A Comparison of Direct versus Indirect Laryngoscopic Visualization during Endotracheal Intubation of Lightly Embalmed Cadavers utilizing the Glide Scope®, Storz Medi Pack Mobile Imaging System™ and the New Storz C-MAC™ Videolaryngoscope

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Abstract

Background: Studies indicate that the skills needed to use video laryngoscope systems are easily learned by healthcare providers. This study compared several video laryngoscopic (VL) systems and a direct laryngoscope (DL) view when used by medical residents practicing intubation on cadavers. The video devices used included the Storz Medi Pack Mobile Imaging System™, the Storz CMAC® VL System and the GlideScope®. **Methods:** After Institutional Review Board (IRB) approval, University of Nebraska Medical Center, Department of Emergency Medicine (UNMC EM) residents were recruited and given a brief pre-study informational period. The cadavers were lightly embalmed. The study subjects were asked to perform intubations on two cadavers using both DL and VL while using the three different VL systems. Procedural data was recorded for each attempt and pre and post experience perceptions were collected. **Results:** N=14. All subjects reported their varied previous intubation experience. The average airway score using DL: for the Storz VL was 1.54 (SD = 0.576) and for the C-MAC was 1.46 (SD = 0.637). Success in intubation of the standard airway using DL was 93% versus a 100% success rate when intubating with indirect VL visualization. **Conclusion:** Based on our data, we believe that the incorporation of VL into cadaver airway management training provided an improved learning environment for the study residents. In our study, the resident subjects were 93% successful with DL intubation even though 50% had less than 30 intubations. As well, there was a 100% success rate when intubating with indirect VL visualization. In conclusion, the researchers believe this cadaver model incorporated with VL is a powerful tool which may help improve the overall learning curve for orotracheal intubation.

Keywords: videolaryngoscopy, Prehospital, direct laryngoscopy, indirect laryngoscopy, intubation, cadaver

Introduction

Airway management is one of the key procedural skills for all healthcare providers, civilian or military, engaged in the emergency management of critically ill or injured patients. In the military arena, examinations of PSD's (potentially survivable death) in Special Operations Forces in Iraq and Afghanistan showed that 8% of PSD's were caused by airway compromise.[1] Kelly et al., reviewed PSD data and revealed that airway compromise was the etiology in 15% of PSD in 2003-2004 and 10% of PSD in 2006.[2] It has been shown that successful intubation will reduce morbidity and mortality in patients who have been critically injured.[3-5] It is therefore of utter importance that healthcare providers learn to proficiently perform this technique. However, it has been demonstrated that healthcare providers do not have uniform levels of training or expertise with this technique.[6-12] Numerous factors play a role in the wide discrepancy of health care providers' ability to intubate. The most obvious factor is airway management training. It has been identified that no standardized and effective training for orotracheal intubation exists throughout different medical fields.[7,9,11,13-15] For example, traditional manikin training has been shown to provide inadequate training for emergency medical technicians (EMTs) because this type of training for direct laryngoscopy only achieved a 50% success rate of intubation in out-of-hospital patients.[6,16,17] This is not surprising, since EMTs have limited training and manage airways in more uncontrolled environments in the field. Furthermore, many patients in an out-of-OR scenario have potentially more disastrous airways.[9,18,19] Therefore, many novices have limited exposure to this type of human training and rely heavily on manikin training. However, even anesthesia residents in controlled environments have a mean intubation success rate below 50% with their first 10 patients and not until they reach 57 patients does their success rate increase to 90%.[20] This certainly demonstrates that the learning curve for direct laryngoscopy is quite flat even in residents who receive experienced attending anesthesia oversight.

Direct laryngoscopy training on manikins alone can help prepare a novice for human intubation,but is inadequate as the sole training modality in providing proficiency at this technique.[21] Several identifiable deficits to traditional direct laryngoscopy/manikin training are, as follows: 1) manikins do not wholly approximate human tissue, anatomy, and secretions; 2) the instructor and student share only a small view of the airway with direct laryngoscopy thus making real time direction and teaching difficult; and 3) an adequate view via direct laryngoscopy requires alignment of the oral, pharyngeal and laryngeal axes. Alignment of these axes can be anatomically challenging and complications frequently occur.[22-26]

Video laryngoscope technology incorporates viewing devices on the distal tip of laryngoscopes which allows the intubator to "see around the corner" during intubation. Studies indicate that the skills needed to use these video laryngoscope systems are easily learned by healthcare providers and students with varied airway management experience, providing a rescue airway device that may be rapidly integrated into either the prehospital and emergency department airway management protocols.[27-39] Similarly, it has been identified by Boedeker et al.,[40] that novice military intubators could easily acquire the skills needed to successfully intubate using VL technology. Our current study compared several newer devices utilizing video technology when used by physicians in training practicing intubation on cadavers. The video devices used included the Storz Medi Pack Mobile Imaging System™ (Karl Storz Endoscopy America, Commerce City, CA) (**Figure 1**), the Storz CMAC® Videolaryngoscope System (**Figure 2**) and the GlideScope® (Verathon Medical, Bothell, WA)(**Figure 3**).

Figure 1

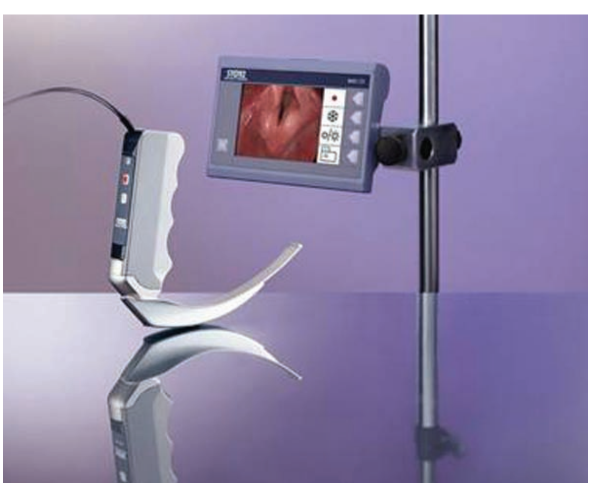

Figure 2

Photos provided courtesy of Storz Endoscopy, El Segundo, CA.

