee, and F. W. Cheney, "Management of the difficult airway: a closed claims analysis," *Anesthesiology*, vol. 103, no. 1, pp. 33–39, 2005.

[67] H. E. Jahromi, M. Gholami, and F. Rezaei, "A randomized double-blinded placebo controlled study of four interventions for the prevention of postoperative nausea and vomiting in maxillofacial trauma surgery," *Journal of Craniofacial Surgery*, vol. 24, no. 6, pp. e623–e627, 2013.

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Research Article

The AirView Study: Comparison of Intubation Conditions and Ease between the Airtraq-AirView and the King Vision

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We conducted a study assessing the quality and speed of intubation between the Airtraq with its new iPhone AirView app and the King Vision in a manikin. The primary endpoint was reduction of time needed for intubation. Secondary endpoints included times necessary for intubation. 30 anaesthetists randomly performed 3 intubations with each device on a difficult airway manikin. Participants had a professional experience of 12 years: 60.0% possessed the Airtraq in their hospital, 46.7% the King Vision, and 20.0% both. Median time difference [IQR] to identify glottis (1.1 [−1.3; 3.9] $P = 0.019$), for tube insertion (2.1 [−2.6; 9.4] $P = 0.002$) and lung ventilation (2.8 [−2.4; 11.5] $P = 0.001$), was shorter with the Airtraq-AirView. Median time for glottis visualization was significantly shorter with the Airtraq-AirView (5.3 [4.0; 8.4] versus 6.4 [4.6; 9.1]). Cormack Lehane before intubation was better with the King Vision ($P = 0.03$); no difference was noted during intubation, for subjective device insertion or quality of epiglottis visualisation. Assessment of tracheal tube insertion was better with the Airtraq-AirView. The Airtraq-AirView allows faster identification of the landmarks and intubation in a difficult airway manikin, while clinical relevance remains to be studied. Anaesthetists assessed the intubation better with the Airtraq-AirView.

1. Introduction

Numerous anatomically shaped indirect laryngoscopes are available on the market. Both the Airtraq© (Prodol Meditec SA, Vizcaya, Spain) and the King Vision (King Systems, Noblesville, IN, USA) allow better glottis visualization and Cormack Lehane score (CL) than direct laryngoscopy [1], a fast learning curve [2], and they both offer a blade that incorporates a tube channel that holds the endotracheal tube (ETT) and guides it towards the glottis [3]. Visualization of the anatomical landmarks and ETT movement and passage is obtained either by direct vision on the device [4] or via a LCD display [5, 6]. The high-quality enlarged images obtained through these different monitors have been shown to be useful tools for training and teaching [7–9] and for managing difficult airway [3], allowing for better coordination between operator and assistant. Recently, a specially designed clip-on wireless camera that relays the image on a separate monitor screen has been commercialized for the Airtraq, improving the ease of tracheal intubation [10].

Smartphones have become increasingly popular among anaesthetists [11] and are carried in pockets and thus readily available. They possess high-quality camera optics allowing image viewing and acquisition, storage, manipulation, and transmission leading to regular usage in association with clinical applications in theatres [12, 13]. A recent study has assessed the usefulness of the iPhone (Apple Inc., Cupertino, CA, USA) as an adjunct aid to assist in fibreoptic intubation and clinical teaching in a difficult airway scenario when a screen for video-assisted bronchoscopy was unavailable [14]. Although it was found more difficult to use compared to a bronchoscope, the iPhone modified bronchoscope offered several advantages for teaching fibreoptic technique.

Recently, an iPhone app (AirView by Mobilemed Sàrl, Switzerland) that allows live visualisation of the intubation process with the Airtraq has been made freely available on the app store. It works in conjunction with a specially designed adapter (A-308) for iPhone 5s, designed and manufactured by Prodol Meditec Limited, Coast, Zhuhai, Guangdong, China,

Figure 1

and distributed through the Airtraq worldwide distributors network (Prodol Meditec SA, Las Arenas, Spain) (see Figure 1).

The aim of this study was to compare success rate, time to ventilation, and quality of intubation between the Airtraq coupled to an iPhone using the new AirView app and the King Vision in a manikin study simulating a difficult airway. The primary endpoint was reduction in time necessary for successful intubation on the first attempt for each device. Secondary endpoints included time necessary to identify the glottis and to insert the tube and inflate its cuff, best view during laryngoscopy before and during intubation, as well as ease of insertion of the device in the mouth, of epiglottis visualisation, and of intubation.

2. Method

The President of the Local Institutional Ethics Committee (Professor P. Francioli, Commission Cantonale d'Ethique de la recherche sur l'être humain, 1012 Lausanne, Switzerland) judged that, according to the national guidelines for clinical research, ethics committee approval was not required. 30 senior anaesthetists attending a difficult airway course in Switzerland gave written consent to participate in this study. Each anaesthetist was given a standardized demonstration by the commercial representative of the Airtraq and King Vision device. The AirView app is downloadable free of charge on the iTunes app store and a specifically designed adaptor warrants a physical connection between an iPhone 5s and the Airtraq (see Figure 2).

Figure 2

All participants used the Airtraq sp (AT) size 3 coupled to an iPhone 5s and the King Vision with a size 3 channeled blade (KVC) with a preloaded lubricated 7.5 mm tube (Mallinckrodt Hi-Contour Oral Tracheal Tube Cuffed; Covidien Ilc, 15 Hampshire Street, Mansfield, MA, USA). They were assigned by envelope randomization to perform 6 intubations (3 with the Airtraq-AirView and 3 with the King Vision) on an airway manikin (ALS SkillTrainer; Laerdal, Stavanger, Norway) simulating a difficult airway with its neck immobilized by a cervical collar (Philadelphia Cervical Collar Co., Thorofare, NJ, USA), causing also reduction in mouth opening to 3 cm.

The timer was started (T_0) when touching the AT or KVC, which was then inserted into the mouth. Once the laryngeal inlet was identified, the time was recorded (T_1). The endotracheal tube (ETT) was advanced into the trachea, the cuff inflated (T_2), and the timer was stopped (T_3) when ventilation of the lungs was visible after connecting the tube to a bag-mask resuscitator (Ambu SPUR II resuscitator, Ambu A/S, 2750 Ballerup).

Table 1

	Airtraq-AirView $n = 90$		King Vision $n = 90$		Delta K-A		P
	Median	IQR	Median	IQR	Median	IQR	
Time to identify glottis	5.3	[3.9; 8.4]	6.4	[4.6; 9.1]	1.1	[−1.3; 3.9]	0.019
Time to inflate the cuff	14.2	[9.1; 18.2]	15.2	[10.9; 26.1]	2.1	[−2.6; 9.4]	0.002
Time to ventilate the lungs	16.6	[11.9; 21.1]	17.9	[13.6; 28.5]	2.8	[−2.4; 11.5]	0.0002

Times are expressed in seconds.

Insertion, intubation, and ventilation success within 60 seconds, time necessary to identify the glottis with the Airtraq (TA_1) or the King Vision (TK_1), to insert the tube and inflate its cuff (TA_2) or (TK_2), and to ventilate the lungs (TA_3) or (TK_3), were recorded. Time differences were defined as TK-TA and if >0, time necessary to fulfill the task using the Airtraq-AirView was shorter; if = 0, no differences in times were observed between the King Vision and the Airtraq-AirView; and if TK-TA was <0, the King Vision allowed quicker times.

Best view during indirect laryngoscopy was assessed as Cormack Lehane [15] (CL 1, 2a, 2b, 3, 4) and percentage of glottic opening (POGO) [16] before and during intubation. Ease of insertion of the device in the mouth, of epiglottis visualisation, and of intubation was also documented (1 = very easy, 2 = easy, 3 = moderate, 4 = difficult, and 5 = very difficult).

The primary endpoint was time reduction necessary for successful intubation on the first attempt for each device. A failed intubation was defined as oesophageal intubation or a time necessary to ventilate the lungs longer than 60 seconds. Secondary endpoints included time necessary to identify the glottis and to insert the tube and inflate its cuff, best view during laryngoscopy before and during intubation, as well as ease of insertion of the device in the mouth, of epiglottis visualisation, and of intubation.

Based on the study by Wetsch et al. [17], a time to ventilate of 33 seconds was deemed clinically relevant. We considered that a time difference of ten seconds (the one-third of 33 seconds) between the two devices in the primary outcome of "time to first ventilation" would be clinically relevant. To detect this difference, with a power of 90% at a two-tailed significance level of 5% (Wilcoxon-Mann-Whitney two groups test), the G* power statistical power analyses software [18] calculated a total sample size of 180 intubations.

Statistical tests used were median or chi-squared where appropriate. Data were analyzed using the JMP 10 statistical package (SAS Institute Inc, Cary, NC, USA).

3. Results

All anaesthetists (16 females and 14 males) had experience in indirect laryngoscopy with an average exposure to airway management of 12 years (SD 9.9).

18 (60.0%) participants used the Airtraq regularly in their clinical setting, 14 (46.7%) the King Vision, and 6 (20.0%) had access to both.

Table 2

Cormack Lehane best view	Airtraq-AirView		King Vision	
	$n = 90$	%	$n = 90$	%
1	70	77.8	81	90.0
2a	20	22.2	8	8.9
2b	0		1	1.1

Insertion, intubation, and ventilation were possible within the allocated time in all cases with both devices by all participants.

Time necessary to identify glottis, to insert the tube and inflate its cuff, and to ventilate the lungs was significantly shorter with the Airtraq-AirView (see Table 1).

Cormack Lehane best view during videolaryngoscopy before intubation was reported as significantly better with the King Vision ($P = 0.03$) while no significant difference was noted during the intubation process (see Table 2).

A CL 1 was present in 72 (80.0%) intubations with the Airtraq-AirView versus 80 (88.9%) with the King Vision and a CL 2 was present in 18 (20.0%) AT intubations versus 10 (11.1%) for the KVC group. Median POGO was described as equal between the Airtraq-AirView group versus King Vision before (86.5% [77.3; 92.6] versus 85.8% [75.2; 91.9]) and during intubation (85.4% [76.2; 91.4] versus 84.8% [75.2; 90.8]).

No statistically significant difference was noted for subjective ease of device insertion or quality of epiglottis visualisation while subjective assessment of ease of tracheal tube insertion was significantly better with the Airtraq-AirView ($P = 0.001$) (see Table 3).

4. Discussion

We showed that the Airtraq coupled to an iPhone with its dedicated AirView app allowed quicker identification of epiglottis and intubation as well as easier tracheal tube insertion on an airway manikin simulating difficult intubation than the King Vision by experienced anaesthetists.

Channeled indirect laryngoscopes are popular devices in cases of difficult intubation and have been shown to reduce intubation time, improve the intubation difficulty scale, and significantly improve the view during laryngoscopy [19–22]. Improved lighting and a view through a screen has been shown to facilitate tracheal inlet visualization [23, 24]. Only individual solutions have been reported on adding variable types of cameras and monitors to these devices [25–27], while

Table 3

	Ease of device insertion		Ease of epiglottis visualisation		Ease of intubation	
	AT-AirView $n = 90$	King Vision $n = 90$	AT-AirView $n = 90$	King Vision $n = 90$	AT-AirView $n = 90$	King Vision $n = 90$
1	51	48	66	68	63	52
2	33	34	24	20	22	15
3	6	8	0	1	5	14
4	0	0	0	1	0	9

using an existing optional video camera for the Airtraq has been shown to improve the ease of tracheal intubation in specific circumstances [10, 28]. We provide the first report about a visualization and intubation app accessible with no charge through the app store and tailored for an existing indirect laryngoscope, allowing direct view with the help of a specific adaptor and comparing its use with a high-resolution videolaryngoscope.

Although all intubations were possible within the allocated time with both devices, times necessary to identify mandatory anatomical landmarks for proper intubation were significantly shorter as was the subjective assessment of tracheal tube insertion with the Airtraq coupled to the AirView app. Ueshima and Asai [29] report even shorter intubation times while using the Airtraq. Their study was designed to compare the ease of tracheal intubation with various external lighting conditions with a regular airway manikin. In another study assessing success rates and endotracheal tube insertion times in a difficult airway setting, Wetsch et al. [30] found that 43 seconds was necessary for intubation with the Airtraq. Although it also used experienced anesthesiologists, their study setting varied as their manikin was trapped in a car, simulating difficult airway and difficulty in airway access. Our study was designed to simulate a difficult airway scenario with a manikin positioned supine on a table, as happening in an hospital setting, similarly to a second study by Wetsch et al. [17], showing same results as ours.

The Cormack Lehane view obtained during the indirect laryngoscopy was reported better with the King Vision while no difference was noted during intubation. Yun et al. [31] compared Cormack Lehane views between different videolaryngoscopes in a tactical setting and were unable to show a difference between the Airtraq and the King Vision. Their setting included paramedics and using the Airtraq with its eyepiece, therefore not allowing external viewing of the intubation process. The percentage of glottic opening is the favored classification in assessing visualization during videolaryngoscopy. It essentially provides a continuous and numerical value across the full range of Cormack Lehane grades I through III, making it more reliable in assessing laryngeal exposition. Assessing performance of indirect laryngoscopes includes vocal cords visualization but focuses more on successful intubation, time necessary for intubation, and the complexity of the maneuver [32]. In our study, shorter time of ventilation and easier intubation with the Airtraq coupled to AirView show promising results.

There are several limitations in our study. First of all, difficult airway research on manikins relies mainly on how realistic the upper airway of the manikin is. New airway devices must be assessed in an objective way without patient harm and manikin-based airway research is accepted [4, 33–35]. Studies have reported considerable disparity in airway anatomy between manikins and actual patients [34]. Because the upper airway anatomy of the manikin used in this study has not been evaluated, the results obtained may be valid only in the manikin we used. Second, blinding of each participant to the device used for intubation is impossible. Some participants may have a preference for one of the two devices studied before the study. In our setting, slightly more anesthesiologists had experience with the Airtraq, while none had had a chance to practice intubation with the AirView app. Third, we conducted this study during a difficult airway course, where mainly experienced anesthesiologists were present with an interest in difficulty airway management. The results obtained may not be reproduced with more junior providers or paramedics. And fourth, the clinical relevance of the time difference found in our study may be irrelevant, even if similar intubation times have been described in different manikin settings [36].

Finally, smartphones are carried by most physicians throughout hospitals and in the operating rooms [11], in both developed and developing countries [37]. The addition of an iPhone to an Airtraq provides a high-quality vision, allowing image manipulation and analysis, recording, and postoperative sharing for teaching purpose, while not modifying the line of sight. However, further thoughts must be given to legal issues, such as recording patient data on a smartphone, private or not. Some countries have enforced laws, such as the Health Information Privacy and Accountability Act (HIPPA) (http://www.hhs.gov/ocr/privacy) governing the use, storage, and dissemination of personal health information. It therefore protects the privacy of an individual's health information and governs the way certain health care providers and benefits plans collect, maintain, use, and disclose protected health information.

We conclude that the Airtraq-AirView allows faster identification of the landmarks and intubation in a simulated difficult airway manikin in comparison to an existing high-quality videolaryngoscope. Anaesthetists assessed the intubation to be better with the Airtraq-AirView.

Clinical trials evaluating the effects of a specially designed app associated to the Airtraq on intubation success in the clinical setting are underway.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

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References

[1] D. Ranieri Jr., S. M. Filho, S. Batista, and P. do Nascimento Jr., "Comparison of Macintosh and Airtraq laryngoscopes in obese patients placed in the ramped position," *Anaesthesia*, vol. 67, no. 9, pp. 980–985, 2012.

[2] G. L. Savoldelli, E. Schiffer, C. Abegg, V. Baeriswyl, F. Clergue, and W. Jean-Luc, "Learning curves of the Glidescope, the McGrath and the Airtraq laryngoscopes: a manikin study," *European Journal of Anaesthesiology*, vol. 26, no. 7, pp. 554–558, 2009.

[3] J.-B. Paolini, F. Donati, and P. Drolet, "Review article: video-laryngoscopy: another tool for difficult intubation or a new paradigm in airway management?" *Canadian Journal of Anesthesia*, vol. 60, no. 2, pp. 184–191, 2013.

[4] C. H. Maharaj, B. D. Higgins, B. H. Harte, and J. G. Laffey, "Evaluation of intubation using the Airtraq® or Macintosh laryngoscopy—a manikin study," *Anaesthesia*, vol. 61, no. 5, pp. 469–477, 2006.

[5] Y. Akihisa, K. Maruyama, Y. Koyama, R. Yamada, A. Ogura, and T. Andoh, "Comparison of intubation performance between the King Vision and Macintosh laryngoscopes in novice personnel: a randomized, crossover manikin study," *Journal of Anesthesia*, vol. 28, no. 1, pp. 51–57, 2014.

[6] M. A. Malik, C. H. Maharaj, B. H. Harte, and J. G. Laffey, "Comparison of Macintosh, Truview EVO2, Glidescope, and Airwayscope laryngoscope use in patients with cervical spine immobilization," *British Journal of Anaesthesia*, vol. 101, no. 5, pp. 723–730, 2008.

[7] M. B. Kaplan, D. Ward, C. A. Hagberg, G. Berci, and M. Hagiike, "Seeing is believing: the importance of video laryngoscopy in teaching and in managing the difficult airway," *Surgical Endoscopy and Other Interventional Techniques*, vol. 20, no. 2, pp. S479–S483, 2006.

[8] K. J. Howard-Quijano, Y. M. Huang, R. Matevosian, M. B. Kaplan, and R. H. Steadman, "Video-assisted instruction improves the success rate for tracheal intubation by novices," *British Journal of Anaesthesia*, vol. 101, no. 4, pp. 568–572, 2008.

