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A comparison of the force applied on oral structures during intubation attempts between the Pentax-AWS airwayscope and the Macintosh laryngoscope: a high-fidelity simulator-based study

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ABSTRACT

Objective: We sought to determine whether the use of Pentax-AWS Airwayscope (AWS) applied less force on oral structures during intubation attempts than a conventional direct laryngoscope (DL).

Design: Prospective cross-over study.

Participants: A total of 37 physicians (9 transitional-year residents, 20 emergency medicine residents and 8 emergency physicians) were enrolled.

Interventions: We used four simulation scenarios according to the difficulty of intubation and devices and used a high-fidelity simulator to quantify the forces applied on the oral structures.

Outcome measures: Primary outcomes were the maximum force applied on the maxillary incisors and tongue. Other outcomes of interest were time to intubation and glottic view during intubation attempts.

Results: The maximum force applied on the maxillary incisors in the normal airway scenario was higher with the use of AWS than that with DL (107 newton (N) vs 77 N, p=0.02). By contrast, the force in the difficult airway scenario was significantly lower with the use of AWS than that of the DL (89 N vs 183 N, p<0.01). Likewise, the force applied on the tongue was significantly lower with the use of AWS than the use of DL in both airway scenarios (11 N vs 27 N, p<0.001 in the normal airway scenario; 12 N vs 40 N, p<0.01 in the difficult airway scenario).

Conclusions: The use of AWS during intubation attempts was associated with decreased forces applied to oral structures in the simulated difficult airway scenario.

Strengths and limitations of this study

- This cross-over study is the first to assess the difference in the actual force on oral structures during intubation attempts with the Pentax-AWS Airwayscope and the direct laryngoscope, by using high-fidelity simulators.
- Approximately 50% of the participants had experienced 100 or fewer intubations in their medical career.
- As our study used simulators, caution should be exercised when extrapolating these findings to a clinical setting.

INTRODUCTION

While direct laryngoscopes (DLs) have been widely used for tracheal intubations, video laryngoscopes have been used in the operating room, intensive care unit and emergency department.[1–3] The Pentax-AWS Airwayscope (AWS) is a rigid video laryngoscope that uses an anatomically-shaped blade and video system to obtain a better glottic view without requiring additional forces. Several studies have reported that the use of AWS is associated with faster intubation in cases of difficult airways[1 4] and lower incidence of dental injury[5] than DL. Potential mechanism by which the use of AWS reduces airway trauma is a reduction in applied forces on the oral structures. However, to our knowledge, differences in applied forces during intubation attempts between the AWS and the DL remain unclear.

To address the knowledge gap, using high-fidelity simulators, we sought to determine whether the use of an AWS decreases applied forces on the maxillary incisors and tongue during intubation attempts compared to those with the use of a DL.

METHODS

Study design and settings

We conducted a prospective cross-over study to examine the forces applied on the oral structures during intubation attempts according to intubation devices. This design enabled each study participant to serve as his or her own control, thereby removing both measured and unmeasured time-invariant confounding.[6 7]

We recruited 37 physicians across Japan in August 2013, including transitional-year residents (postgraduate year (PGY) 1 or 2), emergency medicine residents (PGY 3, 4 and 5) and emergency physicians (PGY ≥6). The study was approved by the institutional ethics committee of St. Marianna University School of Medicine Hospital, and informed consent was obtained from the participants.

Data collection

Baseline characteristics

We documented the characteristics of each participant (PGY and level of training), and self-reported the number of airway management encounters prior to this study (the number of intubations, difficult airway encounters and intubations using an AWS).

Simulation scenarios

We used a high-fidelity airway management simulator (Waseda Kyoto Airway No.5, Kyoto-Kagaku, Kyoto, Japan) to quantify the forces applied on the oral structures,—the maxillary incisors and tongue—during intubation attempts.[8] The implanted sensors in the simulator automatically quantify the forces. The intubation difficulty can be changed by limiting mouth opening.