Figure 3

We sought to compare emergency medicine residents' endotracheal intubation success rates, glottic views, and tracheal intubation times between the Storz Medi Pack Mobile Imaging System, the new Storz C-MAC videolaryngoscope and the GlideScope video laryngoscope system, as well as overall preference of intubation technique and/or video laryngoscope system in a lightly embalmed cadaver airway model. Hopefully, the combination of cadavers (which are preferred by individuals undergoing airway training in a prior study by Yang) with videolaryngoscopy will provide a more powerful learning experience for our training intubators.[41] As well, we will attempt to assess how quickly our study intubators develop the psychomotor skills needed to utilize videolaryngoscopic technology.[41]

Methods

After approval from the Institutional Review Board, a group of University of Nebraska Medical Center Emergency Medicine (EM) residents in post-graduate years 1-3 were recruited. This study was conducted at the University of Nebraska Medical Center Department of Genetics, Cell Biology, and Anatomy and Department of Emergency Medicine's lightly embalmed cadaver procedure lab. It consisted of three parts, a brief pre-study informational period and demonstration to introduce the residents to the equipment being used, performance of intubations on each of the cadaver models, and a post-study questionnaire.

Prior to the study and to provide a clinically relevant model, the cadavers utilized underwent a light embalming technique.[42] This technique utilizes a dilute gluteraldehyde-based embalming fluid mixture and lower pressure infusion to preserve tissue texture and elasticity. Prior to injection, the internal jugular vein was opened to allow free drainage. The carotid artery was injected with ~ eight liters of Champion Millenium Co-inject Beta Factor (diluted 1:16 with tap water). The carotid artery was then injected with ~ eight liters of Champion Millenium Arterial 24 Alpha Factor diluted, 1:10 to 1:16 with tap water. Injection of both fluids was at 500mmHg at a flow rate of 400-500ml/minute. The cadaver was then stored supine in a plastic bag at 4˚ Celsius.

The participants were asked to perform intubations on two cadavers which included performing a total of five intubation exercises on each model using both direct visualization of the glottis and indirect view using the video laryngoscope monitors. The video laryngoscopes used were the Storz Medi Pack Mobile Imaging System™ (Karl Storz Endoscopy America, Commerce City, CA) fitted with a number 3 video MacIntosh blade, the new Storz C-MAC (Karl Storz Endoscopy America, Commerce City, CA) fitted with a number 3 video MacIntosh blade, and the GlideScope (Verathon Medical, Bothell, WA).

The Storz Medi Pack system houses a camera with a fiberoptic light source within a standard MacIntosh blade. This system magnifies the image and displays it onto a video monitor, providing the user with a view from the tip of the blade. This technology enhances the limited view from 15º (as seen under direct laryngoscopy) to an angle of view of 80º.[43] The new Storz C-MAC videolaryngoscope is a portable system which utilizes CMOS and LED technologies. It incorporates a digital camera with light source at the blade tip. The lens provides a 60º angle view and an 80º side field of view to enhance exposure of the glottic opening and facilitate intubation. The GlideScope® videolaryngoscope also consists of a digital camera with a light source on the tip of the laryngoscope blade. The GlideScope blade has a unique 60º arc.

The following are the five intubation sessions conducted in succession on the cadavers by each trainee:

1) Intubation with the Storz video laryngoscope with direct visualization of the glottis without using the video laryngoscope monitor.
2) Intubation with the Storz video laryngoscope with indirect visualization, using the video monitor.
3) Intubation with the Storz C-MAC video laryngoscope with direct view (i.e., without the video monitor).
4) Intubation with the Storz C-MAC video laryngoscope with indirect view (i.e., with using the video monitor).
5) Intubation with the GlideScope with indirect visualization, using the video monitor.

The trainees first performed all five of the training sessions initially on Cadaver A. The same sessions were then repeated on Cadaver B. The trainees used both the Storz videolaryngoscope and CMAC with direct view (without monitor) and indirect view (with monitor). The GlideScope was used with the indirect view only. The trainees were timed during each intubation. The time from the beginning of the intubation until endotracheal tube placement, defined as when the residents placed the endotracheal tube through what they believe are the vocal cords, was recorded. The beginning time of the intubation was defined by when the resident was standing at the head of the bed with the laryngoscope in hand and indicated he/she was going to start the intubation. The video laryngoscope with the accompanying monitor switched on was at the bedside along with a 7.5mm endotracheal tube with inserted stylet.

The success or non-success of the intubation procedure was recorded for each attempt. During placement of the endotracheal tube, confirmation of the trainee's correct placement in the trachea was monitored by the investigator by viewing the video monitor for both the direct and indirect intubation attempts. If this intubation were taking place on a patient, the indirect visualization of the airway would be crucial as it translates in enabling the training anesthesiologist to monitor the intubation process while ensuring the safety of the patient during the procedure.

The subjects recorded and graded the laryngeal view present at the time the laryngoscope was in its final position prior to endotracheal tube insertion with a grading scale from 1 to 4 as described by Cormack and Lehane (1 = good view; 4 = poor view)(see **Figure 4**).

