ORIGINAL RESEARCH

Airway Management in Disaster Response: A Manikin Study Comparing Direct and Video Laryngoscopy for Endotracheal Intubation by Prehospital Providers in Level C Personal Protective Equipment

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PPE: personal protective equipment
TTI: time to intubation
VAS: visual analog scale

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Abstract

Introduction: Airway management is one of many challenges that medical providers face in disaster response operations. The use of personal protective equipment (PPE), in particular, was found to be associated with higher failure rates and a prolonged time to achieve airway control.

Hypothesis/Problem: The objective of this study was to determine whether video laryngoscopy could facilitate the performance of endotracheal intubation by disaster responders wearing Level C PPE.

Methods: In this prospective, randomized, crossover study, a convenience sample of practicing prehospital providers were recruited. Following standardized training in PPE use and specific training in the use of airway devices, subjects in Level C PPE were observed while performing endotracheal intubation on a stock airway in a Laerdal Resusci-Anne manikin system (Laerdal Medical; Stavanger, Norway) using one of three laryngoscopic devices in randomized order: a Macintosh direct laryngoscope (Welch Allyn Inc.; New York USA), a GlideScope Ranger video laryngoscope (Verathon Medical; Bothell, Washington USA), and a King Vision video laryngoscope (King Systems; Noblesville, Indiana USA). The primary outcome was time to intubation (TTI), and the secondary outcome was participant perception of the ease of use for each device.

Results: A total of 20 prehospital providers participated in the study: 18 (90%) paramedics and two (10%) Emergency Medical Technicians-Cardiac. Participants took significantly longer when using the GlideScope Ranger [35.82 seconds (95% CI, 32.24-39.80)] to achieve successful intubation than with the Macintosh laryngoscope [25.69 seconds (95% CI, 22.42-29.42); adj. $P < .0001$] or the King Vision [29.87 seconds (95% CI, 26.08-34.21); adj. $P = .033$], which did not significantly differ from each other (adj. $P = .1017$). Self-reported measures of satisfaction evaluated on a 0% to 100% visual analog scale (VAS) identified marginally greater subject satisfaction with the King Vision [86.7% (SD = 76.4-92.9%)] over the GlideScope Ranger [73.0% (SD = 61.9-81.8%); $P = .04$] and the Macintosh laryngoscope [69.9% (SD = 57.9-79.7%); $P = .05$] prior to adjustment for multiplicity. The GlideScope Ranger and the Macintosh laryngoscope did not differ themselves ($P = .65$), and the differences were not statistically significant after adjustment for multiplicity (adj. $P = .12$ for both comparisons).

Conclusion: Use of video laryngoscopes by prehospital providers in Level C PPE did not result in faster endotracheal intubation than use of a Macintosh laryngoscope. The King Vision video laryngoscope, in particular, performed at least as well as the Macintosh laryngoscope and was reported to be easier to use.

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Introduction

Background

Airway management is one of many challenges that medical providers face in disaster response operations.[1] Whether at the scene of the incident, the decontamination area, or in a hospital setting, disaster responders may encounter patients in need of airway intervention. Achieving airway control is always critical and time sensitive. The suboptimal conditions and personal safety concerns surrounding disaster response can make this process complex and time consuming, transforming a routine procedure into a challenge for disaster responders.

The use of personal protective equipment (PPE) is often necessary to ensure provider safety. This has been demonstrated in many disasters around the world, including the 1994 Sarin gas release in Tokyo (Japan) and the 2001 SARS epidemic in Toronto (Canada).[2,3] Nevertheless, the use of PPE has been shown to affect responders' ability to provide medical care for disaster victims. Many studies examined the impact of PPE use on resuscitation efforts and the performance of high-dexterity skills.[4-6] Airway management, in particular, was found to be associated with higher failure rates and a prolonged time to achieve airway control.[7-10] Despite all of these issues, wearing PPE is still of paramount importance to sustain safety and to maintain the continuity of operations in a disaster response, as moderated by Occupational Safety and Health Administration (OSHA; Washington, DC USA) requirements for PPE set forth in the Code of Federal Regulations.

