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RESPIRATION AND THE AIRWAY

Comparison of Macintosh, Truview EVO2®, Glidescope®, and Airwayscope® laryngoscope use in patients with cervical spine immobilization

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Background. The purpose of this study was to evaluate the effectiveness of the Pentax AWS®, Glidescope®, and the Truview EVO2®, in comparison with the Macintosh laryngoscope, when performing tracheal intubation in patients with neck immobilization using manual in-line axial cervical spine stabilization.

Methods. One hundred and twenty consenting patients presenting for surgery requiring tracheal intubation were randomly assigned to undergo intubation using a Macintosh (n=30), Glidescope® (n=30), Truview EVO2® (n=30), or AWS® (n=30) laryngoscope. All patients were intubated by one of the three anaesthetists experienced in the use of each laryngoscope.

Results. The Glidescope®, AWS®, and Truview EVO2® each reduced the intubation difficulty score (IDS), improved the Cormack and Lehane glottic view, and reduced the need for optimization manoeuvres, compared with the Macintosh. The mean IDS was significantly lower with the Glidescope® and AWS® compared with the Truview EVO2® device, and the IDS was lowest with the AWS®. The duration of tracheal intubation attempts was significantly shorter with the Macintosh compared with the other devices. There were no differences in success rates between the devices tested. The AWS® produced the least haemodynamic stimulation.

Conclusions. The Glidescope® and AWS® laryngoscopes required more time but reduced intubation difficulty and improved glottic view over the Macintosh laryngoscope more than the Truview EVO2® laryngoscope when used in patients undergoing cervical spine immobilization.

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Failure to adequately immobilize the neck during tracheal intubation in patients with cervical spine injuries can result in devastating neurological outcomes.[1] Anatomic studies that mimic complete C4–5 ligamentous injury demonstrate that manual in-line axial stabilization (MIAS) reduces segmental angular rotation and distraction.[2] Consequently, in many institutions, where tracheal intubation is required in patients with potential cervical spine injuries, the rigid cervical collar is removed, and the cervical spine immobilized by means of MIAS. However, a key concern is the fact that with cervical spine immobilization, it is more difficult to visualize the larynx using conventional laryngoscopy.[3–5] Failure to successfully intubate the trachea and secure the airway remains a leading cause of morbidity and mortality, in the operative[6–8] and emergency settings.[9 10]

These issues have prompted, in part, the development of a number of alternatives to the Macintosh laryngoscope, including modifications to the Macintosh, such as the Truview EVO2® (Truphatek International Ltd, Netanya, Israel) laryngoscope blade[11] (Fig. 1A). More recently introduced indirect laryngoscopes include the Glidescope® (Saturn Biomedical System Inc., Burnbaby, Canada)[12–14] and the AWS® (Pentax Corporation, Tokyo, Japan)[15 16]