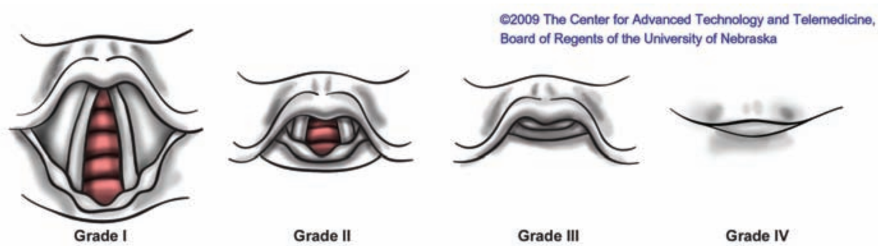

Figure 4

A study questionnaire asked the study subjects to record their job title, pre-training intubation experience (number of patients previously intubated), confidence level in first attempt success in intubating a normal patient, and intubation blade preference for direct view intubations. It also included questions pertaining to the usage of the various video laryngoscopes versus standard laryngoscopy on the cadaver airways, comparison of the visualization capabilities of each technique and user preferences for intubation techniques.

Results

The study group consisted of 14 subjects; all were residents training in post-graduate years 1-3 in an EM residency program in our local university hospital.

Pre-Training Data

Pre-training intubation experience: All subjects reported their previous intubation experience. The data indicates that the study subjects had a varied intubation experience with 14% having experience with 0-5 intubations; 7% reporting 6-10 prior intubations; 7% recording experience with 11-20 intubations; 21% reporting experience with 21-30 intubations; and 50% recording 30+ prior intubations **(see Table 1).**

Table 1.
Prior Intubation Experience of Cadaver Study Participants

Study Participants' Prior Intubation Experience					
Number of Patients Intubated					
	0-5	6-10	11-20	21-30	30+
Number of Study Participants	2 (14.28%)	1 (7.14%)	1 (7.14%)	3 (21.42%)	7 (50%)

Confidence in First Attempt of Intubation (pre-session): Prior to the training session, the study participants recorded their perceived confidence levels in their first attempt in intubating a patient with normal airway. The confidence grading scale was 1-10: 1= not confident and 10 = very confident. The average perceived pre-training confidence level was 7.93 (SD =1.492).

In comparing pre-training confidence levels in first attempt standard airway intubation versus years of practice, our study shows that confidence levels increased as years of practice increased (**see Figure 5**). In comparing pre-training confidence on first attempt intubation of a standard airway versus human intubation experience, our data showed that confidence levels increased as intubation experience increased (**see Figure 6).**

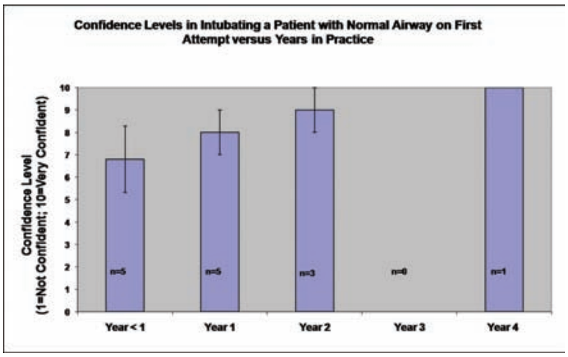

Figure 5. *A Comparison of Confidence Levels in Intubating a Patient with Normal Airway on 1st attempt vs. Years of Practice in Profession.*

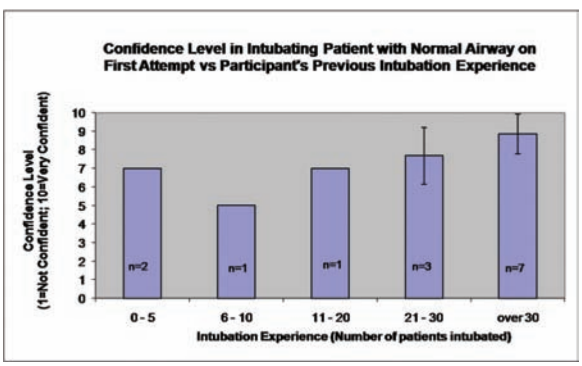

Figure 6. *A Comparison of Confidence Levels in Successfully Intubating a Patient with Normal Airway on 1st Attempt vs. Previous Human Intubation Experience.*

Intubation/Laryngoscopy Blade Preference: The trainees were asked to record their usual/preferred laryngoscopy blade used for intubation. All subjects recorded their preference with 93% noting preference for the Mac blade and 7% indicating preference for the Miller blade.

Intubation Training Performance Data

Comparison of Cormack Lehane Airway Scores: In performing intubation on a cadaver airway using direct visualization of the airway, the average airway score recorded for the Storz VL was 1.54 (SD = 0.576) and for the C-MAC was 1.46 (SD = 0.637). Use of the videolaryngoscope slightly improved visualization of the standard airway as evidenced by an average airway score of 1.04 (SD = 0.189) for the Storz Video Laryngoscope; 1.25 (SD = 0.518) for the C-MAC; and 1.07 (SD = 0.262) for the GlideScope (**see Figure 7**).

Comparison of Success Rates of Intubation: Success in intubation of the standard airway using direct visualization was 93% versus a 100% success rate when intubating with indirect (VL) visualization when using the Storz Videolaryngoscope, Storz C-MAC, and the GlideScope.

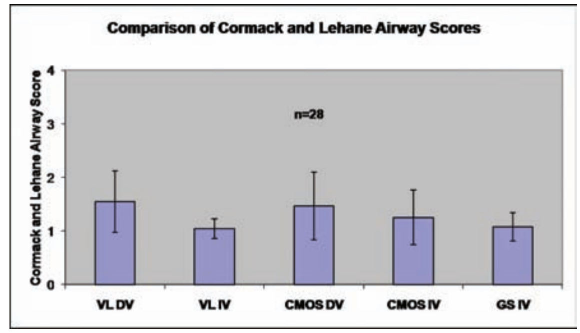

Figure 7. *A Comparison of Cormack and Lehane Airway Scores in Cadaver Airways using Direct View (DV) and Indirect View (IV): Storz Videolaryngoscope (VL), Storz C-MAC™, and GlideScope® (GS). (Average ± standard deviation)(Note-results from both cadavers are combined to give an n = 28).*

Comparison of Intubation Times: During the cadaver intubation study with direct view (standard) versus indirect view laryngoscopy, the subjects were timed to determine if there were any significant differences in the time required for successful intubation. The average direct view intubation time was 10.87 sec (SD = 8.657) for the Storz Video Laryngoscope and 8.96 (SD = 5.708) for the C-MAC as compared to the indirect view intubation time of 11.21 (SD = 9.293) for the Storz Video Laryngoscope, 11.51sec (SD = 7.293) for the C-MAC and 11.87sec (SD = 6.404) for the GlideScope (**see Figure 8**).