[9] H. Zhao, Y. Feng, and Y. Zhou, "Teaching tracheal intubation: Airtraq is superior to Macintosh laryngoscope," *BMC Medical Education*, vol. 14, no. 1, article 144, 2014.

[10] H. Kohama, N. Komasawa, R. Ueki, M. Itani, S.-I. Nishi, and Y. Kaminoh, "Addition of a video camera system improves the ease of Airtraq tracheal intubation during chest compression," *Journal of Anesthesia*, vol. 26, no. 2, pp. 296–298, 2012.

[11] K. B. Dasari, S. M. White, and J. Pateman, "Survey of iPhone usage among anaesthetists in England," *Anaesthesia*, vol. 66, no. 7, pp. 630–631, 2011.

[12] D. Low, B. York, and M. J. Eisses, "A novel use for the Apple (4th generation) iPod Touch in the operating room," *Anaesthesia*, vol. 66, no. 1, pp. 61–62, 2011.

[13] D. K. Low and A. P. Pittaway, "The "iPhone" induction—a novel use for the Apple iPhone," *Paediatric Anaesthesia*, vol. 18, no. 6, pp. 573–574, 2008.

[14] A. Langley and G. M. Fan, "Comparison of the glidescope, flexible fibreoptic intubating bronchoscope, iPhone modified bronchoscope, and the Macintosh laryngoscope in normal and difficult airways: a manikin study," *BMC Anesthesiology*, vol. 14, article 10, 2014.

[15] S. M. Yentis and D. J. H. Lee, "Evaluation of an improved scoring system for the grading of direct laryngoscopy," *Anaesthesia*, vol. 53, no. 11, pp. 1041–1044, 1998.

[16] R. M. Levitan, E. A. Ochroch, S. Kush, F. S. Shofer, and J. E. Hollander, "Assessment of airway visualization: validation of the percentage of glottic opening (POGO) scale," *Academic Emergency Medicine*, vol. 5, no. 9, pp. 919–923, 1998.

[17] W. A. Wetsch, O. Spelten, M. Hellmich et al., "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*, vol. 83, no. 6, pp. 740–745, 2012.

[18] F. Faul, E. Erdfelder, A. Buchner, and A.-G. Lang, "Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses," *Behavior Research Methods*, vol. 41, no. 4, pp. 1149–1160, 2009.

[19] C. H. Maharaj, J. F. Costello, B. H. Harte, and J. G. Laffey, "Evaluation of the Airtraq and Macintosh laryngoscopes in patients at increased risk for difficult tracheal intubation," *Anaesthesia*, vol. 63, no. 2, pp. 182–188, 2008.

[20] C. H. Maharaj, E. Buckley, B. H. Harte, and J. G. Laffey, "Endotracheal intubation in patients with cervical spine immobilization: a comparison of macintosh and airtraq laryngoscopes," *Anesthesiology*, vol. 107, no. 1, pp. 53–59, 2007.

[21] S. K. Ndoko, R. Amathieu, L. Tual et al., "Tracheal intubation of morbidly obese patients: a randomized trial comparing performance of Macintosh and AirtraqŮ laryngoscopes," *British Journal of Anaesthesia*, vol. 100, no. 2, pp. 263–268, 2008.

[22] L. D. Murphy, G. J. Kovacs, P. M. Reardon, and J. A. Law, "Comparison of the king vision video laryngoscope with the macintosh laryngoscope," *Journal of Emergency Medicine*, vol. 47, no. 2, pp. 239–246, 2014.

[23] S. Y. Thong and Y. Lim, "Video and optic laryngoscopy assisted tracheal intubation—the new era," *Anaesthesia and Intensive Care*, vol. 37, no. 2, pp. 219–233, 2009.

[24] P. Niforopoulou, I. Pantazopoulos, T. Demestiha, E. Koudouna, and T. Xanthos, "Video-laryngoscopes in the adult airway management: a topical review of the literature," *Acta Anaesthesiologica Scandinavica*, vol. 54, no. 9, pp. 1050–1061, 2010.

[25] F. Aldridge and J. Craggs, "The Airtraq camera adapter," *Journal of Clinical Anesthesia*, vol. 25, no. 2, p. 160, 2013.

[26] M. Okuda, T. Tagawa, and S. Sakuraba, "Additional monitoring and recording system for the Airtraq," *Journal of Clinical Anesthesia*, vol. 21, no. 4, pp. 310–311, 2009.

[27] Y. Hirabayashi and N. Seo, "A monitor to facilitate use of the Airtraq laryngoscope," *Anaesthesia*, vol. 62, no. 10, p. 1081, 2007.

[28] G. Dhonneur, S. Zraier, J. L. Sebbah, and H. Haouache, "Urgent face-to-face tracheal re-intubation using Video-Airtraq in ICU patients placed in the sitting position," *Intensive Care Medicine*, vol. 40, no. 4, pp. 625–626, 2014.

[29] H. Ueshima and T. Asai, "Tracheal intubation in daylight and in the dark: a randomised comparison of the Airway Scope, Airtraq, and Macintosh laryngoscope in a manikin," *Anaesthesia*, vol. 65, no. 7, pp. 684–687, 2010.

[30] W. A. Wetsch, M. Carlitscheck, O. Spelten et al., "Success rates and endotracheal tube insertion times of experienced emergency physicians using five video laryngoscopes: a randomised trial in a simulated trapped car accident victim," *European Journal of Anaesthesiology*, vol. 28, no. 12, pp. 849–858, 2011.

[31] B. J. Yun, C. A. Brown III, C. J. Grazioso, C. N. Pozner, and A. S. Raja, "Comparison of video, optical, and direct laryngoscopy by experienced tactical paramedics," *Prehospital Emergency Care*, vol. 18, no. 3, pp. 442–445, 2014.

[32] R. Mihai, E. Blair, H. Kay, and T. M. Cook, "A quantitative review and meta-analysis of performance of non-standard laryngoscopes and rigid fibreoptic intubation aids," *Anaesthesia*, vol. 63, no. 7, pp. 745–760, 2008.

[33] G. L. Savoldelli, E. Schiffer, C. Abegg, V. Baeriswyl, F. Clergue, and J. L. Waeber, "Comparison of the Glidescope, the McGrath, the Airtraq and the macintosh laryngoscopes in simulated difficult airways," *Anaesthesia*, vol. 63, no. 12, pp. 1358–1364, 2008.

[34] K. Schebesta, M. Hüpfl, B. Rössler, H. Ringl, M. P. Müller, and O. Kimberger, "Degrees of reality: airway anatomy of high-fidelity human patient simulators and airway trainers," *Anesthesiology*, vol. 116, no. 6, pp. 1204–1209, 2012.

[35] M. R. Rai and M. T. Popat, "Evaluation of airway equipment: man or manikin?" *Anaesthesia*, vol. 66, no. 1, pp. 1–3, 2011.

[36] E. Gaszynska, P. Samsel, M. Stankiewicz-Rudnicki, A. Wieczorek, and T. Gaszynski, "Intubation by paramedics using the ILMA or AirTraq, KingVision, and Macintosh laryngoscopes in vehicle-entrapped patients: a manikin study," *European Journal of Emergency Medicine*, vol. 21, no. 1, pp. 61–64, 2014.

[37] T. E. Sheraton, A. R. Wilkes, and J. E. Hall, "Mobile phones and the developing world," *Anaesthesia*, vol. 67, no. 9, pp. 945–950, 2012.

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Research Article

Percutaneous Transtracheal Jet Ventilation with Various Upper Airway Obstruction

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A "cannot-ventilate, cannot-intubate" situation is critical. In difficult airway management, transtracheal jet ventilation (TTJV) has been recommended as an invasive procedure, but specialized equipment is required. However, the influence of upper airway resistance (UAR) during TTJV has not been clarified. The aim of this study was to compare TTJV using a manual jet ventilator (MJV) and the oxygen flush device of the anesthetic machine (AM). We made a model lung offering variable UAR by adjustment of tracheal tube size that can ventilate through a 14-G cannula. We measured side flow due to the Venturi effect during TTJV, inspired tidal volume (TVi), and expiratory time under various inspiratory times. No Venturi effect was detected during TTJV with either device. With the MJV, TVi tended to increase in proportion to UAR. With AM, significant variations in TVi was not detected with changes in any UAR. In conclusion, UAR influenced forward flow of TTJV in the model lung. The influence of choked flow from the Venturi effect was minimal under all UAR settings with the MJV, but the AM could not deliver sufficient flow.

1. Introduction

An unexpected difficult airway (cannot-ventilate, cannot-intubate status; CVCI) represents a critical situation requiring immediate attention. In 2004, the Difficult Airway Society guidelines recommended percutaneous transtracheal jet ventilation (TTJV) following cannula cricothyroidotomy, as an invasive procedure to address incomplete upper airway obstruction [1, 2]. This procedure is easier and quicker than surgical cricothyroidotomy [3, 4]. Manual jet ventilators (MJVs) are commonly used for TTJV via a 14-G cannula.

However, cannula cricothyroidotomy may be associated with major problems in which insufficient oxygen may be inspired by the patient via the cannula cricothyroidotomy. One of the problems is that the inspired oxygen fraction (FIO_2) of TTJV may not be 1.0, because two different flows (the main jet flow, $FIO_2 = 1.0$, and side flow due to the Venturi effect, $FIO_2 = 0.21$) contribute to the actual FIO_2 [5]. Another, more serious problem is that sufficient tidal volume may not be obtained by TTJV due to the loss of inspired flow to the upper airway, which may depend on upper airway resistance (UAR).

Furthermore, several investigators have reported contradictory findings that the oxygen flush device of anesthesia machines (AMs) should or should not be used as a substitute for MJVs [6–9]. Since the MJV is a highly specialized and uncommon device, we also tried using the oxygen flush device attached to the AM for TTJV and compared this to the MJV in a lung model with variable UAR.

To investigate oxygenation and ventilation during TTJV, using an MJV or AM, we measured side flow due to the Venturi effect during TTJV in Study 1 and inspired tidal volume (TVi) and expiratory time under various inspiratory times and UARs during TTJV in Study 2.

2. Methods

A schematic of our experimental model is shown in Figure 1. An MJV (MCS-3; Yutaka, Japan) and an AM (Aisys, GE Healthcare, USA) with a relief valve (over 1 psi) were prepared in this study. The MJV was connected to the central oxygen port (0.35 MhPa = 50 psi). Release flow volumes with different oxygen pressures and cannula sizes for the MJV, according

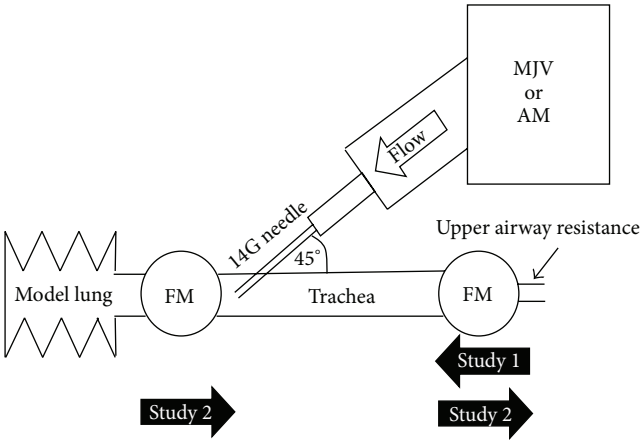

Figure 1: Schematic of the experimental model. MJV, manual jet ventilator (MCS-3, Yutaka, Japan); AM, anesthetic machine (Aisys, GE Healthcare, USA); FM, flowmeter. The "Study 1" arrow indicates the direction of Venturi effect flow during oxygen flush. The "Study 2" arrow indicates the direction of flow during oxygen flush.

to the manufacturer's manual, are shown in Table 1. Oxygen release from the MJV was 1250 mL/s at the settings used in this study. A lung model (Lung Simulator; SMS Technologies, Essex, UK) was used in this study. The compliance value of the model lung was adjusted to 50 mL/cmH_2O. The circuit of the AM or the MJV was connected to the model trachea via a 14-G (1.75-inch) catheter for the cannula cricothyroidotomy. A 14-gauge catheter (Jelco; Smith Medical, MN, USA; 1.75 inches) was placed into the simulated trachea at an angle of 45° toward the model lung. This angle of 45° is commonly recommended [10]. Two kinds of flowmeter were used in this study: one to measure the speed of flow in Study 1 and the other (Haloscale Standard; nSpire Health, CO, USA) to measure the volume of flow in Study 2.

2.1. Study 1. To measure flow due to the Venturi effect, we created a simulated trachea model (Figure 1). A flowmeter (Certifier FA Test System, TSI, MN, USA) was placed on the oral side of the simulated trachea to measure inhaled flow. The MJV (50 psi) or AM (45 psi) with relief valve closed was connected to the 14-gauge catheter. We measured choked flow due to the Venturi effect during the oxygen flush for 1 s with or without the connection to the model lung.

2.2. Study 2. UAR was adjusted between 2.5 and 6.0 mm internal diameter (ID) of the endotracheal tubes (Portex; Smith Medical, MN, USA) adjusted 10 mm of the length on the oral side of the simulated trachea (UAR of 6.0 mm ID simulated no obstruction, 2.5 mm ID simulated severe obstruction). Inspiratory time was 1 s using the MJV or 1, 2, or 3 s using the AM. We used 2 flowmeters, on the oral and lung sides of the cannula, to measure loss of tidal volume (LTV) on the oral-side airway and expiratory tidal volume (TVe) obtained from expiratory flow of the model lung during oxygen flush. Simultaneously, expiratory time with each UAR using the MJV or AM was measured on a stopwatch.

Table 1: Oxygen release volume (mL/s) with MJV.

Adjustment pressure (psi)	14 Gauges	16 Gauges	18 Gauges	20 Gauges
20	690	340	210	130
30	970	390	260	200
40	1180	540	320	230
50	1250	650	380	280

Nippon Megacare Co.; Ltd. Web Page.
http://www.megacare.co.jp/products/02_mcs3.html Accessed by 23 Feb, 2014.

Calculated minute volume (cMV) was determined from the following formula: TVe × 60/(inspiratory time + expiratory time). TVe was determined as excellent if >500 mL; good if >100 mL but ≤500 mL; fair if >50 mL but ≤100 mL; or not acceptable if ≤50 mL and MV was determined as excellent if >5.0 L/min; good if >2.0 L/min but ≤5.0 L/min; fair if >0.5 L/min but ≤2.0 L/min; or not acceptable if ≤0.5 L/min.

2.3. Statistical Analyses. Each measurement was repeated 6 times in this study. Data are expressed as mean ± standard deviation. Analysis of variance and Tukey's test as a post hoc test were used for statistical analyses. Values of $P < 0.05$ were considered statistically significant.

3. Results

3.1. Study 1. The data from Study 1 are shown in Figure 2. With the MJV, although choked flow due to the Venturi effect was detected in each setting without connection to the model lung, no choked flow was detected on connection to the model lung. With the AM, no choked flow was detected in any setting, with or without connection to the model lung.

3.2. Study 2. Increased UAR was associated with increased TVe, decreased LTV, and increased expiratory time with the MJV (Figure 3). Excellent tidal volumes were obtained for UAR <3.5 mm ID with the MJV. However, even with >4.0 mm ID, good tidal volumes were obtained. Increased UAR was associated with prolonged expiratory time. Peak cMV with the MJV was obtained at a UAR of 4.0 mm ID (Figure 4). With the AM, no tidal volume or minute volume was obtained with UAR >3.0 mm ID. At a UAR of 2.5 mm ID with the AM, tidal volume and minute volume were detected but were not acceptable (TVe: 1 s flush, 16.7 ± 5.1 mL; 2 s flush, 14.2 ± 4.9 mL; 3 s flush, 38.3 ± 7.5 mL).

4. Discussion

When the trachea was connected to the model lung, FIO_2 during TTJV was determined as almost 1.0, because choked flow due to the Venturi effect was not detected in our simulated model in this study. The catheter angle of 45° to the trachea and/or lung compliance might have reduced flow due to the Venturi effect. Actually, it was clinically impossible to place a catheter parallel to the trachea. Also, although lung compliance of 50 mL/cmH_2O was slightly lower than normal,

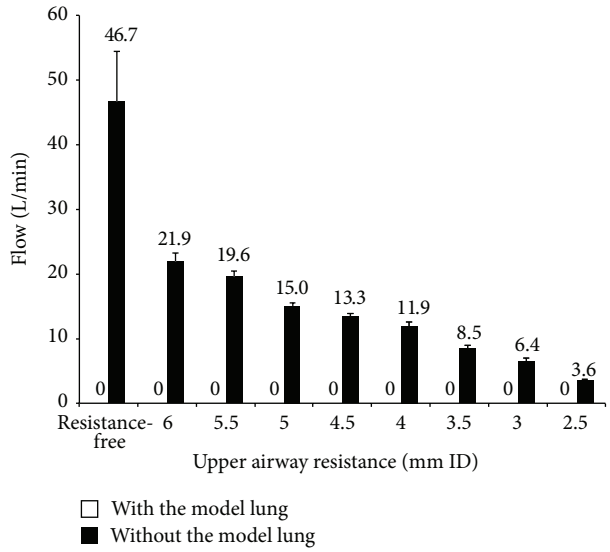

Figure 2: Relationship between UAR and Venturi effect with the MJV. Venturi flows were shown by connection with or without the model lung. Numeric data represents mean values. No flows were detected with the model lung.