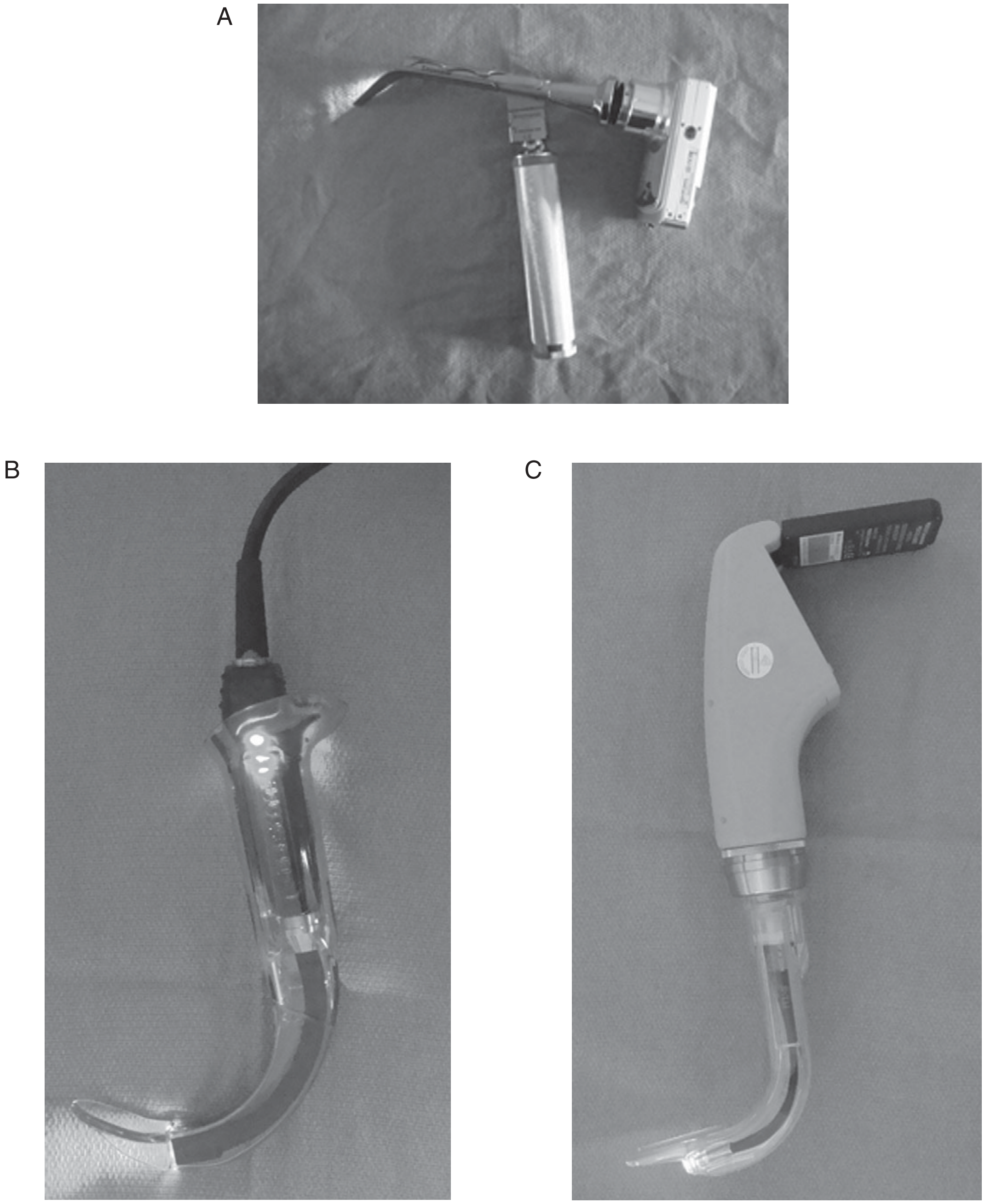

Fig 1 (A) Photograph of the Truview EVO2® laryngoscope with camera attachment which clips onto the eyepiece. The attached camera is a Premier 5.2 mega pixels digital camera made specifically for the Truview EVO2®, with a 5×4 cm LCD screen. (B) Photograph of the Glidescope® with single-use blade placed over fibreoptic system. The Glidescope® is attached to its standard 8.5×15 cm LCD monitor. (C) Photograph of the Pentax AWS® laryngoscope with single-use blade clipped onto the camera system.

(Fig. 1B and C) devices. Advantages over the Macintosh have been demonstrated for the Glidescope®[12 13] and for the AWS®[15] in direct comparison studies. However, the relative efficacies of these devices in comparison with the Macintosh have not been compared in a single study.

The purpose of this clinical trial was to evaluate the effectiveness of the Glidescope®, Truview EVO2®, and the AWS® laryngoscopes when used by experienced anaesthetists in patients undergoing neck immobilization by MIAS. We hypothesized that, in comparison with the Macintosh, these novel laryngoscopes would reduce intubation difficulty, as measured by the intubation difficulty scale (IDS) score.

Methods

After obtaining approval from the Galway University Hospitals Research Ethics Committee (Galway, Ireland),

and written informed patient consent, we studied 120 ASA physical status I–III patients, aged 16 yr of age or older, undergoing surgical procedures requiring tracheal intubation, in a randomized, single blind, controlled clinical trial. Patients were excluded if risk factors for gastric aspiration, difficult intubation, or both (Mallampatti class III or IV; thyromental distance <6 cm; and inter-incisor distance <3.5 cm) were present, or where there was a history of relevant drug allergy. All data were collected by an independent unblinded observer.

