Tracheal intubation during chest compressions using Pentax-AWS[®], GlideScope[®], and Macintosh laryngoscope: a randomized crossover trial using a mannequin

Intubation trachéale avec le Pentax-AWS[®], le GlideScope[®] et le laryngoscope Macintosh pendant des compressions thoraciques: une étude croisée randomisée sur un mannequin

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Abstract

Background A randomized crossover trial was conducted to compare the performance of two videolaryngoscopes (Pentax-AWS[®], GlideScope[®]) with the Macintosh laryngoscope for tracheal intubation during continuous chest compressions on a mannequin.

Methods Thirty-two inexperienced junior interns performed tracheal intubations on an advanced life support simulator with either a normal or difficult airway scenario. The sequence of intubating devices and airway difficulty were randomized. The following data were measured and recorded: time to complete tracheal intubation (primary end point), overall success rate, time to visualize the vocal cords, percentage of glottic opening, dental compression, and ease of intubation.

Results With a normal airway, the times (median [interquartile range]) to complete tracheal intubation were shorter with the Pentax-AWS (12.1 [10.1–14.4] sec) and the GlideScope (14.3 [12.4–17.6] sec) than with the Macintosh laryngoscope (16.5 [13.1–22.1] sec) ($P < 0.03$ for both). The time difference between the two videolaryngoscopes was not statistically significant. With a difficult airway scenario, the times to complete tracheal intubation were 13.9 [10.9–20.4] sec, 19.2 [16.4–32.3] sec, and 30.1 [21.0–56.5] sec, respectively ($P < 0.05$ for all differences). The videolaryngoscopes were also more effective than the Macintosh laryngoscope with respect to secondary outcomes.

Conclusions The two videolaryngoscopes were superior to the Macintosh laryngoscope in terms of performing tracheal intubation during continuous chest compressions on a mannequin. In a difficult airway scenario simulating cardiac arrest, the Pentax-AWS performed better than the GlideScope.

Résumé

Contexte Une étude croisée randomisée a été réalisée afin de comparer la performance de deux vidéolaryngoscopes (Pentax-AWS[®], GlideScope[®]) et du laryngoscope Macintosh pour l'intubation trachéale pendant des compressions thoraciques continues sur un mannequin.

Méthode Trente-deux résidents sans expérience ont réalisé des intubations trachéales sur un simulateur de réanimation avancée dans des scénarios de voies aériennes normales ou difficiles. Les dispositifs d'intubation et la difficulté des voies aériennes ont suivi un ordre d'apparition aléatoire. Les données suivantes ont été mesurées et enregistrées : temps jusqu'à intubation trachéale réussie (critère d'évaluation principal), taux de réussite global, temps jusqu'à visualisation des cordes vocales, pourcentage d'ouverture glottique, compression dentaire et facilité d'intubation.

Résultats Dans les cas de voies aériennes normales, les temps (moyenne [écart interquartile]) jusqu'à intubation trachéale étaient plus courts avec le Pentax-AWS (12,1 [10,1–14,4] sec) et le GlideScope (14,3 [12,4–17,6] sec) qu'avec le laryngoscope Macintosh (16,5 [13,1–22,1] sec) ($P < 0,03$ pour les deux). La différence de temps entre les deux vidéolaryngoscopes n'était pas significative d'un point de vue statistique. Dans les cas de voies aériennes difficiles, les temps jusqu'à intubation trachéale étaient de

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13,9 [10,9-20,4] sec, 19,2 [16,4-32,3] sec, et 30,1 [21,0-56,5] sec, respectivement ($P < 0,05$ pour toutes les différences). Les vidéolaryngoscopes étaient également plus efficaces que le laryngoscope Macintosh en ce qui touchait aux critères d'évaluation secondaires.

Conclusion Les deux vidéolaryngoscopes étaient supérieurs au laryngoscope Macintosh en termes de réalisation d'une intubation trachéale pendant des compressions thoraciques continues sur un mannequin. Dans un cas de voies aériennes difficiles simulant un arrêt cardiaque, le Pentax-AWS est meilleur que le GlideScope.