We used four simulation scenarios according to the difficulty of intubation and devices (a size-3 Macintosh DL and AWS) as follows: (1) intubation of a normal airway using a DL, (2) intubation of a difficult airway using a DL, (3) intubation of a normal airway using an AWS and (4) intubation of a difficult airway using an AWS. We defined a 'difficult airway scenario' as a scenario with a limited mouth opening. Prior to simulations, all participants received a 10 min lecture and 5 min practice session to ensure that they were familiar with proper DL and AWS techniques. The participants were then randomly assigned to one of the four simulation scenarios, and sequentially underwent the other simulation scenarios. All participants were blinded to the difficulty of intubation in all scenarios.

Outcome measures

Primary outcomes were the maximum applied forces on the maxillary incisors and tongue during intubation attempts. Other outcomes of interest were time to intubation and glottic view during intubation attempts. Time to intubation was defined as time to successful placement of an endotracheal tube (ie, an appropriate positioning of the endotracheal tube tip and confirmation of ventilation), regardless of the number of attempts. The glottic view at each intubation attempt was scored by the participant using the Cormack-Lehane grades.[9]

Statistical analysis

To account for the natural pairing of the observations within each participant, and non-normal distribution of the outcome variables, we compared the outcomes between two devices (AWS vs DL) using Wilcoxon signed rank test. In addition, to compare the outcomes with consideration for the intubator's experience, we performed stratified analysis by categorising the intubators into two groups based on the previous study: experienced intubators (n=18) and inexperienced intubators (n=19).[10] Experienced intubators were defined as those who had intubated 100 or more cases, while inexperienced intubators were defined as those who had intubated less than 100 cases. p Values <0.05 were considered statistically significant. All data analyses were performed with Stata software V.13.1 (StataCorp, College Station, Texas, USA).

RESULTS

The characteristics of participants are shown in table 1. Of the 37 participants, 20 were emergency medicine residents. The overall median number of intubations was 80 (IQR, 35–150), with a median of 4 (IQR, 1–10) among those using an AWS.

The maximum force applied on the maxillary incisors in the normal airway scenario was higher with the use of an AWS (107 newton (N) vs 77 N, p=0.02; table 2) than that of a DL. By contrast, the force in the difficult airway scenario was significantly lower with the use of an AWS than that of a DL (89 N vs 183 N, p<0.01). Likewise, the force applied on the tongue was significantly lower with the use of an AWS than that of the use of a DL in both airway scenarios (11 N vs 27 N (p<0.01) in the normal airway scenario; 12 N vs 40 N (p<0.01) in the difficult airway scenario). There were no significant differences in time to intubation by airway device in both scenarios. By contrast, the Cormack-Lehane grade score was significantly lower with the use of AWS than that of a DL in the difficult airway scenario (median, 1.0 vs 2.0, p<0.01).

The sensitivity analysis stratified by the experience of intubators showed the robustness of our findings. For example, in the experienced intubator group, the forces applied on oral structures were significantly lower with

Table 1 Characteristics of participants

Characteristics	All participants n=37
PGY median (IQR)	4 (2.5–6)
Level of training (%)	
Transitional year residents*	9 (24)
Emergency medicine residents	20 (54)
Emergency physicians†	8 (22)
Airway management	
Total number of intubations, median (IQR)	80 (35–150)
Number of difficult airway encounters, median (IQR)	5 (2–10)
Number of intubation using AWS, median (IQR)	4 (1–10)

*Defined as PGY 1 or 2.
†Defined as PGY ≥6.
AWS, Airwayscope; PGY, post-graduate years.

Table 2 Comparisons of Airwayscope with the direct laryngoscope for intubation

Outcomes	AWS n=37	DL n=37	p Value
Forces on maxillary incisors (N), median (IQR)			
Normal airway	107 (54–127)	77 (44–96)	0.02
Difficult airway	89 (6–141)	183 (170–186)	<0.01
Applied forces on tongue (N), median (IQR)			
Normal airway	11 (8–14)	27 (21–39)	<0.01
Difficult airway	12 (9–16)	40 (37–42)	<0.01
Time to intubation (seconds), median (IQR)			
Normal airway	30 (24–45)	26 (23–34)	0.99
Difficult airway	28 (20–48)	36 (25–50)	0.95
Cormack-Lehane grades, median (IQR)			
Normal airway	1 (1–2)	1 (1–2)	0.50
Difficult airway	1 (1–2)	2 (1–2)	<0.01

AWS, Airwayscope; DL, direct laryngoscope; PGY, post graduate years.

the use of an AWS than that with a DL in the difficult airway scenario (table 3). Similarly, in the inexperienced intubator group, the forces applied on oral structures were lower with the use of an AWS than that with a DL in the difficulty airway scenarios (table 4).

