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Comparison of the C-MAC®, Airtraq®, and Macintosh laryngoscopes in patients undergoing tracheal intubation with cervical spine immobilization

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Editor's key points

- Manual inline axial cervical spine stabilization makes it more difficult to visualize the larynx using conventional laryngoscopy.
- Indirect laryngoscopy (Airtraq® and C-MAC®) might offer a better glottic visualization during manual inline stabilization.
- Airtraq® laryngoscope performed better than the C-MAC® and Macintosh laryngoscopes in patients undergoing tracheal intubation with cervical spine immobilization.

Background. We aimed at comparing the performance of the C-MAC®, Airtraq®, and Macintosh laryngoscopes when performing tracheal intubation in patients undergoing neck immobilization using manual inline axial cervical spine stabilization.

Methods. Ninety consenting patients presenting for surgery requiring tracheal intubation were randomly assigned to undergo intubation using a C-MAC® (n=30), Airtraq® (n=29), or Macintosh (n=31) laryngoscope. All patients were intubated by one anaesthetist experienced in the use of each laryngoscope.

Results. The Airtraq® laryngoscope performed best in these patients, reducing the Intubation Difficulty Scale score, improving the Cormack and Lehane glottic view, and reducing the need for optimization manoeuvres, compared with both the Macintosh and the C-MAC®. The C-MAC® and Macintosh laryngoscopes performed similarly. There were no differences in success rates or haemodynamic profiles post-intubation between any of the devices tested.

Conclusions. The Airtraq® laryngoscope performed better than the C-MAC® and Macintosh laryngoscopes in patients undergoing cervical immobilization.

Keywords: equipment, C-MAC® laryngoscope, Airtraq® laryngoscope, Macintosh laryngoscope; intubation, tracheal, difficult intubation, neck immobilization

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Manual inline axial stabilization (MIAS) of the cervical spine is widely used in clinical practice in patients with actual or suspected cervical spinal injuries, in order to reduce the risk of cord injury during tracheal intubation.[1] In fact, MIAS has become established as a standard of care for trauma patients.[2] A key concern is the fact that MIAS makes it more difficult to visualize the larynx using conventional laryngoscopy.[3–5] This can result in failure to successfully intubate the trachea and secure the airway, a complication that remains the leading cause of morbidity and mortality, in the operative[6–8] and emergency settings,[9 10] despite advances in airway management.

MIAS makes direct laryngoscopy more difficult, because of the difficulty in aligning the oral, pharyngeal, and laryngeal axes in order to visualize the cords when the neck is immobilized. In contrast, indirect laryngoscopes only require alignment of the pharyngeal and laryngeal axes, which lie along much more similar angles when compared with the oral axis. This may make tracheal intubation easier to accomplish in these patients.

The C-MAC® (Karl Storz Endoscopy, Tuttlingen, Germany) and Airtraq (Prodol Meditec S.A., Vizcaya, Spain) are indirect laryngoscopes recently introduced into clinical practice. The C-MAC® comprises a standard Macintosh blade connected to a video unit to which images are transmitted from a distal lens placed two-thirds of the way along the blade (Fig. 1A). The C-MAC can be used as a direct or an indirect laryngoscope, and it incorporates a Macintosh blade, so proficiency may be easier to acquire than with other indirect laryngoscopes. The Airtraq® is an indirect laryngoscope incorporating two channels, one of which transfers the image to a proximal viewfinder via a series of prisms and lenses, whereas the other acts as a conduit for the tracheal tube (TT) (Fig. 1B). The Airtraq® has demonstrated promise in a number of settings including simulated easy[11–14] and difficult[11–14] laryngoscopy and in patients at low[15] and higher risk[16–18] for difficult tracheal intubation.

We wished to determine the relative efficacy of the C-MAC® and Airtraq in comparison with the Macintosh laryngoscope in reducing intubation difficulty in patients undergoing MIAS. A prior study from our group demonstrated potential advantages for the C-MAC® over both the Macintosh and Airtraq® laryngoscopes in simulated difficult airway scenarios in manikins.[19] We therefore hypothesized that the C-MAC® laryngoscope would reduce intubation