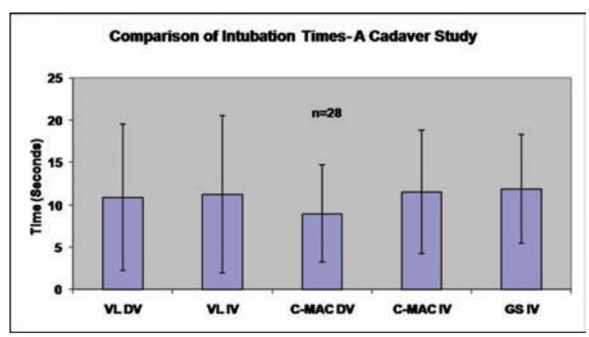

Figure 8. *A Comparison of Intubation Times: Direct View (DV) versus Indirect View (IV) in Standard and Difficult Airways (Cadaver Study). (Note: results from both cadavers are combined to give an n = 28).*

Post-Training Data

Preference for Using the Video Laryngoscope for Difficult Airway Intubation: After the study subjects completed the hands-on cadaver comparison using standard laryngoscopy versus the videolaryngoscope, they were asked to record their preference of technique in difficult airway intubations. The majority, 79%, (11/14) preferred using the video laryngoscope in intubations of the difficult airway (**see Figure 9**).

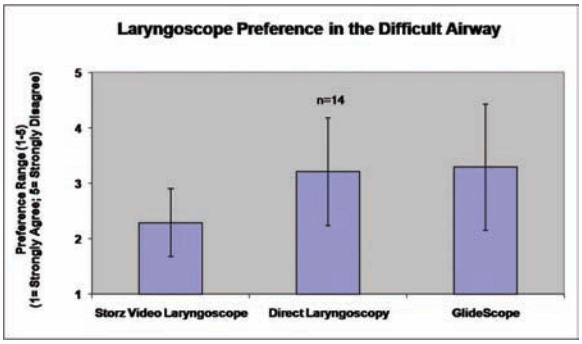

Figure 9. *Trainees' Laryngoscope Preference for Difficult Airway Intubation.*

Ease of Visualization: After the hands-on training session, the subjects were asked which laryngoscopic technique provided the easiest visualization of the glottic opening. Sixty-two percent indicated the GlideScope; 23 % chose the CMAC and 15 % the standard laryngoscope.

Overall Preference for Intubation Technique: The subjects were asked to indicate their preference of intubation technique. Fifty percent of respondents indicated they preferred the GlideScope, while 29% preferred the C-MAC and 21% the video laryngoscope (**see Figure 10**).

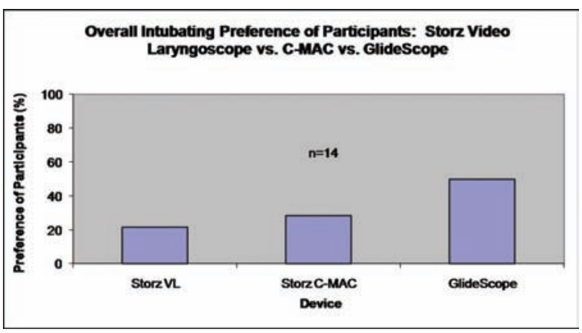

Figure 10. *Trainees' Overall Preference of Laryngoscopic Technique.*

Discussion

For this study, we chose the lightly embalmed cadaver model as they were part of a standard cadaver lab performed annually at the university for EM residents. This model provides great training value to medical students and residents as a step prior to human experience. No simulator yet has the high fidelity as provided by these lightly embalmed cadaver models.

The video laryngoscope is a valuable training tool for intubation training as confirmation of the trainee's correct placement of the endotracheal tube in the trachea can be monitored by the investigator by viewing the video monitor during both direct and indirect intubation attempts. The Storz Telepack and CMAC video laryngoscopes were used for both the direct and indirect intubations. Given the shape of the GlideScope blade, the GlideScope was used only for indirect intubation.

Fifty percent of participants had intubation experience of 30+ patients. In examining the relationship of the trainees experience and recorded airway grades, we found no correlation. However, there is a correlation between pre-training intubation confidence level and years of experience. There is also a direct correlation between confidence level and patient intubation experience. The more intubation experience translates into higher confidence level in intubating a patient with normal airway.

Strengths of the study - An evident strength to our study was the high intubation success rate for study subjects. This success rate not only identified that lightly embalmed cadavers are a feasible alternative to other types of intubation models such as fresh frozen cadavers and human simulators. As well, the high success rate demonstrated that a range of relatively inexperienced to experienced intubators could effectively utilize two different forms of videolaryngoscopy.

Weaknesses of the study - A possible weakness in our study might be that we did not record a post-training confidence level in intubation for comparison to the pre-training confidence level. It would have been valuable to discern if there was a post-training effect on confidence in intubation for those who had little intubation experience. However, it would have been difficult to differentiate if the increased confidence was due to the training and experience effect, or due to the new instrumentation.

Another problem we discovered is that the lightly embalmed cadavers did not provide us with a true difficult airway for comparison of devices. The necks of the lightly embalmed cadavers were extremely flexible. It might have better served our purpose to have chosen cadavers with pre-determined easy and difficult airways for this intubation study. If a "difficult airway cadaver" is unavailable, we could fit a cervical neck brace on a cadaver to create a difficult airway.