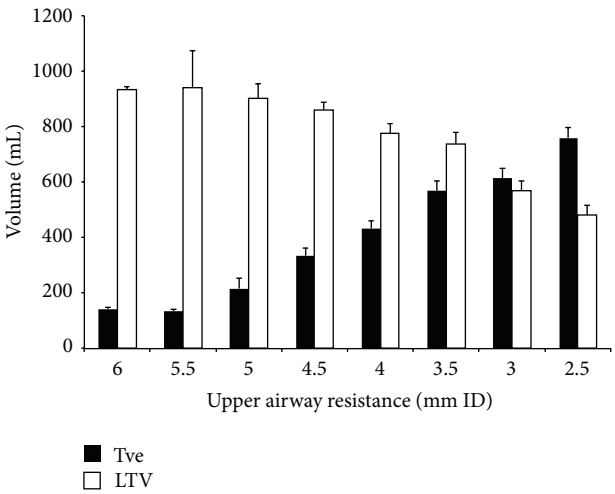

Figure 3: Relationship between upper airway resistance and expiratory tidal volume or loss of tidal volume. Significant differences in expiratory tidal volume were seen with upper airway resistance, except between 3.5 mm ID and 3 mm ID. TVe, expiratory tidal volume; LTV, loss of tidal volume.

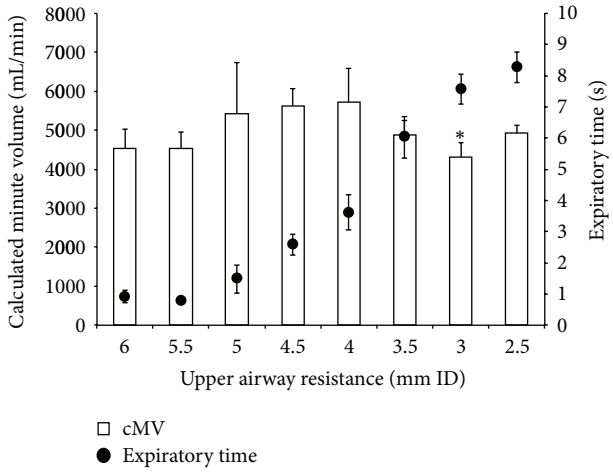

Figure 4: Relationship between upper airway resistance and calculated minute volume or expiratory time. A significant difference in calculated minute volume ($P = 0.47$) was apparent between 3 mm ID and 4 mm ID of upper airway resistance. cMV, calculated minute volume.

we thought that it might suitably reflect compliance due to lung edema in situations of CVCI [11–15].

UAR might influence oxygen delivery to the model lung more strongly during TTJV in this study. However, excellent or good minute volume was seen with all UAR settings with the MJV, because when UAR is lower, tidal volume is lower and expiratory time is shorter. In this study, tidal volume of approximately 140 mL and expiratory time of approximately 1 s, resulting in a calculated minute volume of 4.5 L/min, were obtained with UAR at 6.0 mm ID. Tidal volume of approximately 760 mL and expiratory time of approximately 8 s, which resulted in a calculated minute volume of approximately 4.0 L/min, were obtained with UAR at 2.5 mm ID. Maximum minute volume was obtained with oral-side obstruction of 4.0 mm ID. With severe upper airway obstruction < 3.5 mm ID representing the situation of CVCI, TTJV with the MJV can sufficiently inflate the lung, but expiratory time was increased and minute volume decreased with moderate upper airway obstruction. When lung compliance is lower than 50 mL/cmH_2O, peak minute volume must be obtained with a UAR less than 4.0 m ID because of the decreased tidal volume and shortened expiratory time.

A previous study found that AMs without relief valves can be used for TTJV [8, 9]. However, no acceptable tidal volume was obtained using a modern AM in the present study. Although the driving pressure for the oxygen flush was almost 45 psi with the AM, the limit of the relief valves in recent AMs has ranged between approximate 1 and 5 psi [16, 17]. The oxygen flush flow must not enter the model lung and escape to the expiratory port of the AM through the relief valve. However, with the UAR setting of 2.5 mm ID, slight tidal volume was obtained with a 3 s oxygen flush. If obstruction narrows the airway to <2.5 mm ID, acceptable tidal volume might be obtained.

Another method of oxygen delivery in cannula cricothyroidotomy is a direct connection between the cannula and tube from another oxygen supply. Fassl et al. investigated the driving pressure of sources of oxygen, such as wall-mounted oxygen flowmeters and AM auxiliary oxygen flowmeters [18]. The oxygen flush mechanisms of several kinds of AMs were found to be unable to deliver sufficient flows, as seen in the present study. They concluded that several flowmeters were acceptable to use as oxygen sources for TTJV in their study [18], but these methods needed specialized devices to connect the catheter for TTJV.

This study was limited to a simulated model with a model lung. To investigate more about the physiology of manual jet ventilation, we should repeat this study in animal models in future.

5. Conclusion

UAR influenced forward flow in TTJV of the model lung. The influence of choked flow from the Venturi effect was minimal in all settings of UAR with the MJV. The oxygen flush device of the AM could not deliver sufficient flow.

Conflict of Interests

There was no conflict of interests in this study.

References

[1] J. J. Henderson, M. T. Popat, I. P. Latto, and A. C. Pearce, "Difficult Airway Society guidelines for management of the unanticipated difficult intubation," *Anaesthesia*, vol. 59, no. 7, pp. 675–694, 2004.

[2] R. A. Caplan, J. L. Benumof, F. A. Berry et al., "Practice guidelines for the management of difficult airway: an updated report by the American Society of Anesthesiologists Task Force on the Management of the Difficult Airway," *Anesthesiology*, vol. 98, no. 5, pp. 1269–1277, 2003.

[3] R. M. Craven and R. G. Vanner, "Ventilation of a model lung using various cricothyrotomy devices," *Anaesthesia*, vol. 59, no. 6, pp. 595–599, 2004.

[4] D. T. Wong, K. Lai, F. F. Chung, and R. Y. Ho, "Cannot intubate-cannot vintilate and difficult intubation strategies: results of a Canadian national survey," *Anesthesia and Analgesia*, vol. 100, no. 5, pp. 1439–1446, 2005.

[5] A. Baraka, "Oxygen enrichment of entrained room air during Venturi jet ventilation of children undergoing bronchoscopy," *Paediatric Anaesthesia*, vol. 6, no. 5, pp. 383–385, 1996.

[6] R. G. Patel, "Percutaneous transtracheal jet ventilation: a safe, quick, and temporary way to provide oxygenation and ventilation when conventional methods are unsuccessful," *Chest*, vol. 116, no. 6, pp. 1689–1694, 1999.

[7] M. L. Carl, K. J. Rhee, E. S. Schelegle, and J. F. Green, "Effects of graded upper-airway obstruction on pulmonary mechanics during transtracheal jet ventilation in dogs," *Annals of Emergency Medicine*, vol. 24, no. 6, pp. 1137–1143, 1994.

[8] S. D. Gaughan, J. L. Benumof, and G. T. Ozaki, "Can an anesthesia machine flush valve provide for effective jet ventilation?" *Anesthesia and Analgesia*, vol. 76, no. 4, pp. 800–808, 1993.

[9] P. E. Scuderi, C. H. McLeskey, and P. B. Comer, "Emergency percutaneous transtracheal ventilation during anesthesia using readily available equipment," *Anesthesia & Analgesia*, vol. 61, no. 10, pp. 867–870, 1982.

[10] M. K. Mittal, *Needle Cricothyroidotomy with Percutaneous Transtracheal Ventilation*, Topic 6313 Version 5.0, UpToDate, 2014.

[11] A. Udeshi, S. M. Cantie, and E. Pierre, "Postobstructive pulmonary edema," *Journal of Critical Care*, vol. 25, no. 3, pp. 538.e1–538.e5, 2010.

[12] M. A. van Kooy and R. F. Gargiulo, "Postobstructive pulmonary edema," *American Family Physician*, vol. 62, no. 2, pp. 401–404, 2000.

[13] S. A. Lang, P. G. Duncan, D. A. E. Shephard, and H. C. Ha, "Pulmonary oedema associated with airway obstruction," *Canadian Journal of Anaesthesia*, vol. 37, no. 2, pp. 210–218, 1990.

[14] R. L. Moore and C. A. Binger, "The response to respiratory resistance: a comparison of the effects produced by partial obstruction in the inspiratory and expiratory phases of respiration," *The Journal of Experimental Medicine*, vol. 45, no. 6, pp. 1065–1080, 1927.

[15] M. F. Warren, D. K. Peterson, and C. K. Drinker, "The effects of heightened negative pressure in the chest, together with further experiments upon anoxia in increasing the flow of lung lymph," *American Journal of Physiology*, vol. 137, pp. 641–648, 1942.

[16] C. Thompson, S. Halder, and S. Wimbush, "Effective ventilation following emergency needle cricothyroidotomy," *Resuscitation*, vol. 72, no. 1, pp. 164–166, 2007.

[17] T. M. Cook, J. P. Nolan, P. T. Magee, and J. H. Cranshaw, "Needle cricothyroidotomy," *Anaesthesia*, vol. 62, no. 3, pp. 289–290, 2007.

[18] J. Fassl, U. Jenny, S. Nikiforov, W. B. Murray, and P. A. Foster, "Pressures available for transtracheal jet ventilation from anesthesia machines and wall-mounted oxygen flowmeters," *Anesthesia and Analgesia*, vol. 110, no. 1, pp. 94–100, 2010.

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Research Article

Assessment of Movement Patterns during Intubation between Novice and Experienced Providers Using Mobile Sensors: A Preliminary, Proof of Concept Study

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Background. There are likely marked differences in endotracheal intubation (ETI) techniques between novice and experienced providers. We performed a proof of concept study to determine if portable motion technology could identify the motion components of ETI between novice and experienced providers. *Methods.* We recruited a sample of novice and experienced providers to perform ETIs on a cadaver. Their movements during ETI were recorded with inertial measurement units (IMUs) on the left wrist. The signals were assessed visually between novice and experienced providers to identify areas of differences at key steps during ETI. We then calculated spectral smoothness (SS), a quantitative measure inversely related to movement variability, for all ETI attempts. *Results.* We enrolled five novice and five experienced providers. When visually inspecting the data, we noted maximum variability when inserting the blade of the laryngoscope into the mouth and while visualizing the glottic opening. Novice providers also had greater overall variability in their movement patterns (SS novice 6.4 versus SS experienced 26.6). *Conclusion.* Portable IMUs can be used to detect differences in movement patterns between novice and experienced providers in cadavers. Future ETI educational efforts may utilize portable IMUs to help accelerate the learning curve of novice providers.

1. Introduction

Endotracheal intubation (ETI) is an advanced airway procedure that is defined by a series of movements that result in a tube passing through the glottic opening into the trachea to allow for oxygenation and ventilation. Unsuccessful or prolonged ETI efforts can lead to multiple complications including hypoxia, brain damage, and even death [1–3]. These complications may be magnified when performing ETI in acute care settings including the emergency department and out-of-hospital environments [1, 3, 4]. As a result, learning ETI in acute care settings is challenging and often the learning curve for ETI in these settings is prolonged [5, 6]. Procedural competency is essential for low-frequency and high-consequence procedures such as ETI and therefore it is essential to accelerate the learning curve for emergent ETI.

While there are educational programs for teaching ETI, there are few objective metrics available to assess procedural competency, specifically the kinematics involved in ETI. An improved understanding of the motions involved in ETI and their connections with airway exposure and visualization could impact airway education practices, shedding light on the unrecognized actions needed to accomplish ETI and improve patient outcomes. Previous work with motion capture has identified differences in movement patterns between novice and experienced providers [7]. This work has been restricted to mannequin models due to limited portability of motion analysis technology. Portable inertial measurement units (IMUs) have been used in other clinical settings, but their utility in ETI is unknown [8, 9].

We demonstrate proof of concept that ETI motions can be recorded by portable IMUs. We hypothesize that portable

IMUs can identify movement patterns that differentiate novice from experienced providers when performing ETI outside of mannequins.

2. Methods

2.1. Study Design and Setting. We performed an interventional, observational study examining the movement patterns of providers while performing intubation on a cadaver. After providing informed consent, participants were outfitted with IMUs (Emerald Model, APDM Inc, Portland, OR) on the left wrist. Participants then performed one intubation attempt on a cadaver using the CMAC video laryngoscope (Model 8402, Karl Storz Corp., Tuttlingen, Germany) with a #4 Macintosh blade. Participants used the CMAC as a direct laryngoscope; however, their ETI attempts were recorded for offline review. All intubation attempts were made with the cadaver on the anatomy table (fixed height of 89.5 cm). The providers' movements were recorded with the IMUs. Prior to each ETI attempt, providers were instructed to clap three times, pick up the laryngoscope with their left hand, move the laryngoscope up and down three times, lay the laryngoscope back down, and rest their hands on the table. This provided a unique signal, allowing us to synchronize the videos from the CMAC and the movement patterns from the IMUs to identify the beginning of the intubation attempt. Providers' movements, as recorded by the IMUs, were then compared offline between experienced and novice providers. This study was approved by our Institutional Review Board.

2.2. Selection of Participants. We recruited a convenience sample of five providers from a pool of attending physicians and fourth year emergency medicine residents with each having over 100 ETIs in the clinical setting, and defined these as "experienced" providers. We also recruited a convenience sample of five third and fourth year medical students with each having <10 ETIs in the clinical setting and defined these as "novice" providers. All providers had previous formal airway training. We defined "previous formal airway training" as having attended a structured airway didactics of ≥1 hour in length for experienced providers (emergency medicine resident or attending physician). Novice providers must have attended a structured airway didactics of ≥1 hour in length or completed a rotation in anesthesia. No participants reported significant experience with the CMAC prior to this study. We excluded providers who had performed between 10 and 100 ETIs or if they had no formal airway training.

2.3. Cadaver Preparation. All intubations were made on a single, embalmed, male human cadaver. The cadaver had no oral, pharyngeal, or neck trauma, craniofacial abnormality, or a known history of tracheostomy. We recorded anatomic measurements related to airway placement including thyromental distance (6 cm), thyrohyoid distance (2 cm), and neck circumference (56 cm) at the level of the thyroid cartilage [10]. Initially, a 2-inch incision was made through the skin over the area of the zygomatic arch down towards the jaw line. The skin was reflected inferiorly to expose the underlying structures. The parotid gland and subcutaneous tissues were removed in order to expose the masseter and its origins on the zygomatic arch. The superficial and deep heads of the masseter were detached from the zygomatic arch and retracted inferiorly in order to expose the mandible. In order to permit more free motion of the jaw, the temporalis muscle was then detached from its insertion on the coronoid process of the mandible. This allowed providers to instrument anatomic structures during ETI attempts and created a grade 3 Cormack-Lehane view as assessed by the investigators. We created a grade 3 Cormack-Lehane view as we felt this would allow for greater discrimination between the movement patterns of novice and experienced providers.

2.4. Methods and Measurements. We collected provider demographics and recorded both the movement patterns of the IMUs using the IMU integrated software along with video of the intubation attempt using the integrated CMAC software. Placement of the endotracheal tube (trachea versus esophagus) was assessed by visual inspection by the investigators after each ETI attempt. We defined an intubation attempt each time the blade of the laryngoscope entered the mouth. We defined attempt time as the time in seconds from when the blade of the laryngoscope entered the mouth until it was fully withdrawn from the mouth after placement of the endotracheal tube (either successful placement in the trachea or unsuccessful in the esophagus).

2.5. Outcomes. Our primary outcome was variability in movement patterns assessed by spectral smoothness and visual accelerometer patterns between novice and experienced providers during ETI.

2.6. Analysis. Providers had their movements recorded during ETI using an IMU placed on the posterior aspect of the left wrist. We collected accelerometer data in the x-, y- and z-axes (Figure 1). We visualized the data to identify the IMU and axis with maximum variability and utilized these data for analysis. We segmented the IMU data into portions of the ETI attempt based on previous ETI motion analysis: laryngoscope entering the mouth, obtaining the view of the vocal cords, placing the endotracheal tube, and removing the laryngoscope [7]. We computed 16-point Fast Fourier Transform (FFT) on the segmented signal [11, 12]. A quantitative measure of spectral smoothness (SS) was computed over all trials corresponding to each group (novice and experienced). The SS measure was computed from the FFT of accelerometer data as follows [13]:

(1) X is the FFT vector;

(2) $\mathrm{SS} = \sigma(\delta[X])/\|m(\delta[X])\|$, where $\|\cdot\|$ is the absolute value, $\sigma(\cdot)$ is the standard deviation, $\delta[\cdot]$ is first order differential, and $m(\cdot)$ is the mean function.

SS is a nonnegative (>0) measure, which is inversely proportional to the absolute value of the mean of signal differential. Therefore, the choppier the signal (e.g., greater variability or less smooth), the lower the SS value. This is due to larger differences in successive signal samples and thus

Table 1: Provider characteristics. EM: emergency medicine.