The allocation sequence was generated by random number tables, and the allocation concealed in sealed envelopes, which were not opened until patient consent had been obtained. Patients were randomized to under tracheal intubation with either the Macintosh (size 3 blade in females; size 4 in males), Truview EVO2®, Glidescope® Cobalt, or AWS® laryngoscopes. Tracheal intubation was performed in each patient by one of the three anaesthetists (M.A.M., B.H.H., and J.G.L.). Each investigator had performed at least 50 intubations with each device in manikins, and at least 20 intubations in the clinical setting with each device. A stylet (Portex®, Kent, UK) was inserted into the endotracheal tube (ETT) for intubations with the Glidescope® and Truview EVO2® laryngoscopes. The ETT was placed in the side channel of the Pentax AWS® laryngoscope in advance of the intubation attempt. We used the Truview EVO2® with its camera attachment on the top of the blade (Fig. 1A) in order to magnify the view from the eyepiece. Several measures were used to reduce fogging of the distal lens of the Truview EVO2®, including insufflation of oxygen from the side port, warming of blade with hot water, and use of chemical defogging agents.

All patients received a standardized general anaesthetic. Standard monitoring, included ECG, non-invasive blood pressure (NIBP), Sp_{O_2}, and measurement of end-tidal carbon dioxide and volatile anaesthetic levels. Bispectral Index (BIS®) (Aspect Medical Systems, Norwood, MA, USA) or Entropy® (GE Healthcare, Helsinki, Finland) monitoring was utilized in all patients. Before induction of anaesthesia, all patients were given fentanyl (1–1.5 μg kg^{-1}) i.v.. Propofol (2–4 mg kg^{-1}) was titrated to induce anaesthesia in a dose sufficient to produce loss of verbal response. After induction of anaesthesia, all patients were manually ventilated with sevoflurane (2.0–2.5%) in oxygen, and atracurium (0.5 mg kg^{-1}) was administered. Tracheal intubation was not performed until the BIS/Entropy score had decreased below 60, and additional boli of propofol were administered to increase depth of anaesthesia if required. Three minutes after the administration of neuromuscular blocker, the pillow was removed and the neck immobilized using MIAS applied by an experienced anaesthetist holding the sides of the neck and the mastoid processes, thus preventing flexion/extension or rotational movement of the head and neck.

The trachea was then intubated with a 7.5 gauge ETT in females, and an 8.5 gauge ETT in males, by one of the investigators. After successful tracheal intubation, in all patients, the lungs were mechanically ventilated for the duration of the procedure and anaesthesia was maintained with sevoflurane (1.25–1.75%) in a mixture of nitrous oxide and oxygen in a 2:1 ratio. No other medications were administered, or procedures performed, during the 5 min data collection period after tracheal intubation. Subsequent management was left to the discretion of the anaesthetist providing care for the patient.

The primary endpoint was the IDS score.[17] The IDS score, developed by Adnet and colleagues,[17] is a quantitative scale incorporating multiple indices of intubation difficulty that more objectively quantifies the complexity of tracheal intubations (Appendix). The secondary endpoints were the duration of the tracheal intubation procedure and the rate of successful placement of the ETT in the trachea. The duration of the intubation attempt was defined as the time taken from insertion of the blade between the teeth until the ETT was placed through the vocal cords, as evidenced by visual confirmation by the anaesthetist. However, in patients in whom the ETT was not directly visualized passing through the vocal cords, the intubation attempt was not considered complete until the ETT was connected to the anaesthetic circuit and evidence obtained of the presence of carbon dioxide in the exhaled breath. A failed intubation attempt was defined as an attempt in which the trachea was not intubated, or which required >60 s to perform. A maximum of three intubation attempts were permitted. In the event that tracheal intubation was unsuccessful with the device tested, MIAS was discontinued and tracheal intubation performed with the Macintosh laryngoscope. The duration of the first tracheal intubation attempt, and of the successful attempt in the case that the first attempt was not successful, was recorded. Additional endpoints included the number of intubation attempts and the number of optimization manoeuvres required (use of a bougie, cricoid pressure, and second assistant) to aid tracheal intubation, and the Cormack and Lehane grade at laryngoscopy.[18] The type of bougie used was the Frova airway intubating catheter (William Cook Europe Ltd).