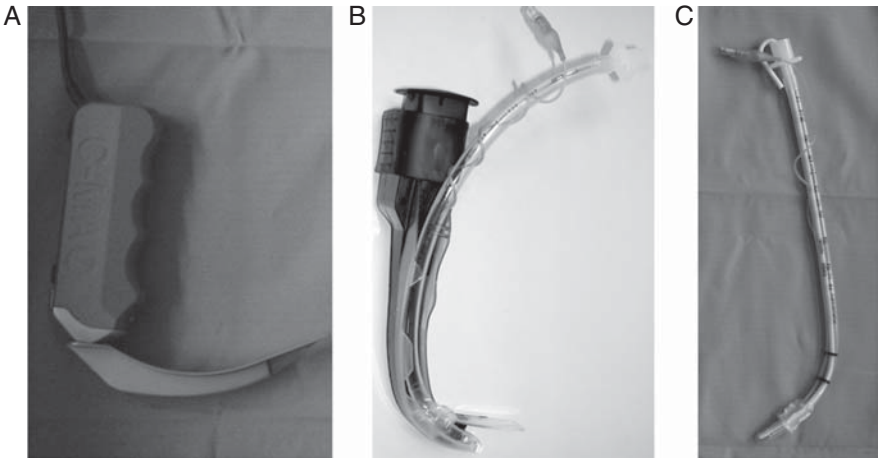

Fig 1 (A) Photograph of the C-MAC® laryngoscope. The cable is connected to a display unit. (B) Photograph of the Airtraq® laryngoscope. The TT is preloaded into the chamber of the device. (C) Photograph of the TT in the hockey stick configuration used for tracheal intubation with the C-MAC®.

difficulty in comparison with the Airtraq® and the Macintosh laryngoscopes.

Methods

After obtaining approval by the Galway University Hospitals Research Ethics Committee (Galway, Ireland), and written informed patient consent, we studied 90 ASA physical status I–III patients, aged 16 yr 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 (Mallampati class III or IV; thyromental distance <6 cm; 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 using online randomization software (http://www.randomization.com), and the allocation concealed in sealed envelopes, which were not opened until patient consent had been obtained. Patients were randomized to undergo tracheal intubation with the Macintosh, Airtraq®, or C-MAC®. All patients received a standardized general anaesthetic. Standard monitoring included ECG, non-invasive arterial pressure, 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 when available. Before induction of anaesthesia, all patients were given fentanyl (1–1.5 $\mu g\ kg^{-1}$) 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 a neuromuscular blocking agent was administered. The choice of neuromuscular blocking agent depended on the clinical context and was determined by the anaesthetist responsible for the case. Tracheal intubation was not performed until the BIS®/Entropy® score had decreased below 60, and additional boli of propofol were administered to increase the depth of anaesthesia if required. After the onset of neuromuscular block, 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 by one anaesthetist (J.M.) experienced in the use of all three laryngoscopes. Thereafter, 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 outcome measure was the intubation difficulty scale (IDS) score as described by Adnet and colleagues.[20] The IDS is a seven-point scoring system which describes the difficulty of intubation based on several parameters including number of attempts, the Cormack and Lehane view, lifting force required, and the position of the vocal cords (see Appendix). Ideal intubation conditions yield an IDS of 0 while progressively more difficult tracheal intubations result in higher scores. Secondary endpoints were the duration of the laryngoscopy attempt, duration of the tracheal intubation procedure, the total time required to secure the airway, and the rate of successful placement of the TT in the trachea. The duration of the laryngoscopy attempt was defined as the time taken from insertion of the blade between the teeth until the anaesthetist had

obtained the best possible view of the vocal cords. The duration of the intubation attempt was defined as the time taken from when the anaesthetist indicated the best view at laryngoscopy until the TT was placed through the vocal cords, as evidenced by visual confirmation by the anaesthetist. In patients in whom the TT was not directly visualized passing through the vocal cords, the intubation attempt was not considered complete until the TT was connected to the anaesthetic circuit and evidence obtained of the presence of carbon dioxide in the exhaled breath. The total time taken to secure the airway was the sum of all laryngoscopy and intubation times over the entire procedure. A maximum of three attempts were permitted after which the anaesthetist utilized an alternative laryngoscope. The alternative laryngoscope was predetermined and randomly selected (Macintosh, C-MAC®, or Airtraq®). While three attempts were permitted with the selected laryngoscope, if the anaesthetist felt it clinically appropriate to abandon the test laryngoscope and use an alternative device, then this was deemed acceptable. A failed intubation attempt was defined as an attempt in which the trachea was not intubated, or where the device was abandoned and another device utilized. Additional endpoints included the number of intubation attempts and the number of optimization manoeuvres required (use of a bougie, external laryngeal pressure, and second assistant) to aid tracheal intubation, the Cormack and Lehane grade at laryngoscopy,[21] the POGO (percentage of glottic opening)[22] score at laryngoscopy, and the total number of passes of the TT in the direction of the vocal cords. At the end of the intubation attempt, the anaesthetist rated the degree of difficulty of use of the device on a 100 mm visual analogue scale (VAS).