	Novice (n = 5)	Experienced (n = 5)
Age in years, (SD)	27 (2.8)	31.4 (1.3)
Sex: male (n)	80% (4)	80% (4)
Handedness: right	100% (5)	100% (5)
Experience	Fourth year medical student: 4 Third year medical student: 1	Fourth year EM resident: 4 EM attending: 1
First attempt success (n)	20% (1)	40% (2)
Attempt time in seconds (mean, SD)	38.3 (9)	33 (5.5)

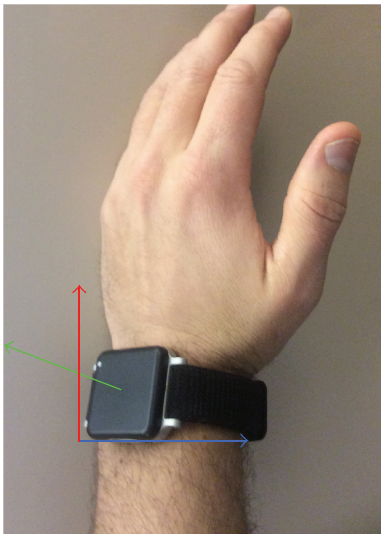

Figure 1: Inertial measurement unit on the left wrist. Blue arrow, x-axis. Red arrow, y-axis. Green arrow, z-axis.

high absolute value of the mean of differential signal. A smooth signal results in low absolute mean value of the differential signal, thereby increasing the SS value. Thus, the SS measure represents the extent of redundant motion variations (i.e., choppiness) associated with ETI attempts [13]. These computations were completed with MATLAB, release 2012b (version 8.0, MathWorks, Inc, Natick, MA).

We also sought to identify patterns that may exist in the movement signals between novice and experienced providers. Movement patterns consist of two aspects, the dispersion or distance traveled and the acceleration or quickness. Dispersion in the x-, y-, and z-axes is not simple straight lines, but it represents complex mathematical signals. As a result, dispersion is often difficult to represent as a single sinusoidal equation. However, each ETI dispersion signal can be represented as a collection of simpler sinusoidal waves with different frequencies (as measured in hertz or Hz) that combine to form the overall sinusoidal equation. The second movement component, acceleration, can be measured by the accelerometers in the IMUs, and expressed as force (in gravitational constants or g). To directly compare the overall movement patterns between novice and experienced providers, we graphed the net value of force, in g^2, by the various simpler sinusoidal frequencies that constitute the overall complex sinusoidal equation for dispersion [11, 12]. Based on the computed 16-point Fast Fourier Transform (FFT) of the overall complex signal, the components can be equally transformed into 16 discrete units representing simpler sinusoidal waves between −60 Hz and 60 Hz. (11, 12) This allowed us to visually compare the movement components, both dispersion and force, between experienced and novice providers.

3. Results

We enrolled five novice (one third year and four fourth year medical students), and five experienced providers (four fourth year emergency medicine residents and one attending physician) (Table 1). Due to troubles with recording, one provider in each group did not have their IMU signal available for analysis and was thus excluded from the study. The IMU data corresponding to the laryngoscope insertion and glottis visualization was then segmented out for further analysis (Figure 2). We compared the IMU data to the videos recorded during the intubation attempt and identified the four segments of the kinematic signals: laryngoscope entering the mouth, obtaining the view of the vocal cords, placing the endotracheal tube, and removing the laryngoscope [7]. The orange box (Figure 2) represents the steps where the laryngoscope entered the mouth and a view of the vocal cords was obtained. Visually, there appeared to be the greatest movement variability during this step; thus, this area is magnified in Figure 3.

After transforming the data via the FFT, the spectral analysis of the Z-component from these sections had a parabolic curve for both novice and experienced providers (Figure 4). This curve was smoother for experienced providers both on visual inspection and when analyzed by spectral smoothness (SS novice 6.4 versus SS experienced 26.6).

When the complex movement patterns in the z-axis were broken down into simpler frequencies, there appeared to be a unique, parabolic relationship between these sinusoidal waves (the description of movement) and force with experienced providers (Figure 4). Experienced providers had a bimodal distribution of forces, where greater forces were noted at lower frequency signals and then again at higher frequency signals.

4. Limitations

There are several limitations to this study. Our study was limited to a small sample. Initially, we sought to compare five

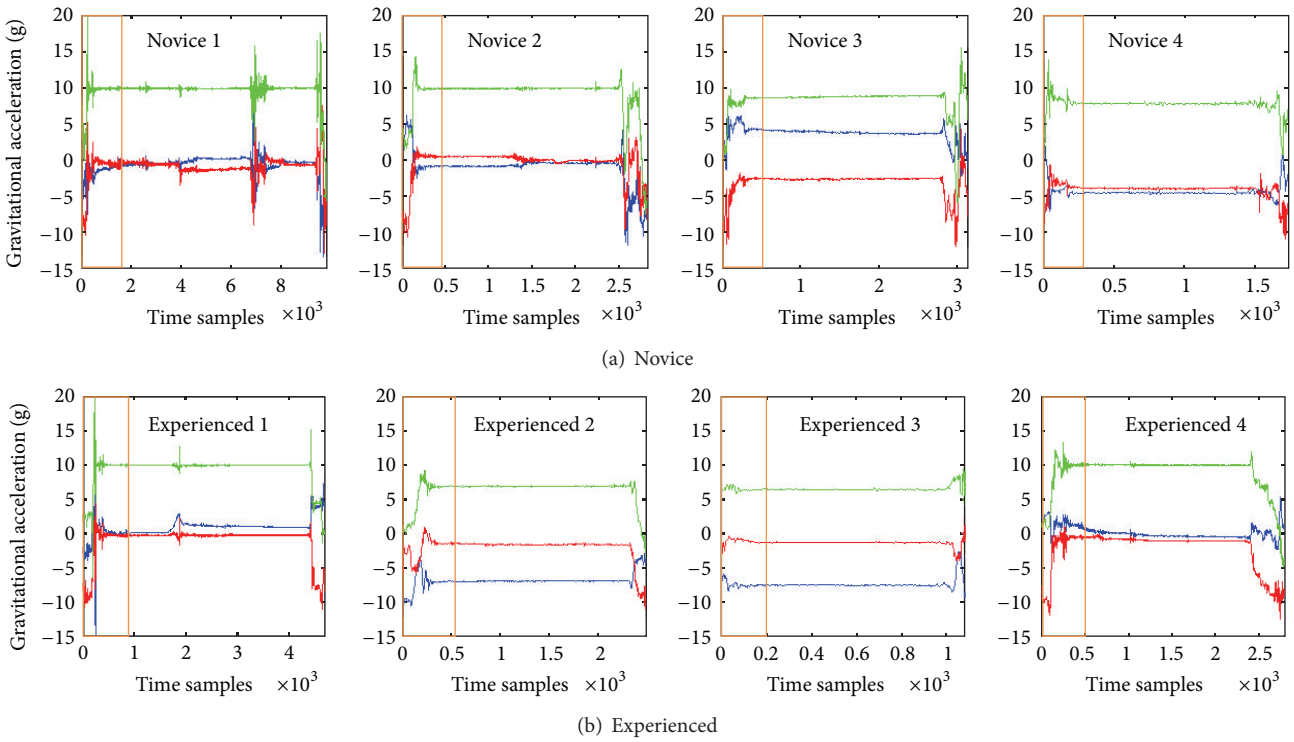

FIGURE 2: Complete movement patterns in the x-, y-, and z-axes for the four novice (a) and experienced (b) providers. The blue line represents movement in the x-axis. The red line represents movement in the y-axis. The green line represents movement in the z-axis. The orange box represents the laryngoscope entering the mouth and obtaining the view of the vocal cords (magnified in Figure 3).

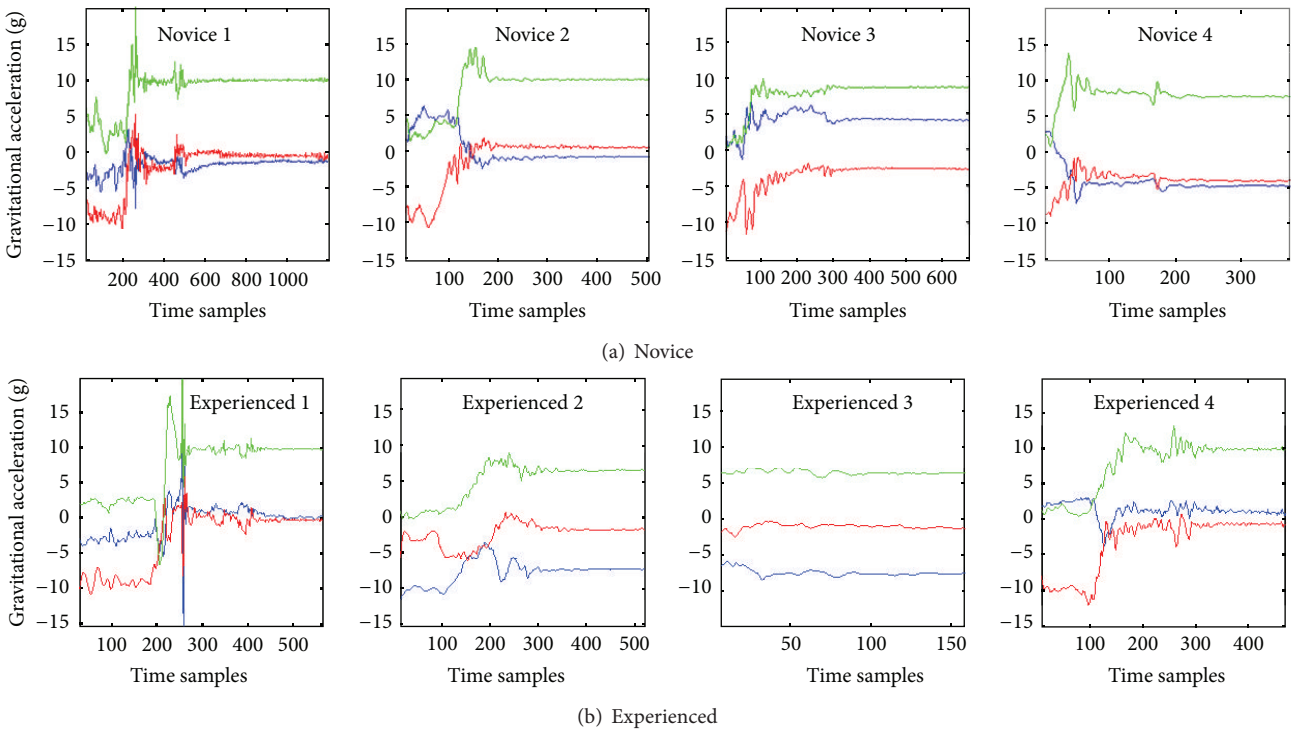

FIGURE 3: Complete movement patterns in the x-, y-, and z-axes for the four novice (a) and experienced (b) providers from blade insertion until glottic visualization. The blue line represents movement in the x-axis. The red line represents movement in the y-axis. The green line represents movement in the z-axis.

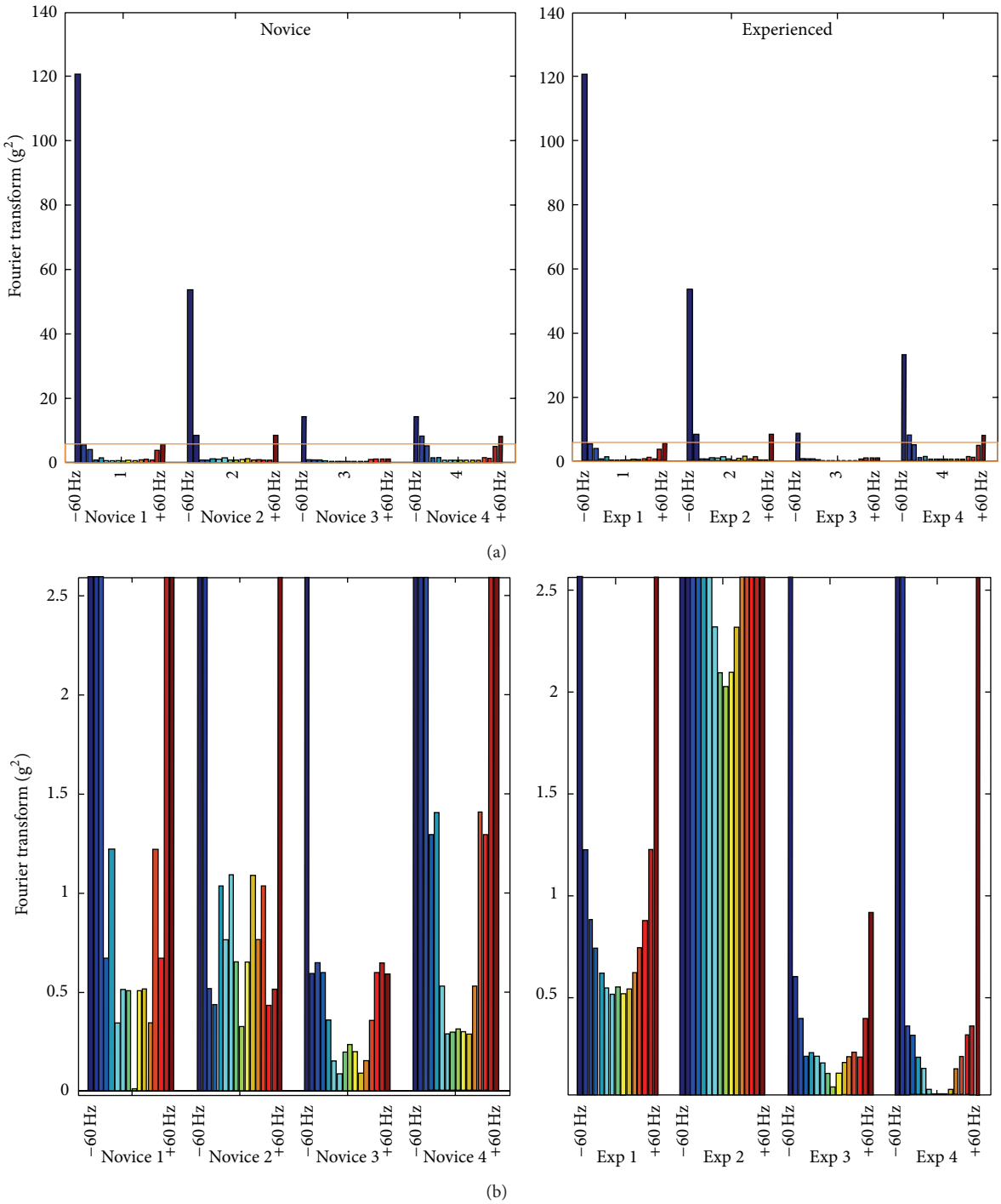

Figure 4: Spectral analysis of the Z-component of IMU signal from insertion until glottic visualization for the four novice and experienced providers. Spectral range (blue to red) for each subject is ±60 Hz divided into 16 equal segments. The overall signals are shown in the top graphs. The orange box represents the areas magnified in the lower graphs. Exp: experienced.

novice and five experienced providers but had to limit the study size to four providers in each group due to incomplete recording of the data. Second, this study was performed in a cadaver model with a difficult airway (grade 3 Cormack-Lehane). The cadaver underwent a modified dissection of tissue, masseter, and temporalis muscle detachment to allow for a grade 3 Cormack-Lehane view. We felt a difficult airway (Cormack-Lehane grade 3) would allow for greater discrimination between the movement patterns of novice and experienced providers. As Cormack-Lehane grade 3 views are infrequently encountered in emergency airway management, we focused our efforts on the cadaver model [14–16]. Also, from a patient safety and research ethics standpoints, we did not feel it was in patients' best interest to perform

multiple intubation attempts on a patient or patients with a difficult airway, especially with novice providers, for a proof of concept study. The cadaver allowed us to standardize the intubation attempts as all attempts could then be made on one airway. While we are able to show proof of concept that IMUs are able to collect data and differentiate between novice and experienced providers in ETI using human tissue, future efforts will be needed to assess IMUs in the clinical setting with varying glottic views. Studies involving comparison between cadaver and human subjects would provide further insight with the kinematics involved in ETI. Other movement patterns that may be critical to ETI success were not investigated. As we were only able to analyze left wrist movement patterns, future investigations may examine other joints (elbow, shoulder, right wrist, etc.) to provide a more complete analysis of the kinematics involved in ETI.

5. Discussion

We were able to identify differences between experienced and novice providers using IMUs in a cadaver model. By identifying these key differences, future work may provide further quantification and impactful feedback during ETI instruction. Eventually, this may be incorporated with a model that allows real-time feedback via instruction and correction while performing the task of ETI in a clinical setting. ETI proficiency is associated with procedural experience with this skill [6]. If we are able to further accelerate the learning curve of providers, competency may be achieved at a faster rate, thus reducing the potential harmful of the learning curve.

In a multicenter analysis including over 6,000 ETIs, the first attempt success rates varied by provider experience with the first year emergency medicine residents having success rate of only 72% compared to 82% and 88% in the second year and third year, respectively [17]. First attempt success also decreases with Cormack-Lehane view where grade 3 views have first attempt success rates near 40%, similar to those noted in our study [16]. Complications occur more frequently in cases where multiple ETI attempts are made [3]. Accelerating the learning could directly address the complications related to multiple attempts in novice providers in the acute setting.

We chose to evaluate the movements of the left wrist in novice and experienced providers during intubation. While there is not yet a clear link between wrist movements and intubation success or side effects, there are distinct differences in the movement patterns of the left wrist between novice and experienced providers [7]. As providers gain experience with emergency airway management, they demonstrate greater intubation success and lower rates of complication related to intubation [17, 18]. Examining the link between these movement patterns and intubation outcomes may provide insight into why these differences in intubation success exist and identify opportunities for improvement in ETI techniques.

To our knowledge, ours is the first study using portable movement mapping technology to evaluate intubation. The benefits of portable sensors have yet to be fully realized in the acute care setting. Portable sensors may not be limited to the use of IMUs but may also make use of other technologies such as smartphones with incorporated cameras and accelerometers. Previous work has shown that smartphones may help with ETI and can even monitor chest compression during cardiopulmonary resuscitation [19–21]. The ubiquitous nature of the technologies incorporated into smartphones represents an ideal tool for capturing information and providing feedback.