Statistical analysis

We based our sample size estimation on the IDS score. On the basis of our prior studies,[19] we considered that a clinically important reduction in mean IDS score was 2.0. Given an expected standard deviation of 2.25 from prior studies,[19] and using an α=0.05 and β=0.2, for an experimental design incorporating four equal-sized groups, we estimated that 29 patients would be required per group. We therefore aimed to enrol 30 patients per group.

All analyses were performed on an intention-to-treat basis. Patient characteristic data and data for duration of intubation attempts and the instrument difficulty score were analysed using one-way analysis of variance (ANOVA), except for data for gender which were analysed using the

Table 1 Patient characteristics of patients enrolled into the study. Data are reported as mean (range) for age, mean (SD), median (inter-quartile range), or as number (%). *Significant between-group difference (P<0.05, χ^2 test)

Parameter assessed	Macintosh	Truview EVO2®	Glidescope®	AWS®
Number per group	30	30	30	30
Male:female ratio*	11:19	20:10	8:22	11:19
Age (yr) (range)	50.8 (18–82)	43.2 (21–83)	45.3 (23–80)	43.9 (20–68)
Body mass index (kg m^{-2})	25.7 (4.1)	25.3 (3.5)	26.5 (3.3)	26.0 (6.0)
ASA classification (median, IQR)	2 (1, 2)	2 (1, 2)	2 (1, 2)	2 (1, 2)
Thyromental distance (cm, median, IQR)	7.25 (7, 8)	8.25 (7.5, 9)	7.5 (7, 8)	8.0 (7, 9)
Inter-incisor distance (cm)	4.2 (0.5)	4.5 (0.6)	4.3 (0.4)	4.2 (0.5)
Mallampatti classification (%)				
I	13 (43.3)	14 (46.7)	10 (33.3)	12 (40)
II	17 (56.7)	16 (53.3)	20 (66.7)	18 (60)
>II	0	0	0	0
Bispectral index or entropy score at tracheal intubation	31.9 (8.0)	29.3 (9.3)	30.3 (9.4)	27.0 (10.4)

χ^2 test. Data for the IDS score, the number of intubation attempts, and the number of optimization manoeuvres were analysed using ANOVA or Kruskal–Wallis ANOVA on ranks as appropriate. The comparisons of haemodynamic data were analysed using two-way repeated measures ANOVA, with group and time-point as the factors. In each case, *post hoc* between group testing was performed using the Student–Newman–Keuls test. Continuous data are presented as means (SD), ordinal data are presented as medians (inter-quartile range), and categorical data are presented as number and as frequencies. The α-level for all analyses was set as P<0.05.

Results

A total of 120 patients were entered into the study. One hundred and thirty-five patients were consented to participate, but 15 patients were not subsequently entered into the study due to delays in their surgical procedure taking place. Thirty patients were randomized to undergo tracheal intubation with each of the four devices under study. There were no significant differences in patient characteristics or baseline airway parameters between the groups, with the exception of a greater number of male patients in the Truview EVO2® group (Table 1). There were no between-group differences with regard to anaesthetic management, and there were no between-group differences in BIS®or Entropy® scores immediately before or after tracheal intubation (Table 1).

The IDS was significantly higher in the Macintosh compared with all other laryngoscopes, and was significantly higher with the Truview EVO2®, compared with both the Glidescope® and the AWS® devices (Fig. 2). All 30 patients were successfully intubated with the Glidescope®, compared with 29 AWS® device, and 28 with the Truview EVO2® and Macintosh laryngoscopes (Table 2). The duration of the first tracheal intubation attempts was significantly shorter with the Macintosh compared with the Truview EVO2® and the Glidescope® groups. The duration of the successful tracheal intubation attempts were significantly shorter with the Macintosh compared with all other laryngoscopes (Table 2).