High-quality chest compression is one of the most crucial elements in cardiopulmonary resuscitation (CPR).¹ Healthcare providers should interrupt chest compressions as infrequently as possible, and they should try to limit interruptions to no longer than ten seconds, except for specific interventions such as airway management.¹ If tracheal intubation could be performed during continuous chest compressions, it would help to sustain circulation during the intubation procedure.

The Pentax-AWS® (Pentax Corporation, Tokyo, Japan) is a portable videolaryngoscope designed for tracheal intubation under normal and difficult airway situations. It consists of a camera, a monitor, and a disposable blade (PBlade®). The PBlade, which has a channel on its right side for holding and guiding the endotracheal tube (ETT), is designed to provide a view of the glottis without the need for alignment of the oral, pharyngeal, and laryngeal axes. In previous studies, it has been demonstrated that the Pentax-AWS improves the glottic view and is a useful device in patients with predicted difficult tracheal intubation.²⁻⁶ We have previously shown that the Pentax-AWS is an effective tool for performing tracheal intubation on a mannequin without interrupting chest compressions.⁷ In other studies, it has been reported that the Pentax-AWS is a more effective device than the Macintosh laryngoscope for the performance of tracheal intubation during uninterrupted chest compressions.⁸⁻¹⁰

The GlideScope® (Verathon®, Bothell, WA, USA) is another popular indirect laryngoscope developed for the management of difficult airways. Studies have demonstrated that the GlideScope may provide a better laryngoscopic view than direct laryngoscopy,¹¹ and it may be advantageous for tracheal intubation in patients with a difficult airway.¹² However, there has been little research on the GlideScope for tracheal intubation during chest compressions.

In the present study, we tested the utility of the GlideScope during chest compressions and compared its performance with both the Pentax-AWS and the Macintosh

laryngoscope. We hypothesized that tracheal intubation via the GlideScope would be possible during CPR without interruption of chest compressions, and we also presumed that this instrument would function as effectively as the Pentax-AWS. To test our hypothesis, tracheal intubations were performed by inexperienced medical personnel (junior interns) using three devices (Macintosh laryngoscope, Pentax-AWS and GlideScope) on a mannequin (ALS simulator, Laerdal, Stavanger, Norway).

Methods

After approval by our hospital's Institutional Review Board, we obtained written informed consent from 32 of our hospital's junior interns who had limited clinical experience. Before recruitment into our study, seven of the participants had never attempted tracheal intubation on real patients. The other 25 volunteers had performed fewer than ten tracheal intubations, i.e., the mean number of intubations was 1.9 (1.7), all under the supervision of an anesthesiologist. None of the participants had prior experience with either the Pentax-AWS or the GlideScope.

Each participant was given a standardized 20-min training session on each of the devices, for a total of 60 min of training. The training program included a demonstration of the intubation technique with each device and verbal instructions on the correct use of the three devices. The participants were allowed to practise tracheal intubations on a Laerdal Airway Management Trainer (Laerdal, Stavanger, Norway) until they achieved three consecutive successful tracheal intubations with each of the three devices (Macintosh laryngoscope, Pentax-AWS, and GlideScope) in a normal airway situation without chest compressions.

As there were three devices, six possible device sequences were possible. Thirty-two sequences were generated using the random number generator at www.random.org and placed in sealed envelopes. The participants selected one of the envelopes after consenting to participate in the study. Randomization of the order of the scenarios (normal and difficult airway) was achieved through card draws. Participants who selected odd-numbered cards performed the normal airway scenario first, followed by the difficult airway scenario, while those who selected even-numbered cards performed the protocol in the opposite order.