Importance

Since the introduction of the GlideScope (Verathon Medical; Bothell, Washington USA) in 2001, video laryngoscopy has gained wide popularity and acceptance in various fields of medicine, including critical care, anesthesia, emergency medicine, and Emergency Medical Services.[11-14] Many of the newer video laryngoscopes have overcome shortcomings and cost prohibitions of previous designs, and it has been speculated that video laryngoscopes will dominate the airway management field in the coming years.[15] The use of video laryngoscopy may prove beneficial for disaster responders wearing PPE, owing to advantages such as its short learning curve, improved glottis visualization, and reduced need for manipulation.[16-19] However, the use of these devices in the field of disaster medicine has not been widely explored.

Goal of this Investigation

This study was designed to compare the Macintosh laryngoscope (Welch Allyn Inc.; New York USA) with two video laryngoscopes using different techniques (Free Endotracheal Tube versus Preloaded Endotracheal Tube) to determine whether video laryngoscopy can facilitate the performance of endotracheal intubation by disaster responders wearing Level C PPE.

Materials and Methods

Study Design and Setting

A prospective, randomized, crossover study was utilized to compare the use of direct laryngoscopy with two video laryngoscopes by providers wearing Level C PPE. The study was conducted at the medical simulation center of a tertiary care hospital. The study was approved by the Lifespan – Rhode Island Hospital (Providence, Rhode Island USA) institutional board review (IRB), and all participants provided written informed consent.

Selection of Participants

A convenience sample of clinically active prehospital providers, with a minimum of two years' experience in airway management and who had medical clearance to use respiratory protection equipment, were enrolled. Participants who volunteered for the study were recruited during three scheduled regular training sessions. Any participant with a history of severe pulmonary disease, severe cardiac disease, uncontrolled hypertension, claustrophobia, or facial abnormalities that precluded an adequate mask fit was excluded from the study.

Interventions

Level C PPE consisted of DuPont (Wilmington, Delaware USA) protective clothing (Tychem CPF3 and Tyvek suits), butyl rubber gloves, boots, and PA301S Powered Air Purifying Respirators (Bullard; Cynthiana, Kentucky USA). The airway devices that were chosen for this study included a size-three blade Macintosh laryngoscope (Welch Allyn Inc.; New York USA), a size-three adult blade GlideScope Ranger (Verathon Medical; Bothell, Washington USA), and a size-three channeled blade King Vision VL (King Systems; Noblesville, Indiana USA). All intubations were performed on a Resusci-Anne manikin system (Laerdal Medical; Stavanger, Norway) set in "normal airway anatomy" mode and placed on a standard hospital gurney. All study participants received a 90-minute standardized training in PPE use and proper use of the airway devices on the day of the study provided by the principal investigator. The training session consisted of a lecture on PPE use, video demonstration of the two video laryngoscopes, and hands on training, in which each participant performed intubation while wearing Level C PPE and achieved at least one successful intubation with each video laryngoscope (Training Session Syllabus, Appendix 1; available online only).

Methods of Measurements

Study participants were enrolled in three sessions from January 2013 through March 2013. After obtaining consent and collecting background information on a research study form, each participant was asked to perform intubation on the Resusci-Anne manikin while wearing a Level C PPE, inflate the endotracheal tube cuff, and ventilate using a self-inflating bag. The participants performed intubations using all three devices in a pre-specified, computer-generated random sequence (Figure 1). The participants were allowed to attempt intubation until successful placement was achieved with no limits on time or number of trials. A 7.0-mm endotracheal tube with sufficient lubrication was used for all attempts. The participants used a semi-rigid stylet with the Macintosh and a GlideRite rigid stylet for the GlideScope Ranger. The King Vision has a guiding channel, requiring no stylet. A 10-mL syringe, an appropriate stylet, and a self-inflating bag were conveniently placed on the gurney prior to each attempt. Study investigators verified correct placement in each attempt by observing for adequate bilateral chest rise and performing five-point auscultation. If an attempt was deemed unsuccessful, it was confirmed by direct visualization. Following completion, the participants were given a survey to report their satisfaction with the ease of use for each device on a visual analog scale (VAS) from zero to 100, with zero being the worst and 100 being the best. All three sessions were video recorded, and the study investigators reviewed the recordings to determine the primary outcomes.