When the C-MAC® device was utilized, we pre-formed the TT into a hockey stick conformation with a stylet (Fig. 1c) as we have previously shown that this facilitates tracheal intubation when compared with a non-styletted TT.[23] For each attempt using the C-MAC®, we used it as an indirect laryngoscope. For each attempt using the Airtraq®, we utilized a video system which incorporates a video camera that attaches to the Airtraq® device and a wireless monitor which receives the images, therefore using the Airtraq® as a video laryngoscope. For all attempts using the Macintosh laryngoscope, the standard non-styletted non-hockey stick TT conformation was utilized.

Statistical analysis

We based our sample size estimation on our primary outcome measure, namely the IDS score. Based on our prior studies,[16] we considered that a clinically important between-group change in the mean IDS score for tracheal intubation was 2.0. Given an expected standard deviation (SD) of 2.25 from prior studies,[16] and using an α=0.05 and a β=0.2, for an experimental design incorporating three equal-sized groups, we estimated that 25 patients would be required per group. We therefore aimed to enrol 90 patients.

All analyses were performed on an intention-to-treat basis. Patient characteristic data and data for the duration of intubation attempts, the instrument difficulty score, the number of intubation attempts, the number of optimization manoeuvres, and VAS instrument difficulty scores were analysed using analysis of variance (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, with *post hoc* testing using the Student–Newman–Keuls test. Each device was compared with both of the other devices in these *post hoc* tests. Data are presented as means (SD) or as medians (inter-quartile range), as appropriate, with categorical data presented as number and as frequencies. The α level for all analyses was set as $P<0.05$.

Results

A total of 90 patients consented to participate in the study. One patient, who had been randomized to the C-MAC® group, was not subsequently entered into the study due to a change in the choice of anaesthetic technique (Laryngeal Mask Airway® utilized). There were no significant differences in patient characteristic or baseline airway parameters between the groups (Table 1). There were no between-group differences with regard to anaesthetic management, and there were no between-group differences in BIS® scores immediately before or after tracheal intubation (Table 1).

The IDS scores were significantly lower in patients intubated with the Airtraq® (median IDS=0) compared with those intubated with either the Macintosh (median IDS=3) or the C-MAC® (median IDS=2) laryngoscope (Fig. 2). The IDS scores were not different between the Macintosh and

Table 1 Characteristics of patients enrolled in the study. Data are reported as mean (SD), median (inter-quartile range), or as number (%)

Parameter assessed	C-MAC®	Airtraq®	Macintosh
Number per group	30	29	31
Male:female ratio	10/20	14/15	19/12
Age (yr)	54 (20)	52 (19)	58 (20)
Body mass index (kg m^{-2})	29 (5)	28 (4)	28 (7)
ASA classification (median, IQR)	2 (2,3)	2 (1,2)	2 (2,3)
Thyromental distance (cm)	8.2 (1.0)	8.2 (1.2)	8.1 (1.2)
Inter-incisor distance (cm)	4.5 (0.7)	4.5 (0.8)	4.3 (0.9)
Mallampati classification			
1	11 (37.7)	13 (44.8)	12 (38.7)
2	19 (63.3)	16 (55.2)	18 (58.1)
>2	0	0	1 (3.2)
Median (IQR)	2 (1, 2)	1 (1, 2)	2 (1, 2)
Bispectral index			
Before tracheal intubation	41 (18)	39 (16)	46 (17)
1 min post-tracheal intubation	40 (18)	40 (16)	46 (14)

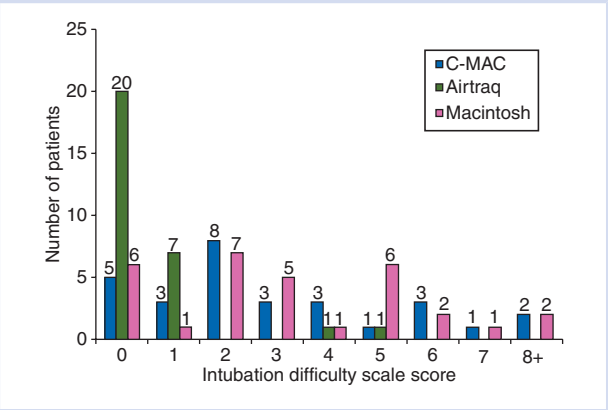

Fig 2 Comparison of IDS score distributions with each laryngoscope. Number of patients is shown above each bar. The IDS scores were lowest with the Airtraq® compared with both Macintosh and C-MAC® laryngoscopes. $P<0.001$ between groups, Kruskal–Wallis ANOVA on ranks.