Context-Pre-hospital and emergency department airway management may involve clinical or scene-related factors as well as patient anatomic features that may preclude endotracheal intubation by direct laryngoscopy, requiring pre-hospital and emergency department healthcare providers to incorporate rescue airway devices into their clinical approach to any patient requiring emergent airway management. The optimal rescue airway device must combine ease of use and training with device-related features that effectively address pre-hospital/ED factors frequently resulting in difficult or impossible glottic visualization by direct laryngoscopy.

Our study demonstrates the ease of use of the study devices as well as the brief training required to achieve proficiency in the use of the Storz Medi Pack Mobile Imaging System, the Storz C-MAC and the GlideScope. Our subjects received only a brief instructional presentation prior to using the study devices, but all subjects successfully performed tracheal intubation of the cadavers. Following completion of the study, 79% reported a preference for the video-assisted systems over direct laryngoscopy, further substantiating the ease of use of the study devices.

Intubation by direct laryngoscopy is a skill that is difficult to learn and maintain.[44] Devices not routinely used in clinical practice must not require complex psychomotor skills and/or extensive training or the skills necessary for proficiency will not be retained. In our study, the Storz Medi Pack Mobile Imaging System, the Storz C-MAC and the GlideScope required minimal training and skills were readily acquired by healthcare providers with a varying degree of direct laryngoscopy experience. The blade of the Storz video laryngoscopes have the same shape as a standard Macintosh blade, and therefore is easy to use and easier to maintain one's intubation skills. The portability of the Storz C-MAC and GlideScope make them the choice equipment for practitioners who are deploying out-of-hospital with limited storage space (*i.e*. paramedics, military medics, etc.). However, one advantage that the Storz C-MAC has over the GlideScope is that it can function as a direct laryngoscope allowing the intubator to immediately switch to indirect laryngoscopy if a difficult airway is encountered or perhaps revert back to direct laryngoscopy if blood or airway secretions disable the optics. Subsequently, the traditional Macintosh blade could theoretically be replaced by the Storz C-MAC with only the addition of a small monitor/battery pack.

One common pre-hospital/ED clinical scenario that often results in poor laryngoscopic views of the glottis is the patient with possible cervical spine injury.[45-46] Cervical spine immobilization with a cervical collar or by in-line stabilization prevents the extension of the head necessary to align the oral and pharyngeal axis potentially impacting the intubator's ability to obtain an optimal glottic view. Studies demonstrating improved glottic visualization with the GlideScope versus direct laryngoscopy using a Macintosh 3 blade in patients with cervical spine immobilization by cervical collar suggest the potential role of the GlideScope or other video-assisted systems as rescue devices in this common pre-hospital/ED scenario.[43,46]

In the prehospital setting, various scene-related factors may impair the paramedic, medic or EMT's ability to achieve direct line-of-sight view of the glottic opening. Optimal positioning of the patient and intubator for direct laryngoscopy may not be possible for a patient entrapped in the wreckage of vehicle. The GlideScope ranger was studied in simulated entrapped manikins. Nakstad et al., showed that a physician intubator could intubate the entrapped manikin 100% of the time.[47] However, when using the direct laryngoscope, the entrapped manikins were only successfully intubated 50% of the time.[47] The Storz Medi Pack Mobile Imaging System, the Storz C-MAC and the GlideScope provide adequate laryngeal views for successful tracheal intubation without the requirement for standard patient and intubator positioning.[48] The complexities of dealing with an airway emergency are significantly increased in an active combat arena. The medic not only has to consider optimizing treatment for the patient, but he or she has to adhere to the tenants of *Tactical Combat Casualty Care* (TCCC)[49] which may require first returning fire, controlling hemorrhage, and then moving the patient to a secondary safe position where the airway can be definitively secured. However even in this secondary position, the medic may not recognize or be able to secure the airway prior to evacuation due to active combat operations. During Operation IRAQI FREEDOM, Brennan et al. experienced that 10% of their patients presented with emergent airway compromise requiring immediate endotracheal intubation, cricothyroidotomy, or tracheotomy.[50] Perhaps, it is during this time period where the patient is handed off and enters a more controlled environment such as with 352nd Special Operations Support Squadron/ Detachment 1, Air Force Special Operations Command. At this point, the VL technology could be deployed to secure the airway. Prior studies have demonstrated the effectiveness of the Storz C-MAC and GlideScope in aircraft ambulances.[48, 51]. However, if the patient's airway has not been secured during aero medical evacuation to a Special Operations Surgery field hospital, then a VL device may assist intubation at the hospital. Tong identified that traditional fiberoptic intubating scopes are unavailable in United Kingdom field hospitals but that a VL device such as the AirTraq® optical laryngoscope is needed to manage combat airways.[52] Our team is currently assisting the NATO Special Operations MEDDAC to configure a deployable field hospital that will have this tool and capability incorporated into it. A modification of the CMAC monitor will also interface with other surgical optical instruments through a Battlefield Telemedicine System (BTS) providing worldwide projection to any tertiary care site. The current model may have limited use by a field medic except to enhance orotracheal intubation training, although, no studies have been performed with this equipment in a live combat scenario. But if the field medic places a supraglottic airway, that device could be removed before intubation when the patient reaches the hospital. This device, such as a laryngotracheal tube, could allow intubation with an endotracheal tube while leaving the laryngeal tube in place, further enhancing safety. This scenario is seen essentially daily in our trauma center. As well, Navy Seal Medics and Reconnaissance combat corpsmen have demonstrated that the use of supraglottic airway devices in simulated combat settings is feasible and effective.[53]