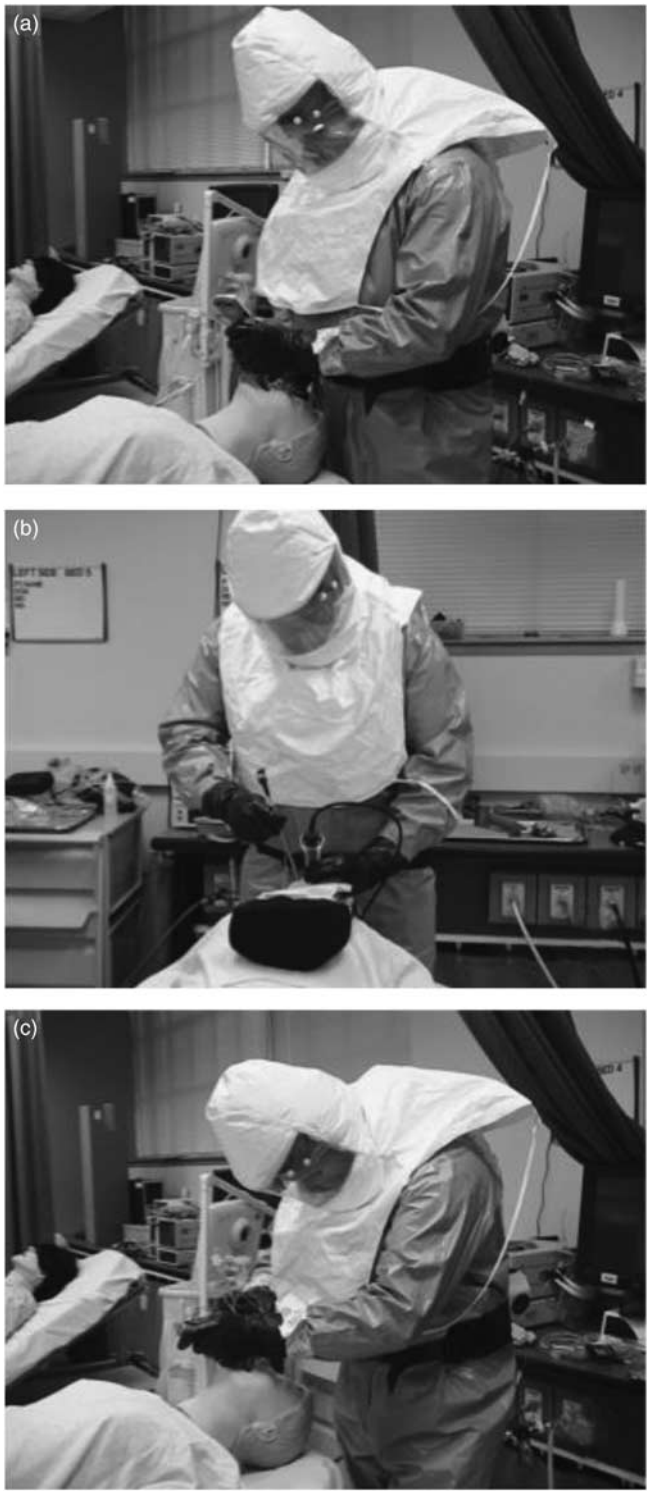

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Figure 1. Study Participant Preforming Intubation with **(a)** the King Vision VL, **(b)** the GlideScope Ranger, and **(c)** the Macintosh Laryngoscope.

Outcome Measures

The primary outcome was time to intubation (TTI). The TTI was defined as the time from insertion of the device in the mouth to a clearly visible chest rise of the manikin when ventilated, and failed attempts were defined as attempts in which the trachea was not intubated. The secondary outcome was participant satisfaction with the ease of use for each device.

Primary Data Analysis

A sample size of $n = 20$ was calculated to be sufficient to detect a 16-second difference with a power of at least 80%. This was based on an *a priori* power analysis for the "within-subjects" comparisons between the PPE conditions for each device and the differences between these effects for different devices approximated using a paired *t*-test. Alpha was conservatively adjusted for up to nine comparisons using a Bonferroni adjustment. The standard deviation used in the analysis was an equal weighting of previously observed values of 24 and seven second differences in prior studies,[7] in anticipation of the variance being related to the mean.