C-MAC® groups (Fig. 2). All 29 patients were successfully intubated with the Airtraq®, compared with 28 of 29 with the C-MAC® and 29 of 31 with the Macintosh laryngoscopes (Table 2). The randomly allocated rescue device utilized for the failed intubation in the C-MAC® group was the Macintosh and a bougie was required to facilitate intubation. The allocated rescue device for the two failed intubations in the Macintosh group was the Airtraq®. This facilitated tracheal intubation on both occasions. There was no difference between the groups with regard to the duration of the first laryngoscopy, and/or intubation attempt, in the number of intubation attempts, or in the total time required to intubate the trachea successfully in each group (Table 2).

A greater number of optimization manoeuvres were required to facilitate tracheal intubation with the Macintosh and C-MAC® laryngoscopes compared with the Airtraq® laryngoscope. There was no difference in the number of optimization manoeuvres required with the Macintosh and C-MAC® laryngoscopes (Table 2). A significantly better Cormack and Lehane glottic view was obtained at laryngoscopy with the Airtraq® compared with the Macintosh and C-MAC® (Fig. 3). There was no difference in the Cormack and Lehane glottic view obtained at laryngoscopy between

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 Airtraq laryngoscope

Parameter assessed	C-MAC®	Airtraq®	Macintosh
Overall success rate (%)	28/29 (97)	29/29 (100)	29/31 (93)
Number of intubation attempts (%)			
1	26 (90)	28 (97)	25 (81)
2	2 (7)	1 (3)	4 (13)
3	1 (3)	0 (0)	2 (6)
Median (IQR)	1 (1, 2)	1 (1, 1)	1 (1, 1)
First tracheal intubation attempt (s)			
Laryngoscopy	14 (7, 26)	11 (8, 16)	12 (9, 21)
Insertion of TT	11 (6, 22)	7 (4, 13)	10 (5, 17)
Overall duration of intubation attempts (s)	27 (18, 47)	19 (14, 27)	23 (14, 47)
Total number of TT passes	1 (1, 2)	1 (1, 1.25)	1 (1, 1)
Cormack and Lehane glottic view (%)			
1	10 (34.5)*	25 (86)	6 (19.4)*
2	15 (51.7)	4 (14)	15 (48.4)
3	4 (13.8)	0	10 (32.2)
Median (IQR)	2 (1, 2)*	1 (1, 1)	2 (2, 3)*
No. of optimization manoeuvres (%)			
0	13 (45)*	29 (100)	11 (35)*
1	12 (41)	0	9 (30)
≥2	4 (14)	0	11 (35)
Median (IQR)	1 (0, 1)*	0 (0, 0)	1 (0, 2)*
Lowest Sa_{O_2} during intubation attempt (%)	98 (96, 98)*	98 (98, 99)	98 (96, 99)*
Incidence of complications			
Blood on laryngoscope blade	0	0	0
Minor laceration	3 (10)	1 (3.3)	2 (6.6)
Dental or other airway trauma	0	0	0
VAS difficulty score	3.1 (1.2, 5.7)*	1.0 (0.25, 2.7)	2.6 (1.2, 4.0)*

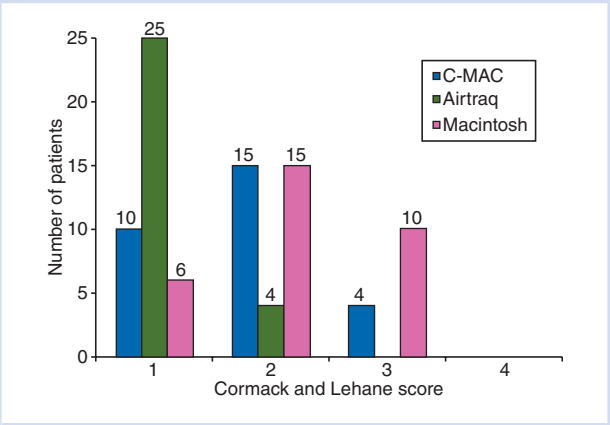

Fig 3 The Cormack and Lehane scores during the first intubation attempt with each laryngoscope. Number of patients is shown above each bar. The Cormack and Lehane scores were lowest with the Airtraq® compared with both Macintosh and C-MAC® laryngoscopes. $P<0.001$ between groups, Kruskal–Wallis ANOVA on ranks.