In comparison of the outcomes with the use of a DL according to the airway scenarios, the forces applied on oral structures were significantly lower in the normal airway scenario (the maximum force applied on the maxillary incisors, 77 N vs 183 N, p<0.01; the force applied on the tongue, 27 N vs 40 N, p<0.01, table 5) compared to those in the difficult airway scenario. Likewise, the Cormack-Lehane grade score was significantly lower in the normal airway scenario (median, 1.0 vs 2.0. p<0.01). In contrast, with the use of an AWS, there were no significant differences in any of the outcomes between the two scenarios.

DISCUSSION

In this prospective cross-over study, we found that the use of AWS, compared to DL, was associated with a lower maximum force on the oral structures during intubation attempts in the difficult airway scenario. Additionally, we also found that the use of AWS was associated with an improved glottic view in the difficult airway scenario.

Applying excessive forces on the oral structures during intubation attempt is associated with direct and indirect adverse events.[11] Dental injury—one of the common direct adverse events—occurs when the force applied to the maxillary incisors exceeds 150 N.[12] Our study demonstrated that the forces applied on the maxillary incisors with the use of AWS are significantly lower than those applied with DL in the difficult airway scenario. Additionally, in the same scenario, the highest quartile of applied forces on the maxillary incisors with the use of AWS did not exceed 150 N. In agreement with these data, a previous simulation study reported that the use of AWS decreases the number of dental clicks compared with the use of DL.[5] These findings collectively suggest that the use of AWS might decrease incidences of dental injuries during intubation attempts.

Table 3 Comparison of the outcomes between Airwayscope and the direct laryngoscope for intubation by experienced intubators (n=18)

Outcomes	AWS n=18	DL n=18	p Value
Forces on maxillary incisors (N), median (IQR)			
Normal airway	110 (62–126)	78 (16–94)	0.09
Difficult airway	105 (7–153)	182 (172–187)	<0.01
Applied forces on tongue (N), median (IQR)			
Normal airway	10 (8–16)	32 (22–42)	<0.01
Difficult airway	12 (10–15)	39 (36–40)	<0.01
Time to intubation (seconds), median (IQR)			
Normal airway	32 (20–45)	25 (21–30)	0.09
Difficult airway	24 (18–38)	27 (23–39)	0.58
Cormack-Lehane grades, median (IQR)			
Normal airway	2 (1–2)	1 (1–2)	0.40
Difficult airway	1 (1–1)	2 (2–2)	<0.01

AWS, Airwayscope; DL, direct laryngoscope; PGY, post graduate years.

Table 4 Comparison of the outcomes between Airwayscope and the direct laryngoscope for intubation by inexperienced intubators (n=19)

Outcomes	AWS n=19	DL n=19	p Value
Forces on maxillary incisors (N), median (IQR)			
Normal airway	107 (44–142)	76 (47–99)	0.17
Difficult airway	77 (4–120)	183 (160–186)	<0.01
Applied forces on tongue (N), median (IQR)			
Normal airway	12 (8–13)	22 (19–32)	<0.01
Difficult airway	13 (5–17)	41 (39–43)	<0.01
Time to intubation (seconds), median (IQR)			
Normal airway	28 (26–47)	38 (35–71)	0.89
Difficult airway	40 (22–61)	28 (25–63)	0.07
Cormack-Lehane grades, median (IQR)			
Normal airway	1 (1–2)	1 (1–1)	0.72
Difficult airway	2 (1–2)	2 (1–3)	0.02

AWS, Airwayscope; DL, direct laryngoscope; PGY, post graduate years.