There were no between-group differences in the number of attempts required with each device (Table 2). However, a greater number of optimization manoeuvres were required to facilitate tracheal intubation in the Macintosh group compared with all other laryngoscopes (Table 2). The AWS® group had a significantly better Cormack and Lehane glottic view obtained at laryngoscopy compared with all other devices, whereas the Macintosh group had the worst scores (Fig. 3). Both the Truview EVO2® and the Glidescope® groups had significantly lower Cormack and Lehane scores compared with the Macintosh (Fig. 3).

There were no between-group differences in the incidence of complications, including the appearance of blood on the laryngoscope blade, or of minor lacerations to the airway (Table 2). There was no incidence of dental or more severe airway laceration with any laryngoscope. Arterial haemoglobin oxygen saturations were maintained best in patients intubated with the Glidescope® laryngoscope (Table 2).

The effects of laryngoscopy and trachea intubation on the mean arterial pressure and on heart rate were relatively modest. Heart rate increased significantly in all groups, except for the AWS® group, after tracheal intubation, but

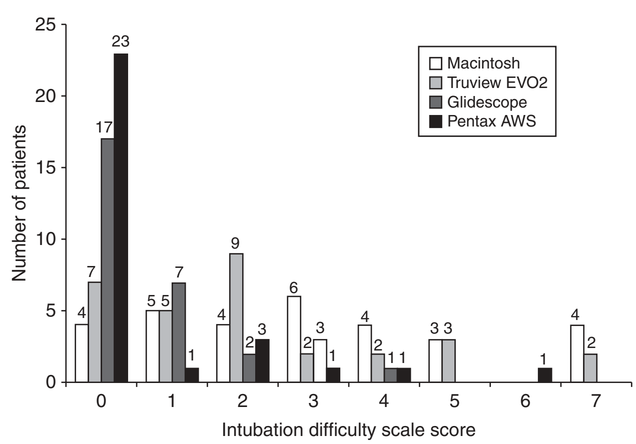

Fig 2 Comparison of IDS score distributions with each laryngoscope. Number of patients is shown above each bar. P<0.001 between the groups, Kruskal–Wallis ANOVA on ranks.

Table 2 Data for intubation attempts with each device. Data are reported as mean (SD), median (inter-quartile range), or as number (%). *Significantly ($P<0.05$) different compared with the Macintosh laryngoscope. †Significantly ($P<0.05$) different compared with all other laryngoscopes

Parameter assessed	Macintosh	Truview EVO2®	Glidescope®	AWS®
Overall success rate (%)	28 (93.3%)	28 (93.3%)	30 (100%)	29 (96.7%)
Number of intubation attempts (%)				
1	26 (87.6)	24 (80)	28 (93.3)	27 (90)
2	2 (6.7)	4 (13.3)	2 (6.7)	3 (10)
3	2 (6.7)	2 (6.7)	0	0
Duration (first attempt)	13.9 (9.2)	22.5 (7.5)*	20.0 (7.5)*	16.3 (6.9)
Duration (successful attempt)	11.6 (6.0)†	20.5 (5.7)	18.9 (6.0)	16.7 (7.6)
No. of optimization manoeuvres (%)				
0	10 (33.3)†	24 (80)	28 (93.3)	27 (90)
1	16 (53.3)	4 (13.3)	2 (6.7)	3 (10)
≥2	4 (13.3)	2 (6.7)	0	0
Lowest Sa_{O_2} during intubation attempt (%)	98.0 (2.1)	98.7 (1.4)	99.4 (0.6)*	98.5 (1.8)
Incidence of complications				
Blood on laryngoscope blade	3 (10)	1 (3.3)	1 (3.3)	8 (26.7)
Minor laceration	2 (6.7)	2 (6.7)	1 (3.3)	0
Dental or other airway trauma	0	0	0	0

had returned to baseline within 5 min in all groups (Fig. 4). Arterial pressure decreased significantly in each group after induction of anaesthesia. After tracheal intubation, mean arterial pressure increased back to baseline levels in the Glidescope® and Truview EVO2® groups, but remained below baseline in the Macintosh and AWS® groups (Fig. 5).