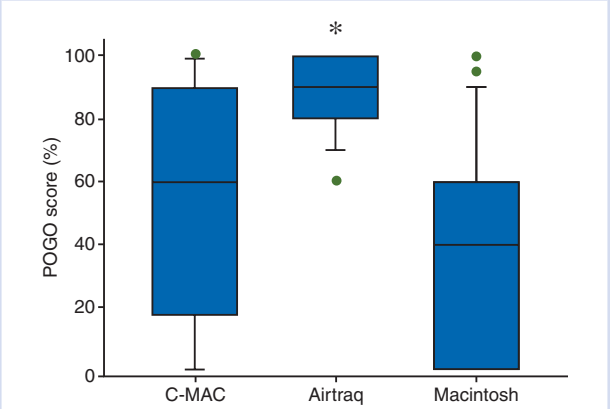

Fig 4 Box plot representing POGO scores with each device. The POGO scores were highest with the Airtraq® compared with both Macintosh and C-MAC® laryngoscopes. The middle line represents the median, whereas the borders of the box are the inter-quartile ranges. Outliers are represented by the solid dots. *$P<0.05$ compared with the Macintosh and C-MAC®, Kruskal–Wallis ANOVA on ranks.

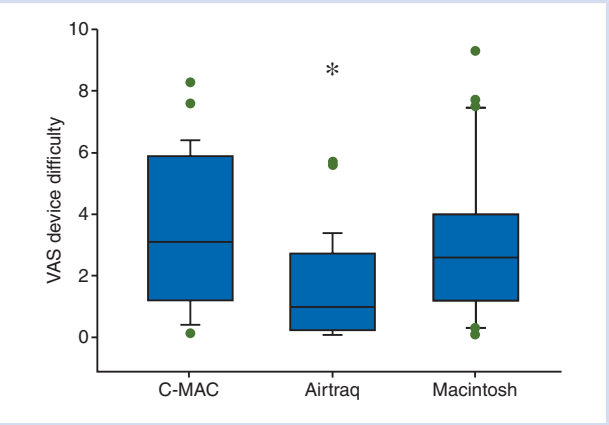

Fig 5 Box plot representing VAS difficulty scores with each device. VAS difficulty scores were significantly lower with the Airtraq® compared with both the Macintosh and the C-MAC®. The middle line represents the median, whereas the borders of the box are the inter-quartile ranges. Outliers are represented by the solid dots. *$P<0.05$ compared with the Macintosh and C-MAC®, Kruskal–Wallis ANOVA on ranks.

Table 3 Data for haemodynamic profile with each device. Data are reported as mean (SD), median (inter-quartile range), or as number (%)

Parameter assessed	C-MAC®	Airtraq®	Macintosh
Heart rate (min^{-1})			
Pre-induction	72 (16)	77 (13)	72 (13)
Pre-intubation	72 (14)	75 (12)	68 (19)
1 min post-intubation	77 (18)	79 (15)	77 (20)
2 min post-intubation	74 (18)	79 (14)	77 (20)
3 min post-intubation	77 (20)	79 (14)	75 (17)
5 min post-intubation	74 (17)	76 (16)	71 (17)
Mean arterial pressure (mm Hg)			
Pre-induction	96 (13)	100 (11)	100 (13)
Pre-intubation	75 (13)	76 (15)	74 (14)
1 min post-intubation	90 (26)	82 (21)	89 (24)
2 min post-intubation	86 (20)	88 (19)	84 (17)
3 min post-intubation	85 (25)	86 (13)	80 (14)
5 min post-intubation	80 (17)	79 (15)	75 (14)

the Macintosh and C-MAC® laryngoscopes. The Airtraq® group had significantly better POGO scores at laryngoscopy compared with the Macintosh and C-MAC® (Fig. 4). There was no difference in POGO scores obtained at laryngoscopy between the Macintosh and C-MAC® laryngoscopes.

There were no between-group differences in the incidence of complications between the groups. There was one minor lip laceration in the Airtraq® group, compared with three and two in the Macintosh and C-MAC® groups, respectively (Table 2). There was no incidence of dental or other airway trauma with any laryngoscope. Arterial haemoglobin oxygen saturations were maintained best in patients intubated with the Airtraq® laryngoscope (Table 2). VAS device difficulty scores were significantly lower with the Airtraq® compared with the C-MAC® and Macintosh laryngoscopes (Fig. 5). VAS device difficulty scores were not different with the C-MAC® compared with the Macintosh.