While our study was designed as a proof of concept, we believe that portable sensors may be able to identify movement patterns between providers with different levels of experience. These technologies can identify patterns of force that may vary with different components of the overall dispersion signal (i.e., there might be dispersion differences between not only novice and experienced providers measured in space, but also the force with which these actions take place). Despite our small sample size, there appear to be differences in the combination of dispersion and force between novice and experienced providers where experienced providers had a bimodal distribution of forces, where greater forces were noted at lower frequency signals and then again at higher frequency signals while this was not seen with novice providers (Figure 4).

Interpreting these findings can be challenging but may be contextualized more easily using an example outside of medicine. When assessing how someone may swing a golf club, there are two components to the swing, the dispersion (or measurement of the distance moved) and the acceleration or force. The golfer needs the ideal "mechanics" or dispersion combined with the proper force at the correct time during the swing. Representing the relationship between the dispersion and force allows for the identification of key differences within the movement pattern. Identifying the unique interaction between dispersion and force may also help to explain the differences in ETI success rates between providers and allow for focused feedback to novice providers.

6. Future Directions

The clinical implications of this line of work are broad. Future work with portable sensors may help to track the movements of novice providers, compare these movements to those of experienced providers, and provide real-time, objective feedback to trainees on their movement patterns. While we have focused on ETI, similar educational models could be developed for other medical procedures. The successful development of these models requires multiple steps:

(1) identify portable sensors that can objectively track movement patterns in the clinical setting;

(2) classify movement patterns that differentiate novice from experienced providers;

(3) incorporate analysis algorithms that will allow for rapid assessment of movement patterns and recognize areas that require focused educational attention (e.g., what portion of the ETI attempt differed from that of previously analyzed experienced ETI attempts);

(4) develop teaching curriculum that incorporates these measurements to allow for impactful, timely feedback.

While we have shown proof of concept that ETI motions can be recorded by portable IMUs (step (1)), future work will be needed to effectively develop this technology into an educational modality (steps (2)–(4)).

Ericsson's model of deliberate practice presents a framework for this information to be leveraged [22, 23]. Ericsson states that deliberate practice must provide immediate feedback, correction, remediation, and repetition [6, 22, 23]. The inclusion of additional feedback to the student from the kinematic data allows for more precise and immediate feedback beyond a simple yes/no of success with the performance of ETI. While kinematic feedback may require a better understanding of the whole body movements of the provider during ETI, we chose to focus our preliminary efforts on the left wrist as there are distinct differences in the movement patterns of the left wrist between novice and experienced providers [7]. Experienced providers also have greater intubation success and lower rates of complication indicating a potential link between movement patterns and intubation success [17, 18]. A more nuanced understanding of the entire ETI process presents additional opportunity for the practitioner to receive immediate feedback on these movement differences and accelerate the learning curve.

Specific to simulation and mannequin based learning, prior studies including Hall et al. have also shown increased skill acquisition with the combination of simulated and mannequin based training [24]. With the additional data gleaned from a more complex mapping of the novice versus experienced movements made during ETI, we may further enhance skill acquisition outside of clinical practice. Segmenting the steps and breaking down the process of ETI may also allow for more precise practice with cadavers and mannequins.

Movement sensor analysis provides valuable, objective data and has been used in a variety of clinical settings. Other studies have used portable sensors to track progression after stroke [8, 9]. This line of work has shown that motion sensor analysis presents a linear relationship with subjective measures of stroke severity. In a similar manner, motion sensor analysis in the use of ETI may provide a more objective measure of techniques utilized in successful ETI beyond subjective feedback of an instruction practitioner. Future efforts are needed to advance the kinematic analysis process and provide subjects with real-time feedback.

7. Conclusion

IMUs can be used to identify the kinematics of both novice and experienced providers in a cadaver model. By further understanding movement patterns for ETI and quantitatively analyzing ETI kinematics, we are better able to understand the mechanics of intubation. These are the first steps in designing a real-time feedback system to accelerate the learning curve of ETI.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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References

[1] A. C. Heffner, D. S. Swords, M. N. Neale, and A. E. Jones, "Incidence and factors associated with cardiac arrest complicating emergency airway management," *Resuscitation*, vol. 84, no. 11, pp. 1500–1504, 2013.

[2] T. C. Mort, "The incidence and risk factors for cardiac arrest during emergency tracheal intubation: a justification for incorporating the ASA Guidelines in the remote location," *Journal of Clinical Anesthesia*, vol. 16, no. 7, pp. 508–516, 2004.

[3] T. C. Mort, "Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts," *Anesthesia and Analgesia*, vol. 99, no. 2, pp. 607–613, 2004.

[4] H. E. Wang, J. R. Lave, C. A. Sirio, and D. M. Yealy, "Paramedic intubation errors: isolated events or symptoms of larger problems?" *Health Affairs*, vol. 25, no. 2, pp. 501–509, 2006.

[5] H. E. Wang, S. R. Seitz, D. Hostler, and D. M. Yealy, "Defining the learning curve for paramedic student endotracheal intubation," *Prehospital Emergency Care*, vol. 9, no. 2, pp. 156–162, 2005.

[6] P. G. Tarasi, M. P. Mangione, S. S. Singhal, and H. E. Wang, "Endotracheal intubation skill acquisition by medical students," *Medical Education Online*, vol. 16, article 7309, 2011.

[7] J. N. Carlson, S. Das, F. de la Torre, C. W. Callaway, P. E. Phrampus, and J. Hodgins, "Motion capture measures variability in laryngoscopic movement during endotracheal intubation: a preliminary report," *Simulation in Healthcare*, vol. 7, no. 4, pp. 255–260, 2012.

[8] E. V. Olesh, S. Yakovenko, and V. Gritsenko, "Automated assessment of upper extremity movement impairment due to stroke," *PLoS ONE*, vol. 9, no. 8, Article ID e104487, 2014.

[9] H. Zhou, H. Hu, and N. Harris, "Application of wearable inertial sensors in stroke rehabilitation," in *Proceedings of the 27th Annual International Conference of the Engineering in Medicine and Biology Society (IEEE-EMBS '05)*, pp. 6825–6828, IEEE, Shanghai, China, September 2005.

[10] M. Naguib, F. L. Scamman, C. O'Sullivan et al., "Predictive performance of three multivariate difficult tracheal intubation models: a double-blind, case-controlled study," *Anesthesia and Analgesia*, vol. 102, no. 3, pp. 818–824, 2006.

[11] L. R. Rabiner and R. W. Schafer, *Introduction to Digital Speech Processing*, Now Publishers, Boston, Mass, USA, 2007.

[12] A. V. Oppenheim, A. S. Willsky, and S. H. Nawab, *Signals & Systems*, Prentice Hall, Upper Saddle River, NJ, USA, 2nd edition, 1997.

[13] A. P. Klapuri, "Multipitch estimation and sound separation by the spectral smoothness principle," in *Proceedings of the IEEE Interntional Conference on Acoustics, Speech, and Signal Processing*, vol. 5, pp. 3381–3384, May 2001.

[14] J. N. Carlson, J. Quintero, F. X. Guyette, C. W. Callaway, and J. J. Menegazzi, "Variables associated with successful intubation attempts using video laryngoscopy: a preliminary report in a helicopter emergency medical service," *Prehospital Emergency Care*, vol. 16, no. 2, pp. 293–298, 2012.

[15] F. X. Guyette, K. Farrell, J. N. Carlson, C. W. Callaway, and P. Phrampus, "Comparison of video laryngoscopy and direct laryngoscopy in a critical care transport service," *Prehospital Emergency Care*, vol. 17, no. 2, pp. 149–154, 2013.

[16] C. A. Graham, A. J. Oglesby, D. Beard, and D. W. McKeown, "Laryngoscopic views during rapid sequence intubation in the emergency department," *Canadian Journal of Emergency Medicine*, vol. 6, no. 6, pp. 416–420, 2004.

[17] M. J. Sagarin, E. D. Barton, Y.-M. Chng, R. M. Walls, and National Emergency Airway Registry Investigators, "Airway management by US and Canadian emergency medicine residents: a multicenter analysis of more than 6,000 endotracheal intubation attempts," *Annals of Emergency Medicine*, vol. 46, no. 4, pp. 328–336, 2005.

[18] J. Toda, A. A. Toda, and J. Arakawa, "Learning curve for paramedic endotracheal intubation and complications," *International Journal of Emergency Medicine*, vol. 6, no. 1, article 38, 2013.

[19] A. Frisch, S. Das, J. C. Reynolds, F. De la Torre, J. K. Hodgins, and J. N. Carlson, "Analysis of smartphone video footage classifies chest compression rate during simulated CPR," *The American Journal of Emergency Medicine*, vol. 32, no. 9, pp. 1136–1138, 2014.

[20] G. A. Hawkes, C. P. Hawkes, C. A. Ryan, and E. M. Dempsey, "The demand for an educational smartphone app," *Resuscitation*, vol. 84, no. 10, p. e139, 2013.

[21] C. P. Hawkes, B. H. Walsh, C. A. Ryan, and E. M. Dempsey, "Smartphone technology enhances newborn intubation knowledge and performance amongst paediatric trainees," *Resuscitation*, vol. 84, no. 2, pp. 223–226, 2013.

[22] K. A. Ericsson, "Deliberate practice and acquisition of expert performance: a general overview," *Academic Emergency Medicine*, vol. 15, no. 11, pp. 988–994, 2008.

[23] K. A. Ericsson, "Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains," *Academic Medicine*, vol. 79, no. 10, supplement, pp. S70–S81, 2004.

[24] R. E. Hall, J. R. Plant, C. J. Bands, A. R. Wall, J. Kang, and C. A. Hall, "Human patient simulation is effective for teaching paramedic students endotracheal intubation," *Academic Emergency Medicine*, vol. 12, no. 9, pp. 850–855, 2005.

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Research Article

Comparison of Pentax-AWS Airwayscope and Glidescope for Infant Tracheal Intubation by Anesthesiologists during Cardiopulmonary Arrest Simulation: A Randomized Crossover Trial

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Background. Recent guidelines for infant cardiopulmonary resuscitation emphasize that all rescuers should minimize interruption of chest compressions, even for endotracheal intubation. We compared the utility of the Pentax-AWS Airwayscope (AWS) with the Glidescope (GS) during chest compressions on an infant manikin. *Methods*. Twenty-four anesthesiologists with more than two years of experience performed tracheal intubation on an infant manikin using the AWS and GS, with or without chest compressions. *Results*. In GS trials, none of the participants failed without compressions, while three failed with compressions. In AWS trials, all participants succeeded regardless of chest compressions. Intubation time was significantly longer with chest compressions with the GS ($P < 0.05$), but not with the AWS. Difficulty of operation on a visual analog scale (VAS) for laryngoscopy did not increase significantly with chest compressions with either the GS or the AWS, while the VAS for tube passage through the glottis increased with compressions with the GS, but not with the AWS. *Conclusion*. We conclude that in infant simulations managed by anesthesiologists, the AWS performed better than the GS for endotracheal intubation with chest compressions.

1. Background

The European Resuscitation Council (ERC) cardiopulmonary resuscitation (CPR) guidelines emphasize the paramount importance of minimizing chest compression interruptions to maximize cerebral and coronary perfusion pressure [1]. Moreover, the guidelines recommend that skilled rescuers should secure the airway without interrupting chest compressions or with only a brief pause to visualize vocal cords and allow passage of the tracheal tube [2].

Direct laryngoscopy with the Miller laryngoscope (Mil) is the most widely used technique for infant tracheal intubation. However, the Mil can be difficult to use even for skilled professionals and could become detrimental in infant emergent situations [3]. Previous studies reported that the Pentax-AWS Airwayscope (AWS; Hoya, Tokyo, Japan) was a more functional device alternative than the conventional Mil for intubation during chest compressions [4, 5].

The Glidescope Cobalt (GS; Verathon Medical, Washington, USA) is a video laryngoscope reported to provide a nonsightline view of the airway. Various clinical and simulation studies indicate that the GS is not only useful for difficult airway management in adults [6–8]. Furthermore, utility of GS for emergent tracheal intubation with chest compressions in adult simulations or clinical study has been suggested [9–11]. Both the AWS and GS provide a nonsightline view and are considered convenient tools for emergent tracheal intubation in adults.

An infant-sized Intlock blade was recently developed for the GS and the utility for emergency airway management by pediatric fellows or novice doctors has been evaluated [12–14]. The result showed GS was inferior to Mil for emergency tracheal intubation in infants or neonates. All reports suggest that the GS inferiority was partially attributed to the small clinical airway management experience with novice doctors or pediatricians [8, 12–14]. Based on these previous reports,

(a) (b)

Figure 1: The two video laryngoscopes for infants used in the study. (a) Pentax-AWS Airwayscope with an infant-sized Intlock blade; (b) Glidescope with size 1 blade.

we considered that definite evaluation of GS during infant chest compression by anesthesiologists, who specialize and routinely perform airway management, is needed.

Comparison of GS and AWS utility by anesthesiologists during infant chest compression has not been validated. Therefore, we decided to compare the utility of AWS to the infant-size GS for anesthesiologists. We hypothesized that the AWS or GS would improve intubation in simulations with chest compressions. In the present study, we compared AWS and GS performance with respect to ease of tracheal intubation by anesthesiologists during chest compressions on an infant manikin.

2. Methods

From May to August 2014, 24 anesthesiologists who had more than two years of experience were recruited from our institute or medical personnel taking an anesthesiology training course at the Osaka Medical College. Selected participants had 4.8 ± 2.8 years of clinical experience in anesthesia. Written informed consent was obtained before the study and participants were asked for previous clinical experience with AWS or GS. This study was approved by the Osaka Medical College Research Ethics Committee.

The ALS Baby Trainer manikin (Laerdal, Stavanger, Norway), designed to accurately represent a three-month-old infant (weight: 11 pounds), was used in the study simulations to perform intubations and chest compressions [15]. Participants used a tracheal tube (Portex, St. Paul, MN, USA) without a cuff and with an internal diameter of 3.5 mm, as well as the AWS and the infant GS with a size 1 blade (Figure 1).

The manikin was placed on a hard, flat table for "on the bed" simulation. Chest compressions were performed by the same Basic Life Support instructor using the two-thumb technique at a depth of about two inches and a rate of 100 compressions per minute in accordance with present guidelines.

Each participant was instructed to insert the tracheal tube, attach a bag valve mask, and attempt to ventilate the lungs of the manikin. Participants were given ten minutes to practice intubation, with the instructor available to give advice. The appropriate equipment for each trial was placed in a box next to the manikin's head. Intubation started when the participant picked up the AWS or GS and ended at the point of manual ventilation after tube insertion. Intubation times were recorded for both tracheal and esophageal intubations. For chest compression trials, participants were not allowed to discontinue compressions. At the end of the study, participants rated the difficulty of using each device for laryngoscope imaging and passage of the tracheal tube through the glottis on a visual analog scale (VAS) from 0 mm (extremely easy) to 100 mm (extremely difficult) [16].

Results obtained from each trial were compared using two-way repeated measures analysis of variance for intubation time and VAS and Fisher's exact test for the success rate. Clinical experience of AWS and GS was compared with Mann-Whitney U test. Data are presented as mean ± SD. $P < 0.05$ was considered statistically significant.

The study was designed as a randomized crossover trial to minimize the learning-curve effect. The order of intervention was randomized for each participant using the random number table, resulting in a total of four interventions per participant (24 patterns).

Results of a nine-doctor preliminary study showed that the time required to ventilate lungs after successful insertion of the AWS was approximately 14 ± 4 s. We estimated that 22 participants would be adequate for two independent groups using $\alpha = 0.05$ and $\beta = 0.2$.

3. Results

Clinical experience of number of the participants with the AWS was significantly higher than that with GS (AWS 60.2 ± 40.8 times versus GS 30.2 ± 20.2 times, $P < 0.05$). All participants had the experience of these two devices more than 10 cases.

3.1. Endotracheal Intubation Success with GS or AWS. The number of successful tracheal intubations for each device is displayed in Table 1. With the GS, no participant failed to achieve intubation without chest compressions, and three failed with compressions (N.S.). With the AWS, all intubations were successful regardless of whether chest compressions were performed.

3.2. Intubation Time with GS or AWS. With the GS, tracheal intubation took significantly longer with chest compressions (26.9 ± 7.8 s) than without compressions (12.7 ± 2.5 s; $P < 0.05$) (Figure 2). In contrast, chest compressions increased intubation time slightly, but not significantly, with the AWS (with compressions, 12.6 ± 2.6 s; without compressions, 11.5 ± 2.6 s).

Intubation time without chest compressions was not significantly longer with the GS than AWS. However, the

Table 1: Tracheal intubation success rates for GS or AWS with and without chest compressions. GS: Glidescope; AWS: Pentax Airwayscope with an infant-sized Intlock.

	Without chest compressions (successful/total)	With chest compressions (successful/total)	P value (Fisher's exact test)
AWS	24/24	24/24	1.00
GS	24/24	21/24	0.23
P value (Fisher's exact test)	1.00	0.23	

Numerator: number of participants who successfully intubated. Denominator: number of participants who attempted tracheal intubation. Differences were analyzed with Fisher's exact test. $^{*}P < 0.05$.