Prior studies identified increased time to intubation as a possible limitation associated with the use of the GlideScope®.[54-57] Although time to intubation was less for direct laryngoscopy than for video-assisted intubation, there was no statistically significant difference in our study. Furthermore, our subjects were unfamiliar with the study devices prior to the brief instructional session and would likely develop increased efficiency in their use with training. This is consistent with a prior study by Wayne et al.[58] In this study, paramedic VL intubation times were slightly longer; however, intubation attempts were reduced and successful intubation rates were 97% successful. This is in comparison to another study by Wang et al.[59] in which overall paramedic DL intubation success rate was 77%. Of note, 88 cricothyroidotomies were performed with 95% of these patients developing major bleeding complications.[59] This surgical complication rate highlights that even though the cricothyroidotomy is a simple procedure, it also has an associated learning curve which is even evident amongst a group of continually trained helicopter service medics.[60]

Our ideas for future studies include: 1) utilizing the cadavers as difficult airway cadaver by restricted neck movement with c-collar; 2) assessing the viability of manikins versus lightly embalmed cadavers; 3) measuring both pre- and post- intubation confidence; 4) assessing live intubation following cadaver lab and incorporate results into a study; 5) assessing the training curve in military medics; and 6) deploying our VL technology in a simulated field combat setting.

Conclusion

Based on our data, we believe that the incorporation of video laryngoscopy into cadaver airway management training provides an improved learning environment for trainees. Our residents had greatly improved intubation success rates with respect to other studies. Konrad et al. demonstrated that 1st year anesthesia residents required 57 orotracheal intubation on humans before they were 90% successful at direct laryngoscopy.[20] In our cadaver study, our resident study subjects were 93% successful even though 50% had less than 30 intubations. One can speculate that the addition of videolaryngoscopy may have had an overall positive effect on the learning curve for direct laryngoscopy. The improved learning curve for direct laryngoscopy was evident in other studies incorporating videolaryngoscopy.[44]

The intubation success rate for videolaryngoscopy was 100% in our study. Although this number seems high, it is not uncommon since prior studies have exhibited 95% to 100% success rate when utilizing videolaryngoscopy.[61] Once again, we have demonstrated that VL is a technology which can be easily learned and effectively performed. The study subjects' overwhelming preference for VL may reflect the study subjects' confidence in this technology's ability to perform in difficult airway situations (which are normally perceived as extremely difficult when using traditional direct laryngoscopy).

Currently there are minimal studies in the military or medical literature regarding the implementation of VL technology for provider training or difficult airway management. However, in the civilian world, this technology is rapidly becoming a standard piece of equipment in a difficult airway cart as well as a standard addition to orotracheal intubation training. In military combat settings, a provider needs to have access to the best equipment and training in order to manage difficult airways in this difficult environment. Since combat casualty care dramatically differs from civilian trauma care, future studies are necessary to help identify the best fit for this new technology in the combat arena.

Though no questions were presented to the study subjects regarding the preferred use of the lightly embalmed cadavers as an airway simulator, the researchers noted the lightly embalmed cadavers provided a more realistic airway model than manikins. This is consistent with Dr Yang's study where intubators preferred the fresh frozen cadaver to airway manikins.[41]

In conclusion, it is our thought that this lightly embalmed cadaver model incorporated with VL is a powerful tool which may help improve the overall learning curve for orotracheal intubation. We believe our study subjects received the benefit of high impact training for direct laryngoscopy as well as gained the psychomotor skills needed to perform VL in a grade II airway. This improved their perceived confidence in dealing with future difficult airways and perhaps allowing them to add one more tool to their difficult airway algorithm.

Disclaimer

These views represent those of the author and are not necessarily intended to represent the views of the University of Nebraska Medical Center or the Department of Veterans Affairs.

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References

1. Holcomb, J. B., McMullin, N. R., Pearse, L., Caruso, J., Wade, C. E., Oetjen-Gerdes, L., et al. (2007). Causes of death in U.S. Special Operations Forces in the global war on terrorism: 2001–2004. *Annals of Surgery*, 245(6):986.

2 Kelly, J. F., Ritenour, A. E., McLaughlin, D. F., Bagg, K. A., Apodaca, A. N., Mallak, C. T., et al. (2008). Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003-2004 versus 2006. *The Journal of Trauma,* 64(2):S21.

3. Garner, A., Rashford, S., Lee, A., Bartolacci, R. (1999). Addition of physicians to paramedic helicopter services decreases blunt trauma mortality. *Australian and .New Zealand Journal of Surgery*, 69:697-701.

4. Sanson, G., Di Bartolomeo, S., Nardi, G., Albanese, P., Diani, A., Raffin, L., Filippetto, C., Cattarossi, A., Scian, E., Rizzi, L. (1999). Road traffic accidents with vehicular entrapment: incidence of major injuries and need for advanced life support. *European Journal of Emergency Medicine,* 6(4):285.

5. Winchell, R.J., Hoyt, D.B., Moore, E.E. (1997). Endotracheal intubation in the field improves survival in patients with severe head injury. *Archives of Surgery*, 132(6):592-597.

6. Bradley, J., Billows, G., Olinger, M., Boha, S., Cordell, W., Nelson, D. (1998). Prehospital oral endotracheal intubation by rural basic emergency medical technicians. *Annals of Emergency Medicine*, 32(1):26-32.

7. Cormack, R. (2006). Failed intubation in obstetric anaesthesia. *Anaesthesia*, 61(5):505-506.

8. Koppel, J.N., Reed, A.P. (1995). Formal instruction in difficult airway management: A survey of anesthesiology residency programs. *Anesthesiology*, 83(6):1343-1346.

9. Leibowitz, A.B. (2006). Tracheal intubation in the intensive care unit: Extremely hazardous even in the best of hands. *Critical Care Medicine*, 34(9):2497.

10. Mason, R.A. (1998). Education and training in airway management. *British Journal of Anaesthesia*, 81(3):305-307.

11. Stewart, R.D., Paris, P.M., Pelton, G.H., Garretson, D. (1984). Effect of varied training techniques on field endotracheal intubation success rates. *Annals of Emergency Medicine*, 13(11):1032-1036.