The effects of laryngoscopy and tracheal intubation on the mean arterial pressure and on heart rate were relatively modest. Heart rate increased significantly in all groups after tracheal intubation, but had returned to baseline within 5 min in all groups, with no between-group differences (Table 3). The mean arterial pressure decreased significantly in all groups after induction of anaesthesia, but there were no between-group differences at any time point (Table 3).

Discussion

Our findings demonstrate that the Airtraq® performed better than the C-MAC® and Macintosh laryngoscopes in patients undergoing cervical immobilization. The C-MAC® did not perform better than the Macintosh and performed poorly compared with the Airtraq® in this patient group, thus disproving our hypothesis. These findings contrast with our previous findings in manikins,[19] where the C-MAC® demonstrated some advantages over the Airtraq® and both devices performed superiorly to the Macintosh. These findings demonstrate the need to translate promising initial findings in manikin studies to more clinically relevant settings. The need for a sequential evaluation approach incorporating initial manikin studies followed by clinical studies is clear if we are to avoid a situation where a poorly designed laryngoscope results in patient harm.[24 25] A large number of novel laryngoscope devices have been introduced into clinical practice in recent years, despite having a relatively limited base supporting their use. Although certain devices, such as the Airtraq, have an emerging evidence base supporting their use in certain clinical situations, these devices must be considered to be non-conventional and remain the focus of ongoing study.

Laryngoscopy and tracheal intubation of the patient with potential cervical spinal injury is a high-risk procedure.[3–5] MIAS reduces segmental angular rotation and distraction and therefore potentially protects the patient from further injury in anatomic studies of simulated C4-5 ligamentous injury.[26] Oral tracheal intubation of 150 patients with traumatic cervical spine injuries with MIAS did not result in any neurological complications in one series.[27] In contrast, quadriplegia has occurred in association with airway management in a cervical spine-injured patient in whom neck immobilization was not performed.[28] Consequently, MIAS has become established as a standard of care for these patients.[2] The development of laryngoscopes that reduce tracheal intubation difficulty in these patients would represent a real advance.

Our findings confirm previous demonstrations, from our group[16–18] and others,[29] that the Airtraq® reduces tracheal intubation difficulty in these patients compared with the Macintosh laryngoscope. In this study, the Airtraq® reduced the intubation difficulty score, enhanced the Cormack and Lehane glottic view, and reduced the number of optimization manoeuvres compared with the Macintosh and the C-MAC®. The Airtraq® was the only device that was successful in achieving tracheal intubation in all patients studied. The Airtraq was the rescue device for the two failed intubations in the Macintosh group and was successful in each case, improving the Cormack and Lehane grade from 3 to 1 and POGO scores from 0 to 80 and 100, respectively. Arterial oxygen haemoglobin saturations were best maintained in the group intubated with the Airtraq® laryngoscope. The recently reported finding that the Airtraq produces 66% less movement of the cervical spine during MIAS when compared with the Macintosh[29] further underlines the utility of this device in this setting.

There are important limitations with regard to our 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. Secondly, the IDS score was initially devised and validated for use with direct laryngoscopy, and its utility when used with indirect laryngoscopes is less clear. Thirdly, this study was carried out by an experienced user of each device. The results seen may differ in the hands of less experienced users. Fourthly, we chose to apply manual inline stabilization of the cervical spine as opposed to utilizing a hard cervical collar as this is what occurs in clinical practice.[30] Finally, additional studies are required to determine the relative efficacy of the C-MAC® in comparison with other devices that have demonstrated advantages over the Macintosh in previous studies, such as the Glidescope®[31 32] and the Airwayscope®.[31–34]

In conclusion, our findings demonstrate that the Airtraq® laryngoscope performed better than the C-MAC® and Macintosh laryngoscopes in patients undergoing tracheal intubation with cervical spine immobilization.

Conflict of interest

None declared.

Funding

Storz® Ltd provided the C-MAC device and Prodol Ltd provided the Airtraq® devices free of charge for use in the study. All other support came from institutional and/or departmental sources.

Appendix

IDS 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] _____

*An attempt is defined as one advancement of the tube in the direction of the glottis during direct laryngoscopy.

Note. IDS score reproduced from Adnet and colleagues.[20]

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