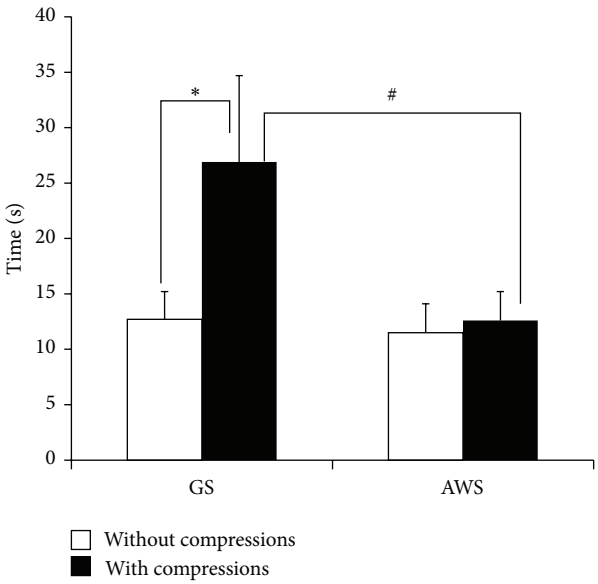

Figure 2: Time elapsed for simulated infant tracheal intubation with and without chest compressions between GS and AWS. GS: Glidescope; AWS: Pentax Airwayscope with an infant-sized Intlock. Results are expressed as mean ± SD and analyzed with two-way analysis of variance. $^{*}P < 0.05$ compared to chest compressions. $^{\#}P < 0.05$ compared to AWS.

intubation time was significantly shorter with chest compressions with the AWS than with the GS ($P < 0.05$).

3.3. VAS Scores for Laryngoscopy and Tube Passage through the Glottis for GS or AWS. As shown in Figure 3, although the VAS score for laryngoscopy was not significantly higher with the GS with chest compressions, the score for tube passage through the glottis was significantly worsened by chest compression. With the AWS, neither VAS score was significantly affected by chest compressions.

VAS scores for laryngoscopy were not significantly different between the AWS and GS. Scores for tube passage through the glottis were significantly lower with chest compressions with the AWS than with the GS ($P < 0.05$).

4. Discussion

Current ERC guidelines emphasize the administration of continuous chest compressions with as few interruptions as possible, including short pauses for airway management [1, 2]. As asphyxia is the most common cause for cardiac arrest in infants, not only continuous chest compression but also rapid and successful airway management is the most important during infant resuscitation [17, 18]. From this viewpoint, airway management such as tracheal intubation is critical for infant CPR. Although the most widely used laryngoscope for these situations is the direct Miller laryngoscope, its difficulty to operate without experience can lead to an unacceptably high incidence of inaccurate intubation [3].

The GS offers accurate visualization of the glottis with clear laryngeal exposure compared to the conventional direct laryngoscope, as it utilizes indirect laryngoscopy and higher magnification. Prior studies have demonstrated that the GS reduces the difficulty of tracheal intubation in direct comparisons with the conventional Macintosh laryngoscope [7–9].

The AWS is a video laryngoscope designed to provide a clear view of the glottis and its surrounding structures. The nonsightline view characteristics of the AWS improve the laryngeal view compared to other laryngoscopes, and its tube guide facilitates rapid and reliable tracheal intubation even for difficult adult cases involving issues such as cervical neck immobility or morbid obesity [19, 20]. Evidence indicates that the AWS is also suitable for difficult airway management and emergent situations and that it is easy for novice doctors to use [21]. Previous studies reported that the AWS with an infant-sized Intlock requires less skill and is well suited for those who perform infrequent intubations in emergency situations [4].

In the present study, we demonstrated that the success rate of intubation with the GS decreased during chest compressions, with a significant increase in intubation time. Intubation time did not significantly increase with the AWS, and all anesthesiologists achieved successful intubation during chest compressions. One probable reason for difficulties experienced with the GS is that the glottis, but not the tube, moved during chest compressions, and the relative positions of the glottis and tube were thus unstable. We speculate that this is the underlying reason for difficulties with the GS. With a nonsightline laryngoscope with a tube guide like the AWS, however, the tube and glottis could move simultaneously while their relative positions remained the same, leading to easy and safe tracheal intubation.

VAS scores for both laryngoscopy and tube passage through the glottis with chest compressions differed significantly between the GS and AWS, with the AWS providing

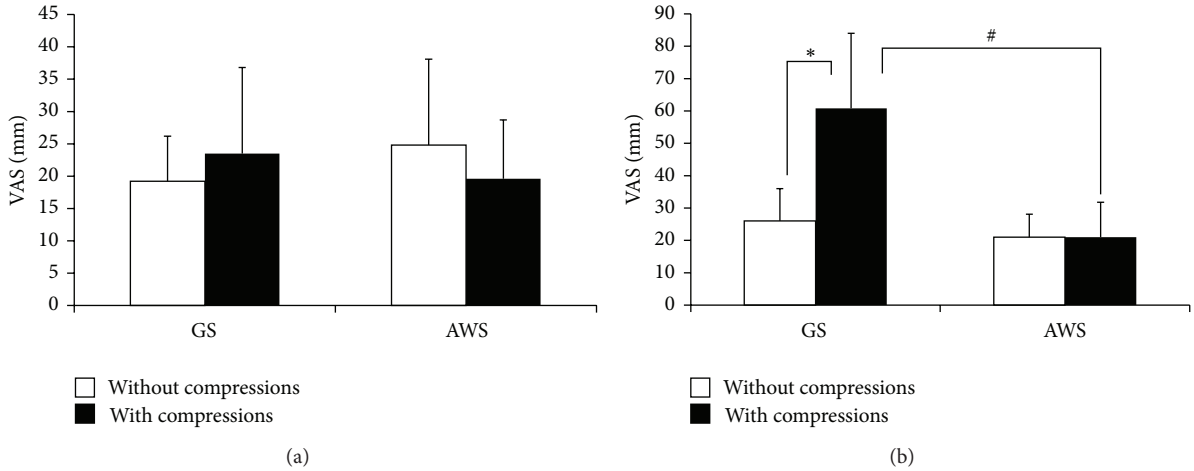

Figure 3: Visual analog scale for simulated infant tracheal intubation with and without chest compressions between GS and AWS. (a) Laryngoscope image; (b) passage of the tube through the glottis. GS: Glidescope; AWS: Pentax Airwayscope with an infant-sized Intlock. Results are expressed as mean ± SD and analyzed with two-way analysis of variance. $^{*}P < 0.05$ compared to chest compressions. $^{\#}P < 0.05$ compared to AWS.

easier laryngoscopy and tube passage. Features of the AWS, such as the target mark, may have contributed to the quick and accurate tube passage through the glottis. Another probable reason for the success of the AWS is the presence of a target mark and built-in conduits. Once the target mark on the AWS is aligned with the glottis as shown in the monitor, the tracheal tube can be pushed through the vocal cords. Although the GS is an effective infant intubation tool, the AWS appears to be more suitable for airway management by anesthesiologists performing chest compressions.

Difficult airway management for infants includes specific physical difficulties, such as a small jaw and subglottic narrowing [22]. Intubation is also complicated by the different location and administration of chest compressions compared to an adult [23, 24]. The AWS would prove useful for prompt and reliable infant airway rescue even in emergent situations.

This study has several limitations worth noting. First, the simulations do not account for factors such as blood, vomit, or secretions in the oropharynx; they also do not include the risk of blurred images due to fogging of the AWS or GS monitor. Second, the AWS and GS were not evaluated in difficult infant airways and the results cannot be extrapolated to other patient situations involving issues such as severely restricted mouth opening. Third, results of VL by experienced operators such as anesthesiologists cannot be extrapolated to other pediatric care settings because most CPR are performed by prehospital care providers and pediatricians. Trials for AWS and GS utility evaluation by prehospital care provider or pediatrician are needed in the future. Fourth, the clinical experience of participants with AWS was significantly higher than that with GS, which may have affected the results. Fifth, chest compressions and intubation were performed on an infant manikin, which leads to shorter airway intervention times than that required for actual patients [25]. Finally, homogeneity of CPR techniques cannot always be assured in clinical situations.

Clinical experience accumulation and randomized trials of AWS and GS use with actual patients receiving CPR are needed in the future.

5. Conclusion

We conclude that the AWS performed better than the GS for endotracheal intubation with chest compressions in infant simulations managed by anesthesiologists.

Abbreviations

CPR: Cardiopulmonary resuscitation
ERC: European Resuscitation Council
AWS: Pentax-AWS Airwayscope
GS: The Glidescope Cobalt.

Conflict of Interests

The authors have no affiliation with the manufacturers of any of the devices described in the paper and declare no financial interest in the material described in the paper. Financial support for the study was provided by their institution and department.

Authors' Contribution

Shunsuke Fujiwara, Nobuyasu Komasawa, and Sayuri Matsunami were involved in the study design, study implementation, data analysis, and paper preparation. Daisuke Okada was involved in the study implementation and data analysis. Toshiaki Minami was involved in study design and paper preparation.

References

[1] J. P. Nolan, J. Soar, D. A. Zideman et al., "European resuscitation council guidelines for resuscitation 2010 section 1. Executive summary," *Resuscitation*, vol. 81, no. 10, pp. 1219–1276, 2010.

[2] D. Biarent, R. Bingham, C. Eich et al., "European Resuscitation Council Guidelines for Resuscitation 2010 section 6. Paediatric life support," *Resuscitation*, vol. 81, no. 10, pp. 1364–1388, 2010.

[3] B. M. Gerritse, J. M. T. Draaisma, A. Schalkwijk, P. M. van Grunsven, and G. J. Scheffer, "Should EMS-paramedics perform paediatric tracheal intubation in the field?" *Resuscitation*, vol. 79, no. 2, pp. 225–229, 2008.

[4] N. Komasawa, R. Ueki, N. Yamamoto, S.-I. Nishi, Y. Kaminoh, and C. Tashiro, "Comparison of Pentax-AWS Airwayscope, Airtraq and Miller laryngoscope for tracheal intubation by novice doctors during infant cardiopulmonary resuscitation simulation: a randomized crossover trial," *Journal of Anesthesia*, vol. 27, no. 5, pp. 778–780, 2013.

[5] A. Tampo, A. Suzuki, S. Sako, T. Kunisawa, H. Iwasaki, and S. Fujita, "A comparison of the Pentax Airway Scope with the Airtraq in an infant manikin," *Anaesthesia*, vol. 67, no. 8, pp. 881–884, 2012.

[6] M. A. Malik, C. H. Maharaj, B. H. Harte, and J. G. Laffey, "Comparison of Macintosh, Truview EVO2, Glidescope , and Airwayscope laryngoscope use in patients with cervical spine immobilization," *British Journal of Anaesthesia*, vol. 101, no. 5, pp. 723–730, 2008.

[7] M. A. Malik, C. O'Donoghue, J. Carney, C. H. Maharaj, B. H. Harte, and J. G. Laffey, "Comparison of the Glidescope , the Pentax AWS, and the Truview EVO2 with the Macintosh laryngoscope in experienced anaesthetists : a manikin study," *British Journal of Anaesthesia*, vol. 102, no. 1, pp. 128–134, 2009.

[8] A. J. Donoghue, A. M. Ades, A. Nishisaki, and E. S. Deutsch, "Videolaryngoscopy versus direct laryngoscopy in simulated pediatric intubation," *Annals of Emergency Medicine*, vol. 61, no. 3, pp. 271–277, 2013.

[9] D. H. Shin, P. C. Choi, and S. K. Han, "Tracheal intubation during chest compressions using Pentax-AWS, GlideScope , and Macintosh laryngoscope: a randomized crossover trial using a mannequin," *Canadian Journal of Anesthesia*, vol. 58, no. 8, pp. 733–739, 2011.

[10] S. O. Park, K. J. Baek, D. Y. Hong, S. C. Kim, and K. R. Lee, "Feasibility of the video-laryngoscope (GlideScope) for endotracheal intubation during uninterrupted chest compressions in actual advanced life support: a clinical observational study in an urban emergency department," *Resuscitation*, vol. 84, no. 9, pp. 1233–1237, 2013.

[11] T. Xanthos, K. Stroumpoulis, E. Bassiakou et al., "Glidescope videolaryngoscope improves intubation success rate in cardiac arrest scenarios without chest compressions interruption: a randomized cross-over manikin study," *Resuscitation*, vol. 82, no. 4, pp. 464–467, 2011.

[12] A. Rodríguez-Núñez, J. Moure-González, S. Rodríguez-Blanco, I. Oulego-Erroz, P. Rodríguez-Rivas, and J. Cortiñas-Díaz, "Tracheal intubation of pediatric manikins during ongoing chest compressions. Does Glidescope videolaryngoscope improve pediatric residents' performance?" *European Journal of Pediatrics*, vol. 173, pp. 1387–1390, 2014.

[13] M. Fonte, I. Oulego-Erroz, L. Nadkarni, L. Sánchez-Santos, A. Iglesias-Vásquez, and A. Rodríguez-Núñez, "A randomized comparison of the glidescope videolaryngoscope to the standard laryngoscopy for intubation by pediatric residents in simulated easy and difficult infant airway scenarios," *Pediatric Emergency Care*, vol. 27, no. 5, pp. 398–402, 2011.

[14] N. Iacovidou, E. Bassiakou, K. Stroumpoulis et al., "Conventional direct laryngoscopy versus videolaryngoscopy with the GlideScope: a neonatal manikin study with inexperienced intubators," *American Journal of Perinatology*, vol. 28, no. 3, pp. 201–206, 2011.

[15] N. Komasawa, K. Atagi, R. Ueki, S.-I. Nishi, Y. Kaminoh, and C. Tashiro, "Comparison of optic laryngoscope Airtraq and Miller laryngoscope for tracheal intubation during infant cardiopulmonary resuscitation," *Resuscitation*, vol. 82, no. 6, pp. 736–739, 2011.

[16] N. Komasawa, R. Ueki, M. Itani, S.-I. Nishi, and Y. Kaminoh, "Validation of the Pentax-AWS Airwayscope utility as an intubation device during cardiopulmonary resuscitation on the ground," *Journal of Anesthesia*, vol. 24, no. 4, pp. 582–586, 2010.

[17] F. E. Babl, R. J. Vinci, H. Bauchner, and L. Mottley, "Pediatric pre-hospital advanced life support care in an urban setting," *Pediatric Emergency Care*, vol. 17, no. 1, pp. 5–9, 2001.

[18] D. Brownstein, R. Shugerman, P. Cummings, F. Rivara, and M. Copass, "Prehospital endotracheal intubation of children by paramedics," *Annals of Emergency Medicine*, vol. 28, no. 1, pp. 34–39, 1996.

[19] T. Asai, E. H. Liu, S. Matsumoto et al., "Use of the Pentax-AWS in 293 patients with difficult airways," *Anesthesiology*, vol. 110, no. 4, pp. 898–904, 2009.

[20] A. Suzuki, Y. Toyama, N. Katsumi et al., "The Pentax-AWS rigid indirect video laryngoscope: clinical assessment of performance in 320 cases," *Anaesthesia*, vol. 63, no. 6, pp. 641–647, 2008.

[21] N. Komasawa, R. Ueki, H. Nomura, M. Itani, and Y. Kaminoh, "Comparison of tracheal intubation by the Macintosh laryngoscope and Pentax-AWS (Airway Scope) during chest compression: a manikin study," *Journal of Anesthesia*, vol. 24, no. 2, pp. 306–308, 2010.

[22] G. N. Peterson, K. B. Domino, R. A. Caplan, K. L. Posner, L. A. Lee, and F. W. Cheney, "Management of the difficult airway: a closed claims analysis," *Anesthesiology*, vol. 103, no. 1, pp. 33–39, 2005.

[23] A. Nishisaki, N. Marwaha, V. Kasinathan et al., "Airway management in pediatric patients at referring hospitals compared to a receiving tertiary pediatric ICU," *Resuscitation*, vol. 82, no. 4, pp. 386–390, 2011.

[24] R. B. Easley, J. E. Segeleon, S. E. Haun, and J. D. Tobias, "Prospective study of airway management of children requiring endotracheal intubation before admission to a pediatric intensive care unit," *Critical Care Medicine*, vol. 28, no. 6, pp. 2058–2063, 2000.

[25] J. J. Gatward, M. J. C. Thomas, J. P. Nolan, and T. M. Cook, "Effect of chest compressions on the time taken to insert airway devices in a manikin," *British Journal of Anaesthesia*, vol. 100, no. 3, pp. 351–356, 2008.