Polyvinyl chloride ETTs (Blue Line® 7.5 mm cuffed ETTs; Smiths Medical, Hythe, Kent, UK) with an inherent anterior curvature, and size 3 Macintosh blades and GlideScope GVL® (Verathon®, Bothell, WA, USA) were used. For intubation attempts with the Macintosh laryngoscope, a malleable stylet was inserted into the ETT and molded to follow the inherent anterior curvature of the tracheal tube. A GlideRite® Rigid Stylet, which was

supplied by the manufacturer, was used for intubation attempts with the GlideScope laryngoscope. For the Macintosh laryngoscope, the mannequin's head and neck were placed in a sniffing position by placing an 8-cm pillow under the occipital area of the mannequin's head. The mannequin's head and neck were placed in a neutral position for both the Pentax-AWS and the GlideScope.

A basic life support provider certified by the American Heart Association performed manual continuous chest compressions at a rate of 100 compressions per minute at a 4–5 cm depth. To simulate a difficult airway, the mannequin's tongue was inflated to a pressure of 130 mmHg, creating edema and generating a Mallampati class 3 condition.

The primary endpoint was the time required to complete tracheal intubation. The time to visualize the vocal cords was defined as the interval from the moment the device was grasped until the participant said, "I see the vocal cords". The time to complete tracheal intubation extended from grasping the device to the end of the procedure, i.e., when the stylet was removed from the ETT (GlideScope and the Macintosh laryngoscope) or when the PBlade was removed from the mannequin's mouth (Pentax-AWS). Successful intubation was defined as visible chest rise after bagging with the bag valve mask device. Failed intubation was defined as either esophageal intubation or exceeding the 120-sec time limit for performing the procedure. The percentage of glottis opening (POGO) scale¹³ describes the extent to which the glottic opening was visible. A POGO scale of 100% indicates visualization of the entire glottic opening from the anterior commissure of the vocal cords to the interarytenoid notch. A POGO scale of 0% corresponds to no visualization of laryngeal structures. Each participant provided a POGO scale rating after each intubation.

A single investigator recorded the presence of significant dental compression (i.e., yes or no). At the end of each scenario, each participant scored intubation difficulty on a visual analogue scale (i.e., a 10-cm line anchored by the two descriptors, "very easy = 0" and "very difficult = 10").

All processes were recorded by camcorder, and all of the time variables were precisely identified by reviewing the video record. Quality of chest compression (rate and depth) was monitored simultaneously by the HeartStart MRx monitor/defibrillator (Philips Medical System, Seattle, WA, USA), which has a CPR feedback system (the Q-CPRTM meter, Stavanger, Norway), to facilitate maintaining the quality of chest compressions throughout the study.

We based our sample size on the time to complete tracheal intubation. Based on our prior study,⁷ we predicted it would take 21 sec (standard deviation, 15 sec) to complete tracheal intubation using the Macintosh laryngoscope during continuous chest compression in the normal airway scenario, and we predicted it would take 15 sec (standard

deviation, 6 sec) using the Pentax-AWS under the same conditions. We hypothesized that tracheal intubation via the GlideScope would be as effective as that with the Pentax-AWS. Based on these figures, using $\alpha = 0.05$ and $\beta = 0.2$, we estimated that 31 participants would be needed. Therefore, our objective was to enroll a minimum of 31 participants.

Since certain time variables included cases with esophageal intubation, Kaplan-Meier analysis was performed to analyze the cumulative success rate associated with the time to glottis visualization and the time to complete intubation. Data for successful tracheal intubation and dental compression were analyzed using the Chi square test or Fisher's exact test, as appropriate. The POGO scale and ease of intubation were analyzed using the Kruskal-Wallis test. A *post-hoc* analysis with Bonferroni correction was conducted to compare the three devices in terms of the overall success rate, the POGO scale, the dental compression, and the ease of intubation. Continuous variables are presented as the median [interquartile range], while ordinal and categorical variables are presented as numbers and as frequencies. We considered P values < 0.05 to be significant. Statistical analysis was performed using the PASW Statistics software package, version 17.0 (SPSS, Chicago, IL, USA).