Generalized estimating equations (correlated residuals) were used to compare the within-subject changes in TTIs and satisfaction based on lognormal and binomial distributions, respectively. The latter modelled the location of the satisfaction scores rated on a VAS, which appropriately constrained the range of scores to fall between zero and one (100%). The variance-covariance matrices were structured as compound symmetric, with model misspecification compensated for using classical sandwich estimation. Pairwise comparisons between groups were carried out with alpha maintained across the three comparisons using the Holm test. Model parameters for groups were back-transformed to geometric means (TTI) and the percentage of the total range (satisfaction) and presented with their 95% confidence limits.

Results

Characteristics of Study Subjects

A total of $n = 20$ prehospital providers participated in the study, including 18 (90%) paramedics and two (10%) Emergency Medical Technicians-Cardiac. There were 19 (95%) men and one woman (5%), and the mean age of the participants was 41 years. All participants were medically cleared to wear respirators, trained to use Level C PPE, and had more than two years of experience in airway management. The median for prior number of intubations was 50 intubations, and participants had limited or no prior experience with the use of video laryngoscopes.

Main Results

Participants wearing Level C PPE took significantly longer to achieve successful intubation using the GlideScope Ranger [geometric mean = 35.82 seconds (95% CI, 32.24-39.80 seconds)] than using either the Macintosh laryngoscope [geometric mean = 25.69 seconds (95% CI, 22.42-29.42 seconds); adj. $P < .0001$] or the King Vision [geometric mean = 29.87 seconds (95% CI, 26.08-34.21 seconds); adj. $P = .033$], which did not significantly differ from each other (adj. $P = .1017$). There was one (5.0%) unsuccessful first pass using the Macintosh laryngoscope (Table 1). Both video laryngoscopes had a first pass success rate of 100%. Self-reported measures of satisfaction evaluated on a VAS ranging from zero to 100 indicated a marginally significant greater satisfaction with the King Vision [mean = 86.7% of VASmax (95% CI, 76.4-92.9%)] over both the GlideScope Ranger (mean = 73.0% of VASmax (95% CI, 61.9-81.8%); $P = .04$) and the Macintosh laryngoscope (mean = 69.9% of VASmax (95% CI, 57.9-79.7%); $P = .05$) prior to adjustment for multiplicity. The GlideScope Ranger and the Macintosh laryngoscope did not differ themselves ($P = .6472$), and the differences were not statistically significant after adjustment for

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Parameter Assessed	MAC (n = 20)	GLS-R (n = 20)	KV (n = 20)
TTI [Mean (95% CI)]	25.69 seconds (22.4-29.4)	35.82 seconds (32.2-39.8)	29.87 seconds (26.1-43.2)
Satisfaction (Mean %)	69.9%	73.0%	86.7%

Table 1. Comparison between Laryngoscopes
Abbreviations: GLS-R, GlideScope Ranger; KV, King Vision video laryngoscope; MAC, Macintosh laryngoscope; TTI, time to intubation.

multiplicity (adj. P = .1197 for both comparisons). However, it should be noted that a ceiling effect for satisfaction might have contributed to the failure to conclusively detect the difference in satisfaction as all groups were in the upper-half of the range and the King Vision scores approached the maximum.

Discussion

In this study, the use of video laryngoscopy did not show any time benefit over the use of the Macintosh laryngoscope when used by experienced prehospital providers wearing Level C PPE. While there was no significant difference in the intubation time between the Macintosh laryngoscope and the King Vision VL, the use of the GlideScope Ranger resulted in a significantly slower intubation time. Both video laryngoscopes demonstrated an improved satisfaction with the ease of use, with the King Vision VL ranking the highest in terms of self-reported satisfaction.

To date, tracheal intubation remains the preferred method of achieving airway control in the field and in hospital settings. Several studies have focused on the use of Laryngeal Mask Airway as an alternative means of controlling the airway by providers operating in PPE, and these studies support their use.[6] This is mainly because of the ease of use of these devices and the improved success rate. Nevertheless, the use of supraglottic airways is considered a temporary measure, and it was found to be associated with worse neurological outcomes and decreased survival to hospital discharge compared to tracheal intubation in out-of-hospital cardiac arrest.[20,21] In this study, the role of video laryngoscopy in achieving airway control in these settings was examined and found to be a more reasonable alternative.