To avoid indirect adverse events, such as vasovagal responses and haemodynamic alterations, emergency airway management requires intubation attempts with minimal forces to the oropharyngeal structures.[11 13 14] A previous report suggested that the use of AWS was associated with a decreased haemodynamic alteration during intubation attempts[13]; however, the authors did not evaluate the actual forces applied on oral structures. In contrast, in the present study, we found that the forces applied on the tongue were significantly lower with the use of AWS compared to that of DL. Our prospective cross-over study corroborated the previous knowledge and extended prior research by demonstrating the mechanism by which the use of AWS reduces intubation-related adverse events.

The reasons for the observed difference in the applied forces between the airway devices in the difficult airway are likely multifactorial. A plausible explanation is that the use of AWS enabled intubations without an excessive effort to achieve a direct line of sight. This is supported by the observed improvement in the glottic view with the use of an AWS. When a DL is used during intubation attempt in a difficult airway, maxillary incisors are reportedly used as the pivot point to lever the soft tissues upward, thereby leading to an excessive force to the maxillary incisors and tongue.[15] However, the reason for the finding that the maximum force applied on the maxillary incisors in the normal airway scenario was higher with the use of AWS than that with DL was unclear and also likely multifactorial. In our study, most intubators were familiar with the use of a DL, while they were less familiar with the use of AWS. Indeed, approximately 80% of the participants had performed less than 10 intubations using an AWS. Therefore, one may surmise that the unfamiliarity with AWS led to this finding. However, the sensitivity analysis demonstrated no significant difference in the applied force on the maxillary incisor between the devices in the experienced intubator group. Alternatively, the size of an AWS—bigger than that of a DL—might have contributed to the finding.

To the best of our knowledge, this is the first study to report the association between the use of AWS and

Table 5 Comparisons of the outcomes according to the airway scenarios in the use of direct laryngoscope and Airway scope

Device and outcomes	Normal airway n=37	Difficult airway n=37	p Value
Direct laryngoscope			
Forces on maxillary incisors (N), median (IQR)	77 (44–96)	183 (170–186)	<0.01
Applied forces on tongue (N), median (IQR)	27 (21–39)	40 (37–42)	<0.01
Time to intubation, (seconds), median (IQR)	26 (23–34)	36 (25–50)	0.06
Cormack-Lehane grades, median (IQR)	1 (1–2)	2 (1–2)	<0.01
Airway scope			
Forces on maxillary incisors (N), median (IQR)	107 (54–127)	89 (6–141)	0.07
Applied forces on tongue (N), median (IQR)	11 (8–14)	12 (9–16)	0.63
Time to intubation (seconds), median (IQR)	30 (24–45)	28 (20–48)	0.74
Cormack-Lehane grades, median (IQR)	1 (1–2)	1 (1–2)	0.31

AWS, Airwayscope; DL, direct laryngoscope; PGY, post graduate years.

decreased forces on the oral structures during intubation attempts. Multiple studies have reported the advantages of AWS for intubation, not only in the routine general anaesthesia setting[1 4 16] but also in several clinical situations—for example, cardiopulmonary resuscitation, pregnant patients with lateral tilt-position and out-of-hospital setting.[17–19] Several simulation studies also reported that novice intubators intubate more successfully and safely with the use of AWS compared with that of DL.[20 21] Furthermore, our findings support the systematic use of an AWS in the critical settings, such as in patients with hypotension and those who cannot tolerate haemodynamic alterations (eg, intracranial haemorrhage).

This study has potential limitations. Approximately half of the participants had experienced 100 or fewer intubations in their medical career, and the median number of AWS uses was 4. However, even the less experienced intubator was able to intubate with less applied forces. In addition, as our study used simulators, an extrapolation of the findings to the clinical setting requires caution.

CONCLUSIONS

In this prospective cross-over study, we found that the use of AWS, compared to DL, was associated with lower maximum forces on the oral structures in the difficult airway scenario. We also found that the use of AWS was associated with an improved glottic view in the difficult airway scenario.

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