Discussion

The adequacy of the laryngeal view obtained is a major factor in determining the difficulty of intubation.[4] Unfortunately, cervical spine immobilization reduces the quality of glottic exposure.[3 4] MIAS prevents head extension and neck flexion, which are necessary for optimal alignment of the three airway axes and exposure of the vocal cords using direct laryngoscopic techniques. Alternative approaches to neck immobilization, such as the use of a rigid collar, tape, and sandbags, may result in an increased incidence of Grade 3 and 4 laryngoscopic views (up to 64%) with conventional laryngoscopy owing to the combination of decreased inter-incisor distance and cervical spine immobility.[5] Consequently, manoeuvres to stabilize the neck in patients at risk of cervical spinal injury may result in failure to secure the airway, which may result in substantial morbidity and even mortality in this patient group. These issues highlight the need to develop alternative approaches to securing the airway in patients at risk of cervical spine injury.

These issues have prompted, in part, the development of a number of alternative laryngoscopes, including the Truview EVO2® laryngoscope,[11] the Glidescope®,[12 13] and the AWS® device.[15] We wished to evaluate the relative

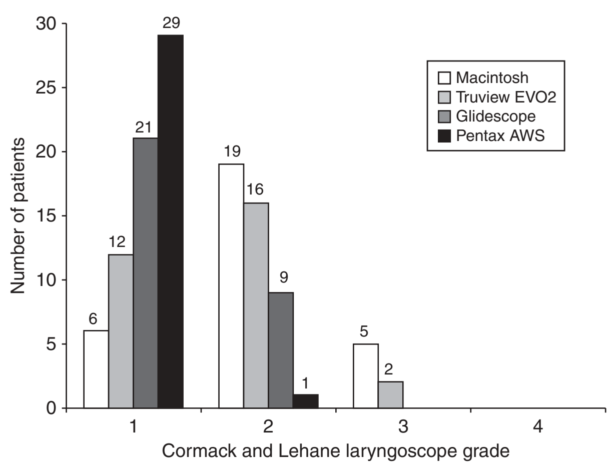

Fig 3 Cormack and Lehane grade view during the first tracheal intubation attempt with each laryngoscope. Number of patients is shown above each bar. $P<0.001$ between the groups, Kruskal–Wallis ANOVA on ranks.

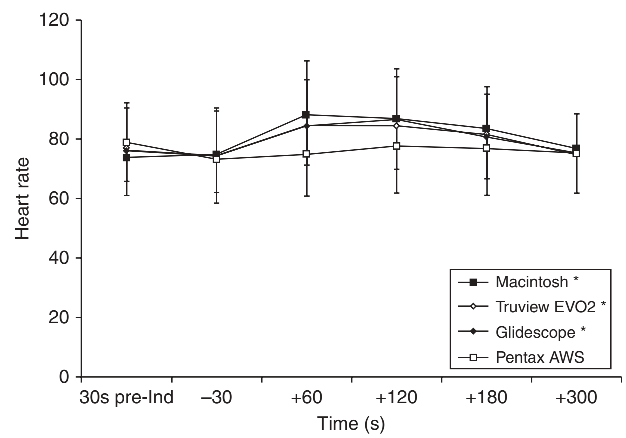

Fig 4 Graph representing the changes in heart rate after tracheal intubation with each device. The data are given as mean (SD). *Significant change in heart rate over time within each group. 30s Pre-Ind, 30 s before induction of anaesthesia; −30, 30 s before tracheal intubation, +60, 60 s post-tracheal intubation; +120, 120 s post-tracheal intubation; +180, 180 s post-tracheal intubation; +300, 300 s post-tracheal intubation.