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Research Article

Comparisons of the Pentax-AWS, Glidescope, and Macintosh Laryngoscopes for Intubation Performance during Mechanical Chest Compressions in Left Lateral Tilt: A Randomized Simulation Study of Maternal Cardiopulmonary Resuscitation

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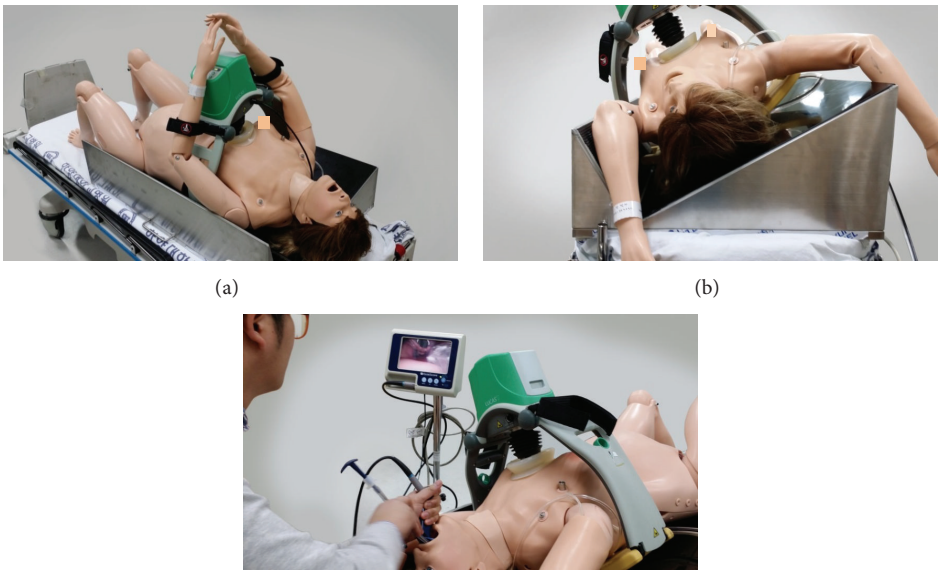
Purpose. Rapid advanced airway management is important in maternal cardiopulmonary resuscitation (CPR). This study aimed to compare intubation performances among Pentax-AWS (AWS), Glidescope (GVL), and Macintosh laryngoscope (MCL) during mechanical chest compression in 15° and 30° left lateral tilt. *Methods*. In 19 emergency physicians, a prospective randomized crossover study was conducted to examine the three laryngoscopes. Primary outcomes were the intubation time and the success rate for intubation. *Results*. The median intubation time using AWS was shorter than that of GVL and MCL in both tilt degrees. The time to visualize the glottic view in GVL and AWS was significantly lower than that of MCL (all $P < 0.05$), whereas there was no significant difference between the two video laryngoscopes (in 15° tilt, $P = 1$; in 30° tilt, $P = 0.71$). The progression of tracheal tube using AWS was faster than that of MCL and GVL in both degrees (all $P < 0.001$). Intubations using AWS and GVL showed higher success rate than that of Macintosh laryngoscopes. *Conclusions*. The AWS could be an appropriate laryngoscope for airway management of pregnant women in tilt CPR considering intubation time and success rate.

1. Introduction

Emergency physicians are primarily responsible for both high-quality chest compressions and rapid advanced airway management in cardiopulmonary resuscitation (CPR) for women who are both pregnant and nonpregnant. The 2010 European Resuscitation Council (ERC) guidelines recommend employing manual displacement of the uterus with left lateral tilt (LLT) to achieve aortocaval decompression during CPR in late pregnancy [1]. High-quality chest compressions could be performed in the LLT position, which is not flat in simulated manikin studies [2]. Mechanical chest compression devices could compress the chest sufficiently regardless of the tilt [2, 3]. Intubation time and the success rate for intubation are influenced by manual chest compressions and the type of laryngoscope [4–6]. The LLT position could also interfere with rapid intubation during chest compressions in the operating setting [7, 8]. Physiological changes in a pregnant woman's airway (i.e., tongue swelling and airway edema) make endotracheal intubation more difficult [9–11]. Decreased functional residual capacity and increased risk of aspiration in a pregnant woman require rapid endotracheal intubation during CPR [12–14].

The optimal degree of LLT is not known. However, ERC guidelines recommend it be between 15° and 30° [1]. In an emergency room or delivery room, where maternal cardiac arrest commonly occurs, several methods are available to achieve the LLT position, whereas the operating table is used



(a) (b) (c)

Figure 1: Endotracheal intubation with the Glidescope during mechanical chest compressions by LUCAS on the wedge. (a) High-fidelity manikin (SimMom) applying LUCAS on the 15° wedge. (b) 30° left lateral tilt position created by custom-made wedge. (c) Trial scene with Glidescope during mechanical chest compressions in the 30° wedge.

in the operating room [15–17]. However, only a foam and hard wedge can maintain an angle of 15°–30° [18, 19]. No study has investigated the optimal laryngoscope to be used for rapid and successful intubation during chest compressions in maternal CPR using a mechanical compression device with an angle of 15° and 30° in the LLT position in an emergency room setting.

The aim of this study was to evaluate laryngoscopes for intubation on simulated difficult airways during maternal CPR with a mechanical compression device at angles of 15° and 30° in the LLT position in an emergency room setting. We hypothesized that the required time and success rate for intubation would be different based on the type of laryngoscope used in the above-mentioned situation.

2. Methods

2.1. Study Design. We conducted a randomized crossover manikin study to examine intubation with three laryngoscopes under two types of tilt during simulated maternal CPR at our university's simulation centre in March, 2014. The local ethics committee approved this study in January 2014 (HYI-14-004-1). We registered the study protocol in Clinical Trials before study initiation (Clinicaltrials.gov: NCT02074072).

2.2. Equipment and Materials. Participants intubated the airway with a direct laryngoscope and two video laryngoscopes using an endotracheal tube with an internal diameter of 6.5 mm (Portex, St. Paul, MN, USA) and the manufacturer stylet. A direct laryngoscope is the Macintosh laryngoscope (MCL), which has a size-4 curved blade with a Satin Slip Stylet (Mallinckrodt Medical, St. Louis, MO, USA). One video laryngoscope option is the Glidescope (GVL), which has a hyperangulated, nonchannelled, standard-size blade (Verathon, Bothell, WA, USA) with a GlideRite Rigid Stylet. Another option is the Pentax-AWS (AWS), which has a channelled, standard blade (Pentax Corporation, Tokyo, Japan). We used a high-fidelity manikin (SimMom, Laerdal, Stavanger, Norway) for chest compressions and airway intubations. The manikin was set with a tongue edema setting and LUCAS 2 (LUCAS Chest Compression System, Physio-Control/Jolife AB, Lund, Sweden) for performing chest compressions at a continuous rate of 100 compressions/min at a depth of 5 cm, according to guidelines [1]. We used 15° and 30° custom-made wedges to simulate the LLT position (1000 × 600 × 156 mm for the 15° wedge and 1000 × 600 × 300 mm for the 30° wedge). The manikin was laid on a backboard (450 × 600 × 10 mm, 3 kg Lifeline Plastic, Sung Shim Medical Co., Bucheon, Korea) and placed on the wedge on a bed (Transport stretcher, 760 × 2110 mm, 228 kg, Stryker Co., Kalamazoo, Michigan, US) (Figure 1).

2.3. Participants. The sample size was calculated based on a previous study regarding the time required for intubation during chest compressions with a 27° LLT [7]. The mean (SD) time was MCL 18.9(4) and AWS 12.6(1.2) to ventilate the lungs after tracheal intubation. To detect a 33% difference in intubation time with a power of 0.8, we estimated that 14 operators would be adequate for each device with a 20% drop rate. We recruited physicians working at one tertiary medical centre in March, 2014. We included healthy volunteers who were between 16 and 60 years old and had more than 50 experiences of intubation using MCL [20]. We excluded people

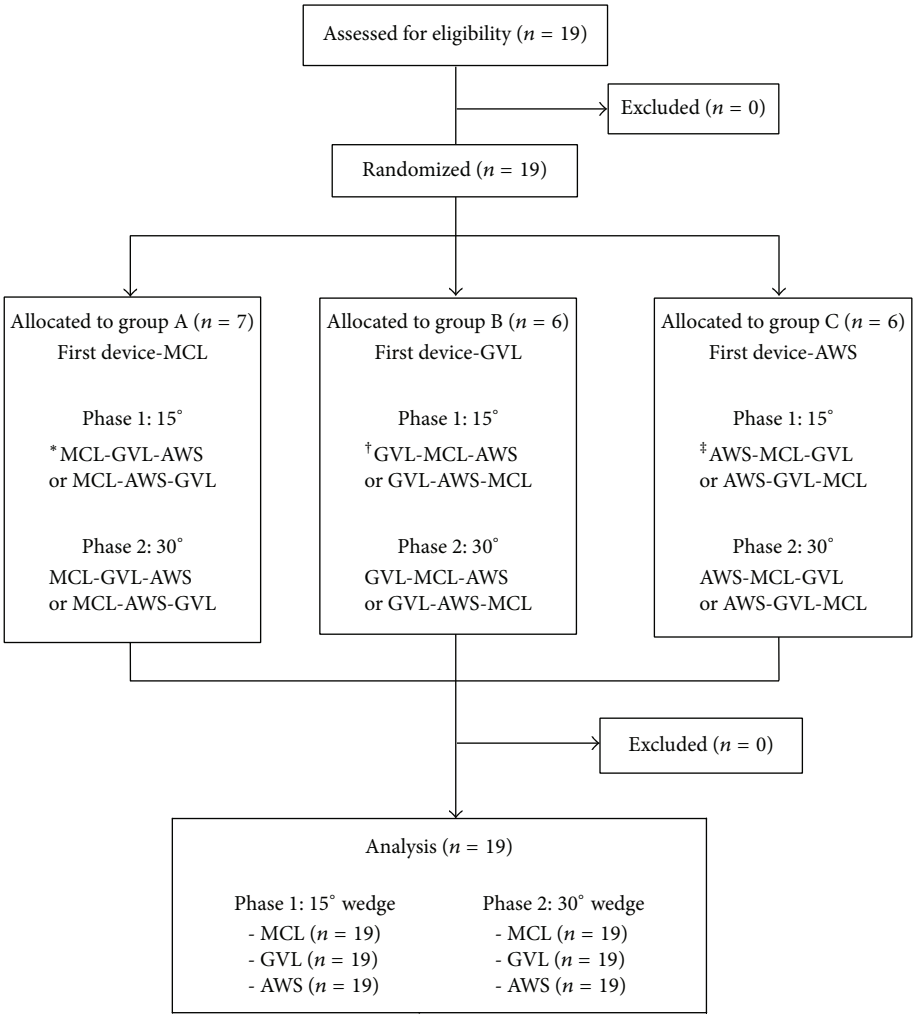


Figure 2: Diagram showing the flow of participants through the study. *MCL = Macintosh laryngoscope; †GVL = Glidescope; ‡AWS = Pentax-AWS.

who had wrist and low back disease. All participants signed a written consent form before being included.

2.4. Interventions. All participants completed a brief questionnaire consisting of demographic information (age, gender, body weight, and height) and prior experiences of intubations and maternal CPR in a clinical situation. Ten minutes prior to starting the trials, participants were allowed to practice intubations with all laryngoscopes to familiarize themselves with the Laerdal Airway Management Trainer (Laerdal, Stavanger, Norway) without chest compressions and tongue edema under supine position. Nineteen participants were enrolled, and they were randomly allocated to three groups (http://www.random.org/). Participants in group A ($n = 7$) performed the first intubation with MCL during chest compressions under simulated 15° and 30° LLT positions, whereas participants in group B ($n = 6$) performed the first intubation with GVL. Group C ($n = 6$) performed the first intubation with AWS. After being allocated to the three groups, the participants were placed in a random order by a computer-generated list of random numbers (http://www.random.org/) to minimize learning effects, and then they performed intubation with the laryngoscopes (Figure 2). For MCL, the manikin's head and neck were placed in a sniffing position utilizing several rolled sheets. When each participant performed intubation with each laryngoscope, continuous chest compressions were performed by LUCAS 2. The height of the bed was 80 cm, which was approximately the height of the participant's mid-thigh level. Participants had a 10-minute break after each intubation in one LLT position and a 30-minute break before.

2.5. Outcomes. Primary outcomes were the intubation time and the success rate for intubation. The intubation time was recorded from the start-point to the mid-point and from the mid-point to the endpoint by a recorder. The recorder was informed about how to record the intubation time and was blinded to the objective of this study. The start-point was when the participant inserted the blade between the teeth after command to start by a recorder. The mid-point was when the participant exposed the vocal cord and stated "I can see." The endpoint was at the first manual ventilation

after intubation, regardless of success or failure of air inflating into the manikin's lungs. The time to visualize the glottis view (TTV) was measured from the start-point to the mid-point, and the time to progress the endotracheal tube (TTP) was consecutively measured from the mid-point to the endpoint. The time to intubate (TTI) was calculated from the start-point to the endpoint (TTV + TTP). We defined intubation failure as follows: when the tip of the tube is not properly placed in the trachea but is placed in the oesophagus or in the oral cavity or when the TTI is 90 sec or more [21, 22].

Secondary outcomes were the glottic view using a Cormack-Lehane score (CLS) and the preference for laryngoscopes. The preference for laryngoscopes was determined by asking the participants to choose the laryngoscope that would be most favourable during maternal CPR.

2.6. Statistical Analysis. The data were compiled using a standard spreadsheet application (Excel, Microsoft, Redmond, WA, USA) and were analysed using the Statistical Package for the Social Sciences (SPSS) 18.0 KO for Windows (SPSS Inc., Chicago, IL, USA). We generated the descriptive statistics and presented them as frequencies and percentages for the categorical data and medians with interquartile ranges (IQR) for the continuous data because the data were not normally distributed. To compare the intubation time among the three laryngoscopes, the Kruskall-Wallis test was used for continuous variables. A χ^2 test was used to compare the categorical variables, such as the success rate for intubation, the CLS, and the laryngoscope preference. A post hoc analysis was conducted with the Mann-Whitney test using a Bonferroni correction. $P < 0.05$ was considered significant. The Kaplan-Meier analysis was performed to analyse the cumulative success rate regarding TTV and TTP.

3. Results

3.1. General Characteristics. Nineteen participants were enrolled. Nineteen intubation trials were performed for each laryngoscope for both 15° and 30° LLT. There was no exclusion in our study. The general characteristics of the participants are shown in Table 1.

Table 1: Demographic characteristics.

Characteristics	Data
Sex (percent)	Male (100)
Age (years)	33 (29–36)
Height (cm)	172 (171–174)
Weight (kg)	78 (75–80)
BMI (kg/m^2)	25.9 (24.2–26.6)
Participants	
PGY2*	3 (15.8)
PGY3	3 (15.8)
PGY4	2 (10.5)
EP†	11 (57.9)
Intubation experiences	
MCL > 50 (times)	19 (100)
GVL > 50 (times)	18 (94.7)
AWS > 50 (times)	5 (26.3)
Clinical experiences	
Maternal CPR	9 (47.4)
Maternal intubation	7 (36.8)
Intubation during maternal CPR	5 (26.3)

Categorical variables are given as numbers (percentage). Continuous variables are given as median (IQR). *PGY: postgraduate years; †EP: emergency physician.

3.2. Tracheal Intubation in 15° LLT Position. TTI was significantly different among the three laryngoscopes. The TTI in AWS was shortest, followed by GVL and MCL (all $P < 0.05$). The TTV in both GVL and AWS was significantly less than that of MCL, whereas there was no significant difference between the two video laryngoscopes ($P = 1.00$). In terms of TTP, progression of ETT using AWS was faster than that of MCL and GVL (all $P < 0.001$). However, there was no significant difference between MCL and GVL ($P = 0.56$) (Table 2).

Intubation using AWS showed the highest success rate, followed by GVL and MCL. The glottis views in the two video laryngoscopes were better than that of MCL.

3.3. Tracheal Intubation in 30° LLT Positions. The TTI in AWS was faster than that of MCL and GVL (all $P < 0.05$). However, there was no significant difference between MCL and GVL ($P = 0.08$). The TTV in GVL and AWS was significantly lower than that of MCL, whereas there was no significant difference between the two video laryngoscopes ($P = 0.71$). In terms of TTP, progression of ETT using AWS was faster than that of MCL and GVL ($P = 0.002$, $P < 0.001$, resp.). However, there was no significant difference between MCL and GVL ($P = 0.55$) (Table 3).

The cumulative success rates related to TTV for AWS and GVL were significantly higher than that of MCL ($P < 0.001$). The cumulative success rate related to TTP for AWS was significantly higher than that of GVL and MCL ($P < 0.001$) (Figure 3).

3.4. Preference for Laryngoscopes. Regardless of tilt degree, 13 participants (68.4%) preferred AWS, and six participants (31.6%) selected GVL when asked which of the three laryngoscopes they prefer for maternal CPR.

4. Discussion

Pregnancy can be a potent contributor to ventilation difficulty because of edema of the upper airway tract, and motion limitation of the thorax and diaphragm may occur unexpectedly [9–11]. Supraglottic airway devices might be useful to protect the airway and provide ventilation during pregnancy. However, it is known that aspiration is a high risk factor for pregnant women [1]. Compared to an endotracheal tube (ETT), supraglottic airway devices are not enough to prevent aspiration. Therefore, emergent endotracheal intubation in pregnant women deserves special emphasis [1, 11].

It can be difficult to perform intubation during CPR because the chest compressions can cause the glottis to move up and down, which makes it hard to maintain proper glottis

Table 2: Tracheal intubation in 15-degree left lateral tilt positions (n = 19).

	15 degrees						
	MCL (n = 19)	GVL (n = 19)	AWS (n = 19)	P value	MCL versus AWS	MAC versus GVL	AWS versus GVL
Intubation time (seconds)							
TTI*	36.9 (31.5–50.7)	22.9 (17.5–33)	12.8 (11.3–15.2)	<0.001	<0.001	0.04	<0.001
TTV†	16.5 (12.8–26.3)	4.9 (4.2–13.5)	5.8 (4–7.6)	<0.001	<0.001	<0.001	1.00
TTP‡	18 (13.8–28)	16.2 (12.7–23.2)	7.0 (5.3–9.2)	<0.001	<0.001	0.56	<0.001
Success rate (percent)							
Success rate	14 (73.7)	18 (94.7)	19 (100)	0.04			
Failure							
Esophageal intubation	3 (15.8)	0 (0)	0 (0)	0.09			
Intubation time >90 s	2 (10.5)	1 (5.3)	0 (0)	0.77			
Cormack and Lehane score							
I-II	7 (36.8)	17 (89.5)	19 (100)	<0.001			
III-IV	12 (63.2)	2 (10.5)	0 (0)				
Preference	0 (0)	6 (31.6)	13 (68.4)	1.00			

Categorical variables are given as numbers (percentage). Continuous variables are given as median (IQR). MCL: Macintosh laryngoscope; AWS: Pentax-AWS; GVL: Glidescope. *Total time for tracheal intubation. †Time to visualize glottis view. ‡Time to progress the tracheal tube from exposure of vocal cords to first ventilation.