12. Underwood, S., McIndoe, A. (2005). Influence of changing work patterns on training in anaesthesia: an analysis of activity in a UK teaching hospital from 1996 to 2004. *British Journal of Anaesthesia*, 95(5):616-621.

13. Goldhill, D.R., Cook, T.M., Waldmann, C.S. (2009). Airway incidents in critical care, the NPSA, medical training and capnography. *Anaesthesia*, 64(4):354-357.

14. Stringer, K., Bajenov, S., Yentis, S. (2002). Training in airway management. *Anaesthesia*, 57(10):967.

15. Owen, H., Plummer, J.L. (2002). Improving learning of a clinical skill: The first year's experience of teaching endotracheal intubation in a clinical simulation facility. *Medical Education*, 36(7):635-642.

16. Sayre, M., Sakles, J., Mistler, A., Evans, J., Kramer, A., Pancioli, A. (1998). Field trial of endotracheal intubation by basic EMTs. *Annals of Emergency Medicine*, 31(2):228-233.

17. Spaite, D. (1998). Intubation by basic EMTs: Lifesaving advance or catastrophic complication? *Annals of Emergency Medicine*, 31(2):276-277.

18. Jaber, S., Amraoui, J., Lefrant, J.Y., Arich, C., Cohendy, R., Landreau, L., Calvet, Y., Capdevila, X., Mahamat, A., Eledjam, J.J. (2006). Clinical practice and risk factors for immediate complications of endotracheal intubation in the intensive care unit: A prospective, multiple-center study. (2006). *Critical Care Medicine*, 34(9):2355.

19. Adnet, F., Lapostolle, F., Ricard-Hibon, A., Carli, P., Goldstein, P. (2001). Intubating trauma patients before reaching hospital — revisited. *Critical Care*, 5(6):290-291.

20. Konrad, C., Schupfer, G., Wietlisbach, M., Gerber, H. (1998). Learning manual skills in anesthesiology: Is there a recommended number of cases for anesthetic procedures? *Anesthesia & Analgesia,* 86(3):635.

21. Mulcaster, J.T., Mills, J., Hung, O.R., MacQuarrie, K., Law, J.A., Pytka, S., Imrie, D., Field, C. (2003). Laryngoscopic intubation: learning and performance. *Anesthesiology,* 98(1):23-27.