Results

Thirty-two participants were enrolled in this study. The majority were male ($n = 23$, 71.9%). Average age was 24.8 (1.2) yr. Each participant performed three tracheal intubations for each scenario. None of the participants dropped out during the study.

Normal airway

The time to visualize the vocal cords was significantly shorter with the two videolaryngoscopes than with the Macintosh laryngoscope, and there was no significant time difference between the Pentax-AWS and the GlideScope (Table 1, Fig. 1A).

The time to complete intubation was also significantly shorter with the two videolaryngoscopes than with the Macintosh laryngoscope, and there was no significant time difference between the Pentax-AWS and the GlideScope (Table 1, Fig. 1B).

One participant (3%) failed to intubate with the Macintosh laryngoscope due to esophageal intubation, but all participants performed successful tracheal intubations with the two videolaryngoscopes. The overall success rate did not differ among the three devices (Table 1).

The POGO scale was significantly higher and the incidence of dental compressions was lower with the two

Table 1 Tracheal intubation in a normal airway ($n = 32$)

	McL	AWS	GLS	<i>P</i> value	McL vs AWS	McL vs GLS	AWS vs GLS
Time to glottis (sec)	7.9 [6.0-12.6]	6.3 [5.29-8.0]	6.1 [5.2-8.0]		0.006*	0.003*	0.813
Time to complete (sec)	16.5 [13.1-22.1]	12.1 [10.1-14.4]	14.3 [12.4-17.6]		0.002*	0.030*	0.142
Overall success rate (%)	31 (96.997)	32 (100.0)	32 (100.0)	0.364			
POGO scale (%)	70 [50-73]	90 [78-90]	80 [80-83]	<0.001 [†]	<0.001 [‡]	<0.001 [‡]	0.066
Dental compression; <i>n</i> (%)	24 (75.0)	3 (9.4)	3 (9.4)	<0.001 [†]	<0.001 [‡]	<0.001 [‡]	0.664
Ease of intubation; (0-10)	6.0 [4.0-7.5]	2.0 [1.0-3.0]	2.0 [1.0-3.5]	<0.001 [†]	<0.001 [‡]	<0.001 [‡]	0.313

Data are given as number (percentage) or median [interquartile range]. * *P* value with statistical significance after Kaplan-Meier analysis; [†] *P* value with statistical significance; [‡] *P* value with statistical significance after *post-hoc* analysis with Bonferroni correction. McL = Macintosh laryngoscope; AWS = Pentax-AWS; GLS = Glidescope; POGO = percentage of glottic opening

Fig. 1 Kaplan-Meier analysis of cumulative success rate related to the time to visualize the vocal cords (A) and the time to complete tracheal intubation (B) in a normal airway scenario with continuous chest compressions

videolaryngoscopes than with the Macintosh. There were no differences between the Pentax-AWS and the GlideScope (Table 1).

The participants rated the two videolaryngoscopes as easier to use than the Macintosh. The Pentax-AWS and the GlideScope were similar in terms of ease of intubation (Table 1).

Difficult airway

The time to visualize the vocal cords was significantly shorter with the two videolaryngoscopes than with the Macintosh laryngoscope, and there was no significant time difference between the Pentax-AWS and the GlideScope (Table 2, Fig. 2A).

It took less time to complete intubation with the two videolaryngoscopes than with the Macintosh laryngoscope. Moreover, the time to complete intubation was significantly shorter with the Pentax-AWS than with the GlideScope (Table 2, Fig. 2B).

Eight participants (25%) failed to complete tracheal intubation with the Macintosh laryngoscope; six participants (19%) failed due to esophageal intubation, and two participants (6%) failed by exceeding the 120-sec time limit. All participants performed successful tracheal intubations with the Pentax-AWS. One participant (3%) failed intubation with the GlideScope by exceeding the time limit. The overall success rate was significantly higher with the two videolaryngoscopes than with the Macintosh, and there was no significant difference in overall success rate between the Pentax-AWS and the GlideScope (Table 2).