Table 3: Tracheal intubation in 30-degree left lateral tilt positions (n = 19).

	30 degrees						
	MCL (n = 19)	GVL (n = 19)	AWS (n = 19)	P value	MCL versus AWS	MCL versus GVL	AWS versus GVL
Intubation time (seconds)							
TTI*	32.4 (22.6–47.1)	21 (16.2–31.2)	13.4 (12.4–16.2)	<0.001	<0.001	0.09	0.001
TTV†	13.9 (9–23.9)	5.2 (4.0–8.9)	5.4 (4.7–8.2)	<0.001	<0.001	0.004	0.71
TTP‡	16.2 (13.6–21.8)	14.6 (12.3–18.6)	7.5 (6.3–9.9)	0.002	0.002	0.55	<0.001
Success rate (percent)							
Success rate	9 (47.4)	17 (89.5)	18 (94.7)	0.001			
Failure							
Esophageal intubation	4 (21.1)	0 (0)	1 (5.3)	0.11			
Intubation time >90 s	7 (36.8)	2 (10.5)	0 (0)	0.007			
Cormack-Lehane score							
I-II	5 (26.3)	18 (94.7)	19 (100)	<0.001			
III-IV	14 (73.7)	1 (5.3)	0 (0)				
Preference	0 (0)	6 (31.6)	13 (68.4)	1.00			

Categorical variables are given as numbers (percentage). Continuous variables are given as median (IQR). MCL: Macintosh laryngoscope; AWS: Pentax-AWS; GLS: Glidescope. *Total time for tracheal intubation. †Time to visualize glottis view. ‡Time to progress the tracheal tube from exposure of vocal cords to first ventilation.

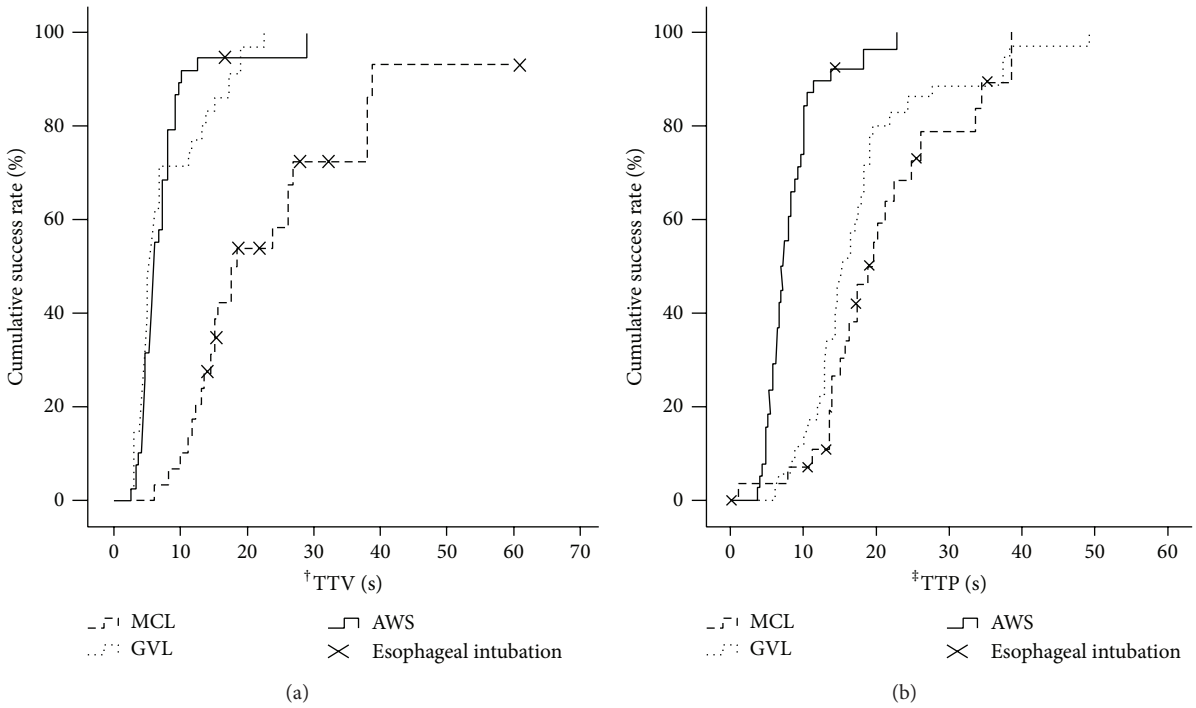


Figure 3: Cumulative success rate related to (a) the time from blade insertion to exposure of the vocal cords (TTV) and (b) the time from exposure of the vocal cords to manual ventilation (TTP) in the left lateral tilt position with mechanical chest compressions. MCL: Macintosh laryngoscope; AWS: Pentax-AWS; GVL: Glidescope; †TTV: time to visualize glottis view; ‡TTV: time to progress the tracheal tube from exposure of vocal cords to first ventilation.

view [7]. Furthermore, because patients are placed in the LLT position during maternal CPR, the lifting force of the intubator to expose the glottis view can be insufficiently transmitted to patients. It is also difficult to handle the laryngoscope with patients in the LLT position [7]. Even if the glottis is fully exposed, chest compressions and the LLT position can interrupt intubators in the progression of the ETT and removal of the stylet [7]. Therefore, the TTI can be affected by the degree of tilt, chest compression, and the type of laryngoscope. Kohama et al. reported TTI in AWS during simulated maternal CPR (normal airway setting, manual chest compression, and 27° LLT position) using an operating table that was shorter than that of MCL [7]. In this study, we evaluated the TTI for laryngoscopes in different settings (tongue edema setting, mechanical chest compression, and two types of LLT positions using 15° and 30° wedges) on a hospital bed in an emergency room and compared it to previous studies. We found that the use of AWS for emergent intubation reduced the TTV and TTP, which resulted in the reduction of the TTI compared with that of MCL at both tilt degrees. The use of GVL significantly decreased the TTV but hardly reduced the TTP, which also resulted in a reduction of the TTI compared with that of MCL. This means that the use of a camera attached to the blade of a video laryngoscope may play a major role in decreasing the time to exposure of the vocal cords. In terms of TTP, AWS showed better outcomes than GVL when compared with MCL. It is believed that the channelled blade applied to AWS enables the ETT to progress effectively [4]. Because AWS does not require a stylet, AWS can also reduce the time required to handle a stylet in GVL during maternal CPR. AWS was the most preferred device among the three laryngoscopes in this study, which we assume is due to the integrated channel of the blade that enables faster tracheal intubation without a stylet.

The ERC guideline recommends a 15°–30° LLT position to remove the caval compression during maternal CPR [1]. Two studies have reported that the TTI was affected by the patient position and the type of laryngoscope used. When using MCL, the TTI in the supine position was shorter than that in the LLT position [8]. However, in terms of AWS, there was no difference in the TTI between these positions [8]. In this study, participants performed intubations at two tilt angles (15° and 30°), excluding the supine position. Angles of 15° and 30° are the minimum and maximum tilt angles, respectively, that are recommended by the ERC guideline for maternal CPR [1]. There were no differences in the TTI between the tilt angles for the three laryngoscopes.

Regarding the success rate for intubation, previous studies have reported that this is affected by chest compressions and the type of laryngoscope used [7]. In the 27° LLT position, MCL showed a lower success rate with chest compressions than without chest compressions [7]. However, AWS showed an equal success rate regardless of chest compression [7]. In the supine position during chest compressions, MCL showed a lower success rate than AWS and GVL [4, 23]. In this study, we evaluated intubation performance in the 15° and 30° LLT

positions during chest compression. AWS and GVL showed better success rates than MCL at both tilt degrees, as expected. The cumulative success rates had the same results.

5. Limitation

There were several limitations of this study.

We used a high-fidelity manikin setting with tongue edema to simulate a difficult airway during pregnancy. This manikin can also simulate difficult airway applying trismus setting, however, which has not been known as typical change of maternal airway. However, the actual maternal airway cannot be simulated by only tongue edema. Furthermore, there could be various clinical anatomic changes due to pregnancy in addition to tongue edema. Therefore, the measured intubation performance in this study could differ from that of actual maternal CPR. Further studies using more sophisticated manikin or clinical trials would be needed.

Recently, mechanical chest compression devices have been widely used, and some studies have reported that mechanical chest compression devices could show better outcomes than manual chest compressions [3]. We used LUCAS Chest Compression System (Physio-Control/Jolife AB, Lund, Sweden) for even and uninterrupted chest compressions. The effect of mechanical chest compressions on performing intubation during chest compressions might differ from that of manual chest compressions.

The most appropriate bed height for chest compressions is different from that of intubation. To best perform chest compressions, the bed height needs to be at lower- to mid-thigh level [24, 25]. In contrast, the bed height has to be raised to sternum level to perform intubation well. When intubation is performed using MCL, intubation performance could be influenced by the height of the bed. This is because the sightline view of the intubator is equated to the glottic opening to successfully intubate using MCL. However, in this study, the bed height was fixed at 80 cm, which was approximately mid-thigh level for the participants performing chest compressions. Therefore, the effects of bed height changes on intubation performance were not reflected in the study.

The pressures generated by laryngoscopes can cause deleterious effects to the soft tissues of the upper airway. If capillaries of airway soft tissue are engorged due to pregnancy, it can easily bleed under the pressure generated by laryngoscopes. In previous study, intubation using GVL could reduce the forces to the soft tissues of upper airway when compared to that of MCL [26]. Likewise, video laryngoscopes are considered to be advantageous to lower the pressure to the soft tissue of upper airway in maternal airway management. However, the pressures generated by laryngoscopes are not considered in this study.

6. Conclusions

The AWS could be an appropriate laryngoscope for airway management of pregnant women in tilt CPR considering intubation time and success rate.

Conflict of Interests

Hyunggoo Kang, as the corresponding author of this paper, declares that there is no conflict of interests related to this paper.

Authors' Contribution

Sanghyun Lee and Wonhee Kim contributed equally to this study. Sanghyun Lee and Wonhee Kim were involved in all aspects of the study design, designing and managing the study, interpreting findings, and cowriting the paper. Hyunggoo Kang, Yoonjae Lee, and Jun Hwi Cho were involved in critical revision of the paper for important intellectual content. Tae Ho Lim, Jaehoon Oh, and Changsun Kim were involved in study concept and design, interpretation of the data, critical revision of the paper for important intellectual content, and final approval of the version to be published.

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References

[1] J. Soar, G. D. Perkins, G. Abbas et al., "European Resuscitation Council Guidelines for Resuscitation 2010 Section 8. Cardiac arrest in special circumstances: electrolyte abnormalities, poisoning, drowning, accidental hypothermia, hyperthermia, asthma, anaphylaxis, cardiac surgery, trauma, pregnancy, electrocution," *Resuscitation*, vol. 81, no. 10, pp. 1400–1433, 2010.

[2] S. Kim, J. S. You, H. S. Lee et al., "Quality of chest compressions performed by inexperienced rescuers in simulated cardiac arrest associated with pregnancy," *Resuscitation*, vol. 84, no. 1, pp. 98–102, 2013.

[3] M. Westfall, S. Krantz, C. Mullin, and C. Kaufman, "Mechanical versus manual chest compressions in out-of-hospital cardiac arrest: a meta-analysis," *Critical Care Medicine*, vol. 41, no. 7, pp. 1782–1789, 2013.

[4] S. K. Han, D. H. Shin, and P. C. Choi, "Utility of the Pentax-AWS without interruption of chest compression: comparison of the Macintosh laryngoscope with the Pentax-AWS in manikin model," *Resuscitation*, vol. 81, no. 1, pp. 69–73, 2010.

[5] D. H. Shin, P. C. Choi, and S. K. Han, "Tracheal intubation during chest compressions using Pentax-AWS, GlideScope, and Macintosh laryngoscope: a randomized crossover trial using a mannequin," *Canadian Journal of Anesthesia*, vol. 58, no. 8, pp. 733–739, 2011.

[6] N. Komasawa, R. Ueki, M. Itani, S.-I. Nishi, and Y. Kaminoh, "Validation of the Pentax-AWS airwayscope utility as an intubation device during cardiopulmonary resuscitation on the ground," *Journal of Anesthesia*, vol. 24, no. 4, pp. 582–586, 2010.

[7] H. Kohama, N. Komasawa, R. Ueki et al., "Utility of the Pentax-AWS airwayscope and macintosh laryngoscope for airway management during chest compressions in 27 left-lateral tilt: a manikin simulation study of maternal cardiopulmonary resuscitation," *Journal of Anesthesia*, vol. 27, no. 5, pp. 671–675, 2013.

[8] N. Komasawa, R. Ueki, M. Itani, H. Nomura, S.-I. Nishi, and Y. Kaminoh, "Evaluation of tracheal intubation in several positions by the Pentax-AWS airway scope: a manikin study," *Journal of Anesthesia*, vol. 24, no. 6, pp. 908–912, 2010.

[9] M. S. Suresh, C. L. Mason, and U. Munnur, "Cardiopulmonary resuscitation and the parturient," *Best Practice & Research: Clinical Obstetrics & Gynaecology*, vol. 24, no. 3, pp. 383–400, 2010.

[10] S. E. King and D. A. Gabbott, "Maternal cardiac arrest-rarely occurs, rarely researched," *Resuscitation*, vol. 82, no. 7, pp. 795–796, 2011.

[11] T. L. Vanden Hoek, L. J. Morrison, M. Shuster et al., "Part 12: cardiac arrest in special situations: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care," *Circulation*, vol. 122, pp. S829–S861, 2010.

[12] H. Finegold, C. A. Troianos, and H. Basi, "Use of advanced airway techniques in the pregnant patient," *Anesthesiology Clinics*, vol. 31, no. 3, pp. 529–543, 2013.

[13] H. Lombaard, P. Soma-Pillay, and E.-M. Farrell, "Managing acute collapse in pregnant women," *Best Practice & Research: Clinical Obstetrics & Gynaecology*, vol. 23, no. 3, pp. 339–355, 2009.

[14] F. M. Jeejeebhoy and L. J. Morrison, "Maternal cardiac arrest: a practical and comprehensive review," *Emergency Medicine International*, vol. 2013, Article ID 274814, 8 pages, 2013.

[15] D. A. Gabbott, "Uterine displacement during CPR in the pregnant patient—why bother?" *Resuscitation*, vol. 84, no. 3, pp. 267–268, 2013.

[16] S. S. Lipman, J. Y. Wong, J. Arafeh, S. E. Cohen, and B. Carvalho, "Transport decreases the quality of cardiopulmonary resuscitation during simulated maternal cardiac arrest," *Anesthesia & Analgesia*, vol. 116, no. 1, pp. 162–167, 2013.

[17] S. Lipman, K. Daniels, S. E. Cohen, and B. Carvalho, "Labor room setting compared with the operating room for simulated perimortem cesarean delivery: a randomized controlled trial," *Obstetrics & Gynecology*, vol. 118, no. 5, pp. 1090–1094, 2011.

[18] J. K. Ip, J. P. Campbell, D. Bushby, and S. M. Yentis, "Cardiopulmonary resuscitation in the pregnant patient: a manikin-based evaluation of methods for producing lateral tilt," *Anaesthesia*, vol. 68, no. 7, pp. 694–699, 2013.

[19] M. Butcher, J. Ip, D. Bushby, and S. M. Yentis, "Efficacy of cardiopulmonary resuscitation in the supine position with manual displacement of the uterus vs lateral tilt using a firm wedge: a manikin study," *Anaesthesia*, vol. 69, no. 8, pp. 868–871, 2014.

[20] S. M. Je, Y. C. Cho, H. J. Choi, B. Kang, T. Lim, and H. Kang, "An application of the learning curve-cumulative summation test to evaluate training for endotracheal intubation in emergency medicine," *Emergency Medicine Journal*, 2013.

[21] J. L. Benumof, R. Dagg, and R. Benumof, "Critical hemoglobin desaturation will occur before return to an unparalyzed state following 1 mg/kg intravenous succinylcholine," *Anesthesiology*, vol. 87, no. 4, pp. 979–982, 1997.

[22] S. D. Weingart and R. M. Levitan, "Preoxygenation and prevention of desaturation during emergency airway management," *Annals of Emergency Medicine*, vol. 59, no. 3, pp. 165–175, 2012.

[23] T. Xanthos, K. Stroumpoulis, E. Bassiakou et al., "Glidescope videolaryngoscope improves intubation success rate in cardiac arrest scenarios without chest compressions interruption: a randomized cross-over manikin study," *Resuscitation*, vol. 82, no. 4, pp. 464–467, 2011.

[24] A. Lewinsohn, P. B. Sherren, and D. S. Wijayatilake, "The effects of bed height and time on the quality of chest compressions delivered during cardiopulmonary resuscitation: a randomised crossover simulation study," *Emergency Medicine Journal*, vol. 29, no. 8, pp. 660–663, 2012.

[25] C. K. Hong, S. O. Park, H. H. Jeong et al., "The most effective rescuer's position for cardiopulmonary resuscitation provided to patients on beds: a randomized, controlled, crossover mannequin study," *Journal of Emergency Medicine*, vol. 46, no. 5, pp. 643–649, 2014.

[26] M. Carassiti, R. Zanzonico, S. Cecchini, S. Silvestri, R. Cataldo, and F. E. Agrò, "Force and pressure distribution using Macintosh and GlideScope laryngoscopes in normal and difficult airways: a manikin study," *British Journal of Anaesthesia*, vol. 108, no. 1, pp. 146–151, 2012.