22. Helm, M., et al. (2006). Factors influencing emergency intubation in the pre-hospital setting- a multicentre study in the German Helicopter Emergency Medical Service. *British Journal of Anaesthesia* 96(1):67-71.
23. Hussain, L., Redmond, A. (1994). Are pre-hospital deaths from accidental injury preventable? *British Medical Journal*, 308:1077-1080.
24. Nicholl, J., Hughes, S., Dixon, S. (1998). The costs and benefits of paramedic skills in pre-hospital trauma care. *Health Technology Assessment*, 2:10-15.
25. Mort, T. (1998). Unplanned tracheal extubation outside the operating room: a quality improvement audit of hemodynamic and tracheal airway complications associated with emergency tracheal reintubation. *Anesthesia & Analgesia*, 86(6):1171-1176.
26. Miller, C.G. (2000). Management of the difficult intubation in closed malpractice claims. *ASA Newsletter,* 64(6):13-16 & 19.
27. Sakles, J.C., Laurin, E.G., Rantapaa, A.A., Panacek, E.A. (1998). Airway management in the emergency department: a one-year study of 610 tracheal intubations. *Annals of Emergency Medicine*, 31(3):325-332.
28. Sagarin, M.J., Barton, E.D., Chng, Y.M., Walls, R.M; (on behalf of the National Emergency Airway Registry (NEAR) Investigators) (2005). Airway management by U.S. and Canadian emergency medicine residents: A multicenter analysis of more than 6,000 endotracheal intubation attempts. *Annals of Emergency Medicine*, 46(4):328-336.
29. Jones, J.H., Murphy, M.P., Dickson, R.L., Somerville, G.G., Brizendine, E.J. (2004). Emergency physician-verified out-of-hospital intubation: Miss rates by paramedics. *Academic Emergency Medicine,* 11(6):707-709.
30. Thomas, S.H., Harrison, T., Wedel, S.K. (1999). Flight crew airway management in four settings: A six-year review. *Prehospital Emergency Care,* 3(4):310-315.
31. Pratt, J.C., Hirshberg, A.J. (2005). Endotracheal tube placement by EMT-basics in a rural EMS system. *Prehospital Emergency Care*, 9(2):172-175.
32. Benjamin, F.J., Boon, D., French, R.A. (2006). An evaluation of the GlideScope, a new video laryngoscope for difficult airways: A manikin study. *European Journal of Anaesthesiology*, 23:517-521.
33. Lim, T.J., Lim, Y., Liu, E.H. (2005). Evaluation of ease of intubation with the GlideScope or Macintosh laryngoscope by anaesthetists in simulated easy and difficult laryngoscopy. *Anaesthesia,* 60(2):180-183.
34. Boedeker, B.H., Hoffman, S., Murray, W.B. (2007). Endotracheal intubation training using virtual images: Learning with the mobile telementoring intubating video laryngoscope. *Studies in Health Technology and Informatics* 125:49-54.
35. Gaiser, R.R. (2000). Teaching airway management skills: How and what to learn and teach. *Critical Care Clinics*, 16(3):515-25.
36. Kaplan, M.B., Ward, D.S., Berci, G. (2002). A new video laryngoscope – an aid to intubation and teaching. *Journal of Clinical Anesthesia*, 14(8):620-626.
37. Kaplan, M.B., Ward, D., Hagberg, C.A., Berci, G., Hagiike, M. (2006) Seeing is believing: the importance of video laryngoscopy in teaching and in managing the difficult airway. *Surgical Endoscopy*, 20 Suppl 2:S479-S483.
38. Levitan, R.M., Ochroch, E.A., Stuart, S., Hollander, J.E. (2000). Use of the intubating laryngeal mask airway by medical and nonmedical personnel. *American Journal of Emergency Medicine*, 18(1):12-16.
39. Plummer, J.L., Owen, H. (2001). Learning endotracheal intubation in a clinical skills learning center: a quantitative study. *Anesthesia & Analgesia*, 93(3):656-662.
40. Berg, B.W., Vincent, D.S., Murray, W.B., Boedeker, B.H. (2009). Videolaryngoscopy for intubation skills training of novice military airway managers. *Studies in Health Technology and Informatics*, 142:34-36.
41. Yang, J., Kim, Y., Chung, H., Cho, J., Lee, H., Kang, G., Kim, E., Lim, T., Cho, Y. (2010). Comparison of four manikins and fresh frozen cadaver models for direct laryngoscopic orotracheal intubation training. *Emergency Medicine Journal*, 27(1):13.
42. Anderson, S.D. (2006). Practical light embalming technique for use in the surgical fresh tissue dissection laboratory. *Clinical Anatomy,* 19(1):8-11.
43. Low, D., Healy, D., Rasburn, N. (2008). The Use of the Berci DCI® Videolaryngoscope for teaching novices direct laryngoscopy and tracheal intubation. *Anaesthesia*, 63:195-201.
44. Maharaj, C.H., Costello, J.F., Higgins, B.D., Harte, B.H., Laffey, J.G. (2006). Learning and performance of tracheal intubation by novice personnel: A comparison of the Airtraq and Macintosh laryngoscope. *Anaesthesia,* 61:671-677.
45. Agrò, F., Barzoi, G., Montecchia, F. (2003). Tracheal intubation using a Macintosh laryngoscope or a GlideScope in 15 patients with cervical spine immobilization. *British Journal of Anaesthesia*, 90(5):705-706.
46. Robitaille, A., Williams, S.R., Tremblay, M.H., Guilbert, F., Theriault, M., Drolet, P. (2008). Cervical spine motion during tracheal intubation with manual in-line stabilization: Direct laryngoscopy versus GlideScope videolaryngoscopy. *Anesthesia & Analgesia*, 106(3):935-941.
47. Nakstad, A., Sandberg, M. (2009). The GlideScope Ranger® video laryngoscope can be useful in airway management of entrapped patients. *Acta Anaesthesiologica Scandinavica*, 53(10):1257-1261.
48. Boedeker, B.H., Berg, B.W., Bernhagen, M., Murray, W.B. (2009). Endotracheal intubation in a medical transport helicopter-comparing direct laryngoscopy with the prototype Storz CMAC videolaryngoscope in a simulated difficult intubating position. *Studies in Health Technology Informatics,* 142:40-42.
49. Butler, F., Haymann, J., & George Butler, E. (1996). Tactical combat casualty care in special operations. *Military Medicine*, 161(Suppl 1):3-16.
50. Brennan, J., Gibbons, M. D., Lopez, M., Hayes, D., Faulkner, J., Eller, R. L., et al. (2011). Traumatic airway management in operation Iraqi freedom. *Otolaryngology—Head and Neck Surgery,* 144(3):376.
51. Boedeker, B.H., Berg, B.W., Bernhagen, M.A., Murray, W.B. (2009). Endotracheal intubation comparing a prototype Storz CMAC and a GlideScope videolaryngoscope in a medical transport helicopter – A pilot study. *Studies in Health Technology and Informatics,* 142:37-39.
52. Tong, J. (2007). The management of difficult direct laryngoscopy and intubation in a field hospital: An alternative to fibreoptic endoscopy. *JR Army Med Corps,* 153(3):181-183.
53. Calkins, M., Robinson, T. (1999). Combat trauma airway management: Endotracheal intubation versus laryngeal mask airway versus combitube use by navy SEAL and reconnaissance combat corpsmen. *The Journal of Trauma,* 46(5): 927.
54. Sun, D.A., Warriner, C.B., Parsons, D.G., Klein, R., Umedaly, H.S., Moult, M. (2005). The GlideScope video laryngoscope: Randomized clinical trial in 200 patients. *British Journal of Anaesthesia,* 94(3):381-384.
55. Cooper, R.M., Pacey, J.A., Bishop, M.J., McCluskey, S.A. (2005). Early clinical experience with a new videolaryngoscope (GlideScope©) in 728 patients. *Canadian Journal of Anesthesia*, 52(2):191-198.

56. Biro, P., Weiss, M. (2001). Comparison of two video-assisted techniques for the difficult intubation. *Acta Anaesthesiologica Scandinavica*, 45:761-765
57. Kaplan, M.B., Hagberg, C.A., Ward, D.S., Brambrink, A., Chhibber, A.H., Heidegger, T., Lozada, L.,et al. (2006). Comparison of direct and video-assisted views of the larynx during routine intubation. *Journal of Clinical Anesthesia*, 18:357-362.
58. Wayne, M.A., McDonnell, M. (2010). Comparison of traditional versus video laryngoscopy in out-of-hospital tracheal intubation. *Prehospital Emergency Care*, 14(2):278-282.
59. Wang, H.E., Mann, N.C., Mears, G., Jacobson, K., Yealy, DM. (2011). Out-of-hospital airway management in the United States. *Resuscitation,* 82(4):378-385.
60. Robinson, K. J., Katz, R., & Jacobs, L. M. (2001). A 12-year experience with prehospital cricothyrotomies. *Air Medical Journal*, 20(6):27-30.
61. Nouruzi-Sedeh, P., Schumann, M., Groeben, H. (2009). Laryngoscopy via Macintosh blade versus GlideScope: Success rate and time for endotracheal intubation in untrained medical personnel. *Anesthesiology*, 110(1):32-37.

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