Table 2 Tracheal intubation in a difficult airway ($n = 32$)

	McL	AWS	GLS	<i>P</i> value	McL vs AWS	McL vs GLS	AWS vs GLS
Time to glottis (sec)	17.5 [10.3-28.5]	7.8 [6.4-10.5]	9.0 [7.2-12.0]		<0.001*	<0.001*	0.435
Time to complete (sec)	30.1 [21.0-56.5]	13.9 [10.9-20.4]	19.2 [16.4-32.3]		<0.001*	0.006*	0.013*
Overall success rate (%)	24.0 (75.0)	32.0 (100)	31.0 (96.997)	<0.001 [†]	0.002 [‡]	0.013 [‡]	0.500
POGO scale (%)	30 [20-60]	80 [70-80]	70 [60-78]	<0.001 [†]	<0.001 [‡]	<0.001 [‡]	<0.001 [‡]
Dental compression; <i>n</i> (%)	28.0 (90.3))	8.0 (25.0)	18.0 (58.1)	<0.001 [†]	<0.001 [‡]	0.004 [‡]	0.008 [‡]
Ease of intubation; (0-10)	8.0 [6.0-10.0]	3.0 [1.0-4.0]	3.5 [3.0-4.5]	<0.001 [†]	<0.001 [‡]	<0.001 [‡]	0.080

Data are given as number (percentage) or median [interquartile range]. * *P* value with statistical significance after Kaplan-Meier analysis;

[†] *P* value with statistical significance; [‡] *P* value with statistical significance after *post-hoc* analysis with Bonferroni correction. McL = Macintosh laryngoscope; AWS = Pentax-AWS; GLS = Glidescope; POGO = percentage of glottic opening

Fig. 2 Kaplan-Meier analysis of cumulative success rates related to the time to visualize the vocal cords (A) and the time to complete tracheal intubation (B) in a difficult airway scenario with continuous chest compressions

The POGO scale was greater with the Pentax-AWS than with the other two devices, and it was greater with the GlideScope than with the Macintosh (Table 2). Dental compression was less frequent with the two video-laryngoscopes than it was with the Macintosh, and it was also less frequent with the Pentax-AWS than with the GlideScope (Table 2).

Participants rated the two videolaryngoscopes as easier to use than the Macintosh, with no difference between the Pentax-AWS and the GlideScope (Table 2).

Discussion

The results of this study demonstrated that the two video-laryngoscopes were more effective than the Macintosh laryngoscope for performing tracheal intubation during continuous chest compressions on a mannequin in both normal and difficult airway scenarios. They functioned better with respect to the primary outcome (time to complete intubation) and other secondary outcomes (time to visualize the vocal cords, POGO scale, dental compression, and ease of

intubation). Success rate was greater with the two videolaryngoscopes only with the difficult airway scenario.

There are few studies concerning tracheal intubation during uninterrupted chest compressions.^{7-10,14-16} The laryngoscopes employed in the majority of these previous studies were the conventional Macintosh laryngoscope and the Pentax-AWS.^{7-10,14,15} While four studies⁷⁻¹⁰ reported that the Pentax-AWS was more effective than the Macintosh laryngoscope, two studies^{14,15} reported no significant difference.

In our view, the Pentax-AWS is an effective tool for securing the airway during chest compressions and is more effective than the conventional Macintosh laryngoscope. In the difficult airway scenario, median time to complete intubation was 14 sec with the Pentax-AWS and 30 sec with the Macintosh. According to the current (2010) American Heart Association Guidelines for Cardiopulmonary Resuscitation, five cycles of CPR takes about two minutes, or approximately 24 sec per cycle. Based on these results, it is possible to complete tracheal intubation with the Pentax-AWS without interrupting chest compressions before one cycle of CPR ends.