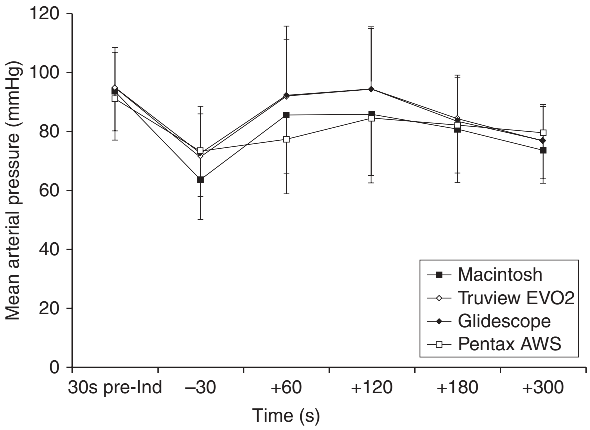

Fig 5 Graph representing the changes in mean arterial pressure after tracheal intubation with each device. The data are given as mean (SD). 30s Pre-Ind, 30 s before induction of anaesthesia; −30, 30 s before tracheal intubation, +60, 60 s post-tracheal intubation; +120, 120 s post-tracheal intubation; +180, 180 s post-tracheal intubation; +300, 300 s post-tracheal intubation.

efficacies of these novel laryngoscopes when used by experienced anaesthetists in the clinical setting of cervical spine immobilization using MIAS, and to compare these devices with the gold standard Macintosh laryngoscope.

Prior studies have demonstrated that the Glidescope® reduces the difficulty of tracheal intubation in patients undergoing cervical spine immobilization when compared with the Macintosh laryngoscope.[12 20] Our study confirms and extends these findings, and demonstrates that the Glidescope® reduced the IDS, improved the Cormack and Lehane grade, and reduced the number of optimization manoeuvres compared with the Macintosh. The Glidescope® was the only device that was successful in achieving tracheal intubation in all patients studied. Of interest, we found that the Glidescope® increased the duration of intubation attempts compared with the Macintosh, a finding which contrasts with some,[20 21] but not all,[13] previous studies. The authors did experience some difficulties advancing the tracheal tube towards the view of the video-monitor with the Glidescope, a finding previously reported by other investigators.[13] This did not reduce the success of tracheal intubation attempts, but was the principal reason for the increased duration of tracheal intubation in these patients. We utilized a 'hockey-stick' J-curvature of the stylet at the end of the tube, and passed the tube from the lateral side of the patient's mouth, as described by Sun and colleagues[13] and found that this approach worked well. In comparison with the other devices tested, the duration of intubation attempts, the Cormack and Lehane glottic view, and the number of optimization manoeuvres were not different from that required for the Truview EVO2®. In contrast, the duration of intubation attempts was longer, and the Cormack and Lehane glottic grade was higher with the Glidescope® compared with the AWS® laryngoscopes.

The Truview EVO2® laryngoscope may possess advantages over the Macintosh laryngoscope in patients at low risk for difficult intubation.[11 22] In addition, case reports exist which attest to its successful use in patients with difficult airways in whom laryngoscopy with the Macintosh laryngoscope failed.[23] In our study, the Truview EVO2® did reduce the IDS, enhanced the Cormack and Lehane glottic view, and reduced the number of optimization manoeuvres, when compared with the Macintosh. However, in certain respects, particularly in regard to duration of intubation attempts, the Macintosh performed superiorly to the Truview EVO2® laryngoscope. Furthermore, the Truview EVO2® did not perform as well as the other devices tested in this study. The duration of intubation attempts and the IDS were significantly higher with the Truview EVO2® in comparison with the Glidescope® and AWS® laryngoscopes. We used the Truview EVO2® with its camera attachment on the top of the blade in order to magnify the view of vocal cords via the eyepiece, but which also made the Truview EVO2® quite cumbersome to use. We experienced considerable difficulties advancing the tracheal tube towards the view of the digital camera, a finding again previously reported by other investigators.[22] This difficulty was the principal reason for the increased duration of tracheal intubation in these patients. There were also problems with fogging on the distal lens which reduced image quality. Several measures were used to reduce lens fogging, including insufflation of oxygen from the side port, warming of blade with hot water, and use of chemical defogging agents, with limited success.