The impact of PPE on the performance of airway management skills is well established in the literature. Studies report prolonged intubation times and a higher failure rate associated with the use of PPE.[6,7,22] However, this effect was not significant in this study, with only one intubation attempt exceeding 60 seconds. This may be due to a number of factors, including the controlled environment in which this study was conducted, the position of the manikin, and the familiarity of the study participant with PPE and field intubations. In a true disaster environment, this effect would of have been more pronounced with more consequences on airway management skills.

Additionally, in this study design, the Macintosh attempt served as the control attempt for each participant. Consequently, only participants experienced with direct laryngoscopy were enrolled. Combined with the normal airway anatomy of the manikin used in this study experience, this contributed to the faster TTIs reported in the Macintosh attempts. This is also consistent with the literature where improved intubation times with GlideScope are reported when used by non-experts or in difficult airways.[17]

The two video laryngoscopes used in this study share many features that might appeal to disaster responders. They are easy to operate, durable, portable, and have battery lives extending to 90 minutes. More importantly, both devices are operational outdoors and offer disposable blades. The GlideScope Ranger has a selection of blades that come in both adult and pediatric sizes. The King Vision has a mounted LCD screen incorporated on the handle of the device that eliminates the need to divert one's sight away from the airway. The King Vision also offers a blade with a guiding channel that facilitates a controlled insertion of the endotracheal tube, minimizing the manipulation required to achieve airway control and overcome the dexterity issues associated with wearing Level C PPE.

Video laryngoscopes with a guiding channel have consistently been superior in achieving airway control when compared with video laryngoscopes utilizing a rigid stylet for ETT insertion. In a head-to-head comparison between the Pentax Airway Scope and the GlideScope with 140 patients with normal airways, the Pentax Airway Scope was found to be more successful on the first attempt, it was less traumatic, and it required fewer optimization maneuvers.[23] In another study, the Airtraq performed better than the GlideScope, C-Mac, and the Macintosh laryngoscope with regard to intubation time, glottic opening, ease of intubation, and the need for external laryngeal pressure application.[24]

The evolving technology of video laryngoscopy offers many other advantages over direct laryngoscopy. Disposable blades can be of tremendous value in responding to epidemics and mass-causality incidents. Video recordings of intubations can be used for documentation and teaching purposes. Moreover, the recent work of Moiser and colleagues on Telemedicine and the introduction of Telebation, a remote airway management system using current wireless technologies, offers a unique application for video laryngoscopy in disaster response. Disaster responders operating in remote areas can utilize this model to virtually acquire assistance with difficult intubations from airway experts anywhere in the world and without them needing to be physically present at the disaster scene.

Emergency preparedness and disaster training cannot be emphasized enough in the face of raising numbers of disasters, epidemics, and the threat of terrorism. Airway management in the context of PPE use is a unique challenge for a disaster responder that requires further attention. Future research in this area should focus on establishing guidelines, standardizing airway management training, and integrating available technologies in disaster response. The choice of intubation technique and equipment used will be dictated by the situation. Airway compromise with

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secretions or blood, anatomic distortions secondary to trauma or swelling, and many other circumstances will enter into the appropriate selection of technique and equipment to secure an airway. The data from this study show that video laryngoscopy may be added to armamentarium of choices.

Limitations

This study was performed in a simulated environment on an airway manikin with "normal anatomy" settings, which does not resemble the distractions, chaos, and patient variations encountered in real-life disasters. However, as with many other aspects of disaster medicine, conducting prospective studies is often not feasible and can be associated with many obstacles.

With regard to the choice of participants, the authors acknowledge that disaster medical responders come from various medical disciplines. This study attempted to recruit a homogenous sample of participants and only experienced prehospital providers were enrolled. The reason for this choice was this group's familiarity with the use of PPE and field intubations.

Finally, the majority of study participants had intensive training and experience with the use of direct laryngoscopy and limited or no experience with the use of video laryngoscopy. They were given the chance to practice with the study devices to achieve only a single successful intubation. If the participants received the same training with video laryngoscopy as they did with direct laryngoscopy, it is reasonable to assume that their intubation times would improve. Thus, the results of this study cannot be extrapolated to novice clinicians or providers with greater video laryngoscopy experience.

Conclusion

The use of video laryngoscopes by prehospital providers in Level C PPE did not result in faster endotracheal intubation than the use of the Macintosh laryngoscope. The King Vision video laryngoscope, in particular, performed at least as well as the Macintosh laryngoscope and was reported to be easier to use.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X17000188

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