The GlideScope is one of the most popular videolaryngoscopes. However, little is known about its efficacy in securing the airway during chest compressions. In one study, Kim *et al.*¹⁵ reported that there were no significant differences between the Macintosh, the Pentax-AWS, and the GlideScope in the time taken for intubation. In the present study, the GlideScope was as effective as the Pentax-AWS during uninterrupted compressions in a normal airway scenario. However, in a difficult airway scenario, the Pentax-AWS was more effective than the GlideScope, with shorter time to complete tracheal intubations, higher POGO score, and less dental compression.

The less favourable outcomes of the GlideScope compared with the Pentax-AWS during continuous chest compressions in the difficult airway scenario may be explained by two main factors. First, participants encountered difficulties in advancing the tracheal tube toward the trachea. These difficulties with the GlideScope appeared to be the principal reason for the increased time to complete tracheal intubation compared with the Pentax-AWS. Second, the Pentax-AWS has a unique tube guide system, the PBlade, which is a side channel into which the ETT is placed before starting intubation. Once the device is inserted, the glottis is visualized and centred on the target marked on the liquid crystal display screen, at which point the ETT is passed through the glottis. This design feature seems to facilitate the passage of the ETT into the glottis when there are up and down movements during intubation.

The GlideScope may have several advantages over the Pentax-AWS in certain clinical settings. First, the GlideScope is easier to introduce into the oropharynx because its blade is narrower than that of the Pentax-AWS, and it

comes in various sizes (GVL 2, 3, 4, and 5). This advantage would be most noticeable when the patient has a limited mouth opening. Second, the view may be less affected by secretions or blood because the GlideScope blade has a unique angulation (bends 60° at the mid-line) and the video camera embedded in the blade is located higher than that in the Pentax-AWS. Third, due to the anti-fogging mechanism, the GlideScope provides a consistently clear view. Although the GlideScope may have several advantages over the Pentax-AWS, the characteristic side channel tube guidance system of the Pentax-AWS seems to accentuate its advantages over the GlideScope during chest compressions.

Perhaps the conventional Macintosh laryngoscope can also be used to secure the airway during chest compressions. Gatward *et al.*¹⁷ reported that continuing chest compressions has a minor effect on the time for tracheal intubation. Two other studies^{14,15} reported no significant difference between the Macintosh laryngoscope and the videolaryngoscopes in the time taken for intubation. However, marked delays in intubation during chest compression have been reported in some studies with the Macintosh laryngoscope.⁹ Moreover, overall success rates were significantly lower with the Macintosh laryngoscope than with the Pentax-AWS.^{7,8,10} Success rates of 100% have been reported for the Pentax-AWS compared with success rates of 57.1%,⁸ 74.3%,¹⁰ and 81.3%⁷ reported for the Macintosh.⁸ In the present study, the overall success rate for the Macintosh laryngoscope was similar to that of the Pentax-AWS in a normal airway scenario (96.9% vs 100%, respectively). However, in a difficult airway scenario, there was a significant difference in the overall success rate (75% vs 100%, respectively). The Macintosh laryngoscope seems to have some limitations when securing the airway during chest compressions, especially in difficult airway situations.

This study has some limitations. First, this is a mannequin-based rather than a clinical study. The mannequin may not reproduce the precise intubation conditions of real patients. Second, the specific difficult airway scenario simulated in our study cannot represent all difficult airway conditions; thus, the results in our study cannot be generalized to other difficult airway conditions. Third, certain measurements, such as the time to visualization of the vocal cords, the POGO scale, and the ease of intubation, are subjective by nature.

In conclusion, under conditions of both normal and difficult airways, both the Pentax-AWS and the GlideScope were more effective than the Macintosh laryngoscope in terms of performing tracheal intubations without interruption of chest compressions on a mannequin simulating cardiac arrest. The GlideScope and the Pentax-AWS were equally effective during continuous chest compressions in the normal airway scenario. However, in a difficult airway situation, the Pentax-AWS performed better than the GlideScope.

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Competing interests None declared.

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