The Pentax AWS® laryngoscope has recently been introduced into clinical practice. Recent studies indicate that this device may have advantages over the Macintosh in patients undergoing cervical spine immobilization.[15] This device also appears to cause less cervical spine movements during tracheal intubation when compared with the Macintosh or McCoy® laryngoscopes.[24] Our study confirms and extends these findings, and demonstrates that the AWS® reduced the IDS, enhanced the Cormack and Lehane glottic view, and reduced the number of optimization manoeuvres compared with the Macintosh. The AWS® did increase the duration of the successful, but not the first, intubation attempt compared with the Macintosh, a finding in good agreement with prior studies.[15] The AWS® significantly reduced the IDS, and provided the best Cormack and Lehane glottic view, compared with all other devices tested. Of interest, there was one failure to intubate in the AWS® group which was not related to poor view of vocal cords but to an inability to position the glottis in the centre of target symbol on the monitor display. The problem has been previously reported in case series and, in that case, was overcome with the use of a gum elastic bougie.[25] Finally, the AWS® caused less haemodynamic stimulation than the other laryngoscopes. Heart rate was not altered significantly with this device during intubation attempts, in contrast to the other devices, which significantly increased heart rate. Blunted heart rate response to intubation has also been described with the Airtraq®,[19] a similar device to the AWS®. These findings may reflect the fact these devices provide a view of the glottis without need to align the oral, pharyngeal, and tracheal axes, reducing cervical movement,[24] thereby reducing the potential for haemodynamic stimulation.

An important potential advantage of the Glidescope® and AWS® devices is that they have single-use disposable blades. This removes concerns regarding the potential for multi-use intubation devices to facilitate transmission of prions, which are thought to be responsible for causing variant Creutzfeldt–Jakob disease.[26 27] These concerns arise from the difficulties in ensuring that all proteinaceous material has been removed from reusable laryngoscope blades during cleaning and sterilization.[28 29] In recognition of these concerns, the guidelines of the Association of Anaesthetists of Great Britain and Ireland state that 'single use intubation aids' should be used where possible.[30]

Three important limitations exist regarding this study. First, we acknowledge that the potential for bias exists, as it is impossible to blind the anaesthetist to the device being used. Furthermore, certain measurements used in this study, such as laryngoscopic grading, are by their nature subjective. In fact, the appropriateness of using the Cormack and Lehane classification with indirect laryngoscopes, which may reduce the difficulty of obtaining a good glottic view, but not reduce the difficulty of tracheal intubation, is open to question. The advantage of using the Cormack and Lehane classification is that it is well understood by clinicians, and widely used in clinical practice. Reassuringly, there was a good agreement between subjective indices of difficulty of intubation and more objective measures, such as the IDS.[17] Secondly, this study was carried out in experienced users of each device. The results seen may differ in the hands of less experienced users. Finally, the relative efficacies of these devices in comparison with other promising devices such as the Airtraq®,[19 31] McCoy®,[24 32] McGrath®,[33 34] Bonfils®[35] intubating Laryngeal Mask Airway®,[36] or Bullard®[36] laryngoscopes have not been determined. Further comparative studies are needed to determine the relative efficacies of these devices.

In conclusion, Glidescope® and AWS® laryngoscopes appear to possess more advantages over the Macintosh laryngoscope than the Truview EVO2® laryngoscope when used by experienced anaesthetists in patients undergoing cervical immobilization.

Funding

Pentax Ltd provided the AWS® device and disposable blades, and Truphatek Ltd provided the Truview EVO2® laryngoscope, free of charge for use in the study. All other support came from institutional, departmental, or both sources.

Appendix

Intubation difficulty scale score

The IDS score is the sum of the following seven variables.

N1	Number of intubation attempts >1	——
N2	The number of operators >1	——
N3	The number of alternative intubation techniques used	——
N4	Glottic exposure (Cormack and Lehane grade minus 1)	——
N5	Lifting force required during laryngoscopy (0, normal; 1, increased)	——
N6	Necessity for external laryngeal pressure (0, not applied; 1, applied)	——
N7	Position of the vocal cords at intubation (0, abduction/not visualized; 1, adduction)	——

Note: IDS score reproduced from Adnet and colleagues.[17]

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