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APPARATUS

Evaluation of intubation using the Airtraq® or Macintosh laryngoscope by anaesthetists in easy and simulated difficult laryngoscopy – a manikin study*

C. H. Maharaj,[1,2] B. D. Higgins,[2] B. H. Harte[1] and J. G. Laffey[1,2]

1 Department of Anaesthesia, University College Hospital Galway, Ireland
2 Department of Anaesthesia, Clinical Sciences Institute, National University of Ireland, Galway, Ireland

Summary

The Airtraq® Laryngoscope is a novel intubation device which allows visualisation of the vocal cords without alignment of the oral, pharyngeal and tracheal axes. We compared the Airtraq® with the Macintosh laryngoscope in simulated easy and difficult laryngoscopy. Twenty-five anaesthetists were allowed up to three attempts to intubate the trachea in each of three laryngoscopy scenarios using a Laerdal® Intubation Trainer followed by five scenarios using a Laerdal SimMan® Manikin. Each anaesthetist then performed tracheal intubation of the normal airway a second time to characterise the learning curve. In the simulated easy laryngoscopy scenarios, there was no difference between the Airtraq® and the Macintosh in success of tracheal intubation. The time taken to intubate at the end of the protocol was significantly lower using the Airtraq® (9.5 (6.7) vs. 14.2 (7.4) s), demonstrating a rapid acquisition of skills. In the simulated difficult laryngoscopy scenarios, the Airtraq® was more successful in achieving tracheal intubation, required less time to intubate successfully, caused less dental trauma, and was considered by the anaesthetists to be easier to use.

Correspondence to: Dr John Laffey
E-mail: john.laffey@nuigalway.ie
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Inability to successfully intubate the trachea remains a leading cause of anaesthetic morbidity and mortality [1, 2], notwithstanding recent developments in airway management strategies [3]. The absence of any single factor that reliably predicts the existence of a difficult airway [4] means that many difficult intubations are not recognised until after induction of anaesthesia. Despite recent developments in airway device technology, the curved laryngoscope blade described by Macintosh in 1943 remains the most popular device used to facilitate orotracheal intubation, and constitutes the gold standard [5].

The Airtraq® is a new intubation device that has been developed for the management of the normal and the difficult airway (Fig. 1). It is designed to provide a view of the glottis without alignment of the oral, pharyngeal and tracheal axes. The blade of the Airtraq® consists of two side by side channels. One channel acts as the housing for the placement and insertion of the tracheal tube, and the other channel terminates in a distal lens. A battery operated light is present at the tip of the blade. The image is transmitted to a proximal viewfinder using a combination of lenses and prisms, rather than fibreoptics. The viewing lens allows visualisation of the glottis and surrounding structures, and the tip of the tracheal tube. The Airtraq® is anatomically shaped and standard tracheal tubes of all sizes can be used. A clip-on wireless video system is also available which allows viewing on an external screen. This may be particularly useful for teaching purposes.

To use the Airtraq® device, the blade must be inserted into the mouth in the midline, over the centre of the tongue, the tip positioned in the vallecula (Fig. 2). Where necessary, the epiglottis can be lifted by elevating the

Figure 1 Photograph of the Airtraq® laryngoscope with a tracheal tube in place in the side channel.

blade into the vallecula. The tracheal tube does not obstruct the endoscopic view of the vocal cords during intubation, unlike, for example, the Bullard laryngoscope [6]. Once the view of the glottis has been optimised, the tracheal tube is passed through the vocal cords, held in place, and the device removed (Fig. 2).

The performance of the Airtraq® in the management of the airway (both normal and difficult) remains to be determined. The purpose of this study was to evaluate the usefulness of this new device for use by experienced anaesthetists in anatomically correct manikins. We hypothesised that, in the hands of experienced anaesthetists, the Airtraq® would perform comparably to the Macintosh laryngoscope in the normal airway. In the difficult airway, we hypothesised that the Airtraq® would prove superior to the Macintosh laryngoscope. We compared its performance to that of the Macintosh laryngoscope in simulated scenarios of varying degrees of difficulty of tracheal intubation.

Methods

Following ethical committee approval and written informed consent, 25 anaesthetists with at least 2 years clinical experience consented to participate in the study.

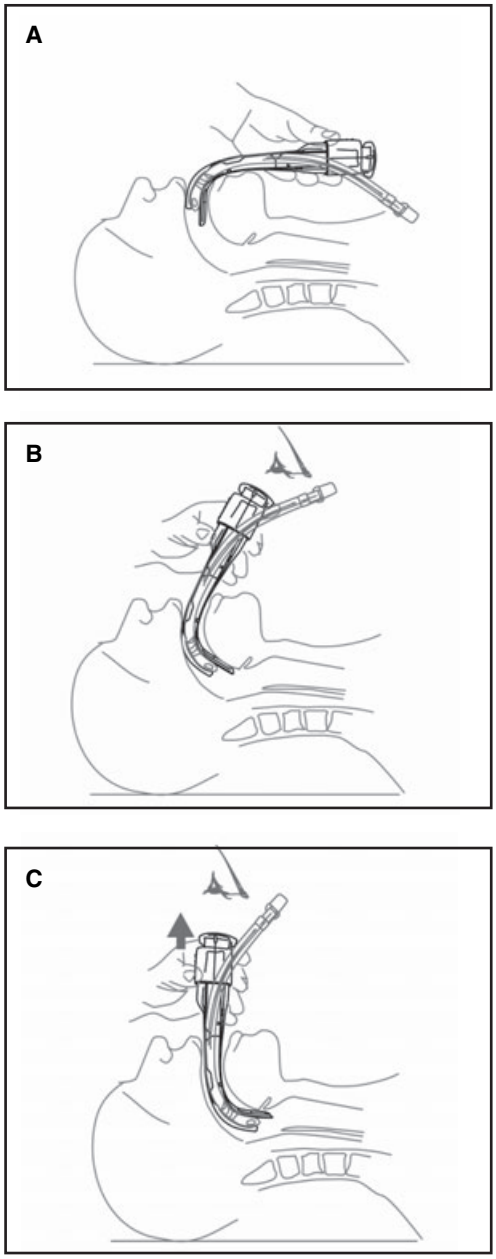

Figure 2 Technique of tracheal intubation with the Airtraq® laryngoscope. The device is held in the left hand and passed into the mouth over the tongue, in the midline (A). Once the device has been passed over the back of the tongue, the view from the viewfinder is used to position the tip in the vallecula (B). The view of the glottis can be optimised by lifting the epiglottis by elevating the blade into the vallecula (C). Once the glottis is in the centre of the view seen from the viewfinder, the ETT is then passed from its position in the channel through the vocal cords. The ETT is then moved laterally to remove it from the channel, the device is withdrawn, and the ETT secured.

No anaesthetist had prior experience of using the Airtraq®, and all had performed a minimum of 500 tracheal intubations using the Macintosh laryngoscope.

Each anaesthetist was given a standardised 2-min demonstration of the Airtraq® device by one of the investigators, which included a demonstration of the intubation technique and a set of seven instructions regarding the correct use of the device (Appendix 1). Each participant was then allowed two practice intubations using each device. All intubations were performed using a 7.5-mm cuffed tracheal tube. The sequence in which each participant used the devices was randomised, and each anaesthetist used the devices in the same sequence throughout the protocol.

The design of the study was a randomised crossover trial. Each anaesthetist first performed tracheal intubation with each device in a Laerdal Airway Management Trainer (Laerdal, Stavanger, Norway) in the following laryngoscopy scenarios:

1 normal airway in the supine position;
2 normal airway in the left lateral position
3 normal airway with the neck immobilised using a hard cervical collar.

The participants then performed tracheal intubation in a SimMan® manikin (Laerdal, Kent, UK) in the following difficult laryngoscopy scenarios:

4 tongue oedema
5 cervical spine rigidity
6 pharyngeal obstruction
7 cervical rigidity with pharyngeal obstruction
8 jaw trismus.

At the end of this protocol, each subject performed tracheal intubation of the normal airway a second time in the Laerdal® Airway Management Trainer with the Airtraq® to characterise the learning curve.

The primary endpoints were the rate of successful placement of the tracheal tube (ETT) in the trachea and the time required for successful tracheal intubation. A failed intubation attempt was defined as an attempt in which the trachea was not intubated, or which required >120 s to perform. The duration of the successful intubation 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 participant. Where the ETT was not visualised passing through the vocal cords, the intubation attempt was not considered complete until the ETT was connected to a self-inflating bag and lung inflation confirmed. The final tracheal tube position was verified in all cases by an investigator.

Additional endpoints included the number of intubation attempts, the number of optimisation manoeuvres required (re-adjustment of head position, use of a bougie, second assistant) to aid tracheal intubation and the severity of dental trauma. The severity of dental trauma was calculated based on the number of audible teeth clicks (0, 1 or ≥ 2) with the Laerdal airway trainer, and based on a grading of pressure on the teeth (none $= 0$, mild $= 1$, moderate/severe ≥ 2) in the SimMan® manikin. At the end of each scenario, each participant scored the ease of use of each device on a visual analogue scale (from $0 =$ Extremely Easy to $10 =$ Extremely Difficult).

Data for the success of tracheal intubation attempts were analysed using Fisher's exact test. Data for duration of the first and the successful intubation attempt and the instrument difficulty score were analysed using *t*-test for two group comparisons. For three group comparisons, a one-way analysis of variance (ANOVA) or Kruskall-Wallis analysis, with post hoc Student-Neuman-Keuls testing, was performed, as appropriate. The number of intubation attempts, number of optimisation manoeuvres and severity of dental trauma were analysed using the Mann–Whitney Rank sum test for two group comparisons and the Kruskall-Wallis analysis, with post hoc Student-Neuman-Keuls testing for three group comparisons.

Continuous data are presented as means (standard deviation (SD)), ordinal data are presented as medians (quartiles (interquartile range)), and categorical data are presented as number and as frequencies. The α level for all analyses was set at $p < 0.05$.

Results

Twenty-five anaesthetists of varying seniority participated in this study. Each participant had previously performed at least 500 intubations using the Macintosh laryngoscope, and no participating anaesthetist had prior experience of using the Airtraq® device (Table 1).

Scenario 1 – normal airway

All anaesthetists successfully intubated the trachea using both devices (Table 2). Two anaesthetists required two attempts to intubate the trachea with the Airtraq® laryngoscope at the start of the protocol. There was no difference in the time taken for successful tracheal intubation attempts using the Airtraq® compared to the

Table 1 Details of the anaesthetists who participated in the study.

Grade	No. of Participants	Experience in Anaesthesia (years)	Estimated no. of Intubations performed
Consultant	10 (40%)	15.6 (4.0)	11 700 (6500)
Specialist Registrar	10 (40%)	5.8 (2.3)	4300 (1702)
SHO/Registrar	5 (20%)	5.2 (4.6)	2600 (2500)

Data are given as mean (SD) or number (percentage).

Table 2 Data from easy laryngoscopy scenario in Laerdal® Airway Trainer.

Parameter Assessed	Macintosh	Airtraq®*	Airtraq®**
Overall success rate; %	25 (100)	25 (100)	25 (100)
Duration of 1st intubation attempt; s	14.2 (7.4)	19.0 (16.2)	9.5 (6.7)†
No. of intubation attempts; %			
1	25 (100)	23 (92)	25 (100)
2	0	2 (8)	0
3	0	0	0
No. of optimisation manoeuvres; %			
0	23 (92)	25 (100)	25 (100)
1	2 (8)	0	0
≥ 2	0	0	0
Severity of dental trauma; teeth clicks			
0	19 (76)	24 (96)	25 (100)
1	5 (20)	1 (4)	0
≥ 2	1 (4)	0	0

Data are reported as mean (SD) or as number (percentage).
*Use of the Airtraq® device at the start of the protocol.
**Use of the device at the end of the protocol.
†Significantly ($p < 0.05$) different compared to both other groups.

Macintosh Laryngoscope (Fig. 3). At the end of the protocol, all anaesthetists again intubated the trachea using the Airtraq®. The duration of this intubation attempt was significantly shorter than the earlier attempts with the Macintosh and Airtraq® laryngoscopes, illustrating the rapid acquisition of skills with the Airtraq® (Fig. 3). The anaesthetists rated the Airtraq® as significantly less difficult to use in this scenario (Fig. 4).

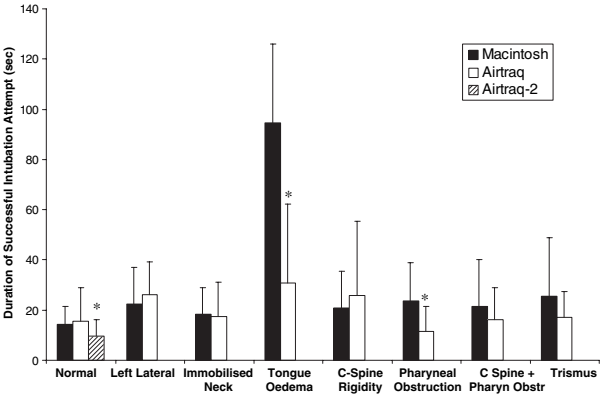

Figure 3 Graph representing the time required to successfully intubate the trachea with each device in each scenario tested. The data are given as mean (SD). ⋆Significantly different compared to the Macintosh Laryngoscope. Airtraq-2 denotes the use of the device at the end of the protocol. Normal, normal airway; Left Lateral, intubation of the normal airway in the left lateral position; Immobilised Neck, intubation of the normal airway with a hard cervical collar in place; Tongue Oedema, SimMan® Tongue Oedema Scenario; C-Spine Rigidity, SimMan® Cervical Spine Rigidity Scenario; Pharyngeal Obstruction, SimMan® Pharyngeal Obstruction Scenario; C Spine + Pharyn Obstr, SimMan® combined Cervical Spine Rigidity and Pharyngeal Obstruction Scenario; Trismus, SimMan® Jaw Trismus Scenario.

Scenario 2 – normal airway with head in left lateral position

The Airtraq® performed comparably to the Macintosh Laryngoscope in this scenario. One anaesthetist failed to intubate the trachea with the Airtraq® (Table 3). The duration of tracheal intubation attempts was similar with each device (Fig. 3). There was a trend to less dental trauma with the Airtraq® compared to the Macintosh laryngoscope (Table 3). No difference was reported in the degree of difficulty of use of each device (Fig. 4).

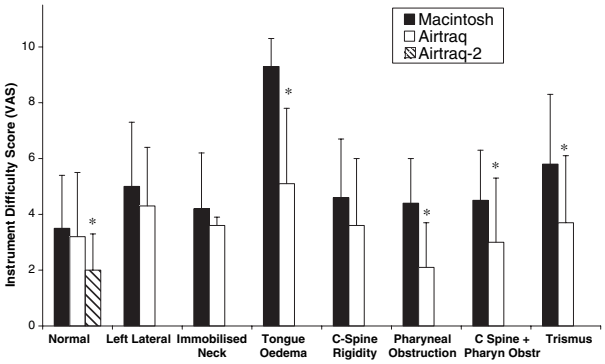

Figure 4 Graph representing the user rated degree of difficulty of use of each instrument in each scenario tested. The data are given as mean (SD). ⋆Significantly different compared to the Macintosh Laryngoscope. Airtraq-2 denotes the use of the device at the end of the protocol. For abbreviations, see legend to Fig. 3.

Table 3 Data from laryngoscopy in left lateral position scenario in Laerdal® Airway Trainer.

Parameter assessed	Macintosh	Airtraq®
Overall success rate; %	25 (100)	24 (96)
Duration of 1st intubation attempt; s	22.4 (14.6)	27.2 (16.5)
No. of intubation attempts; %		
1	25 (100)	21 (84)
2	0	3 (12)
3	0	1 (4)
No. of optimisation manoeuvres; %		
0	20 (80)	24 (960)
1	5 (20)	1 (4)
≥ 2	0	0
Severity of dental trauma; teeth clicks		
0	19 (76)	25 (100)
1	3 (12)	0
≥ 2	3 (12)	0

Data are reported as mean (SD) or as number (percentage).

Table 4 Data from cervical immobilisation scenario in Laerdal® Airway Trainer.

Parameter assessed	Macintosh	Airtraq®
Overall success rate; %	25 (100)	25 (100)
Duration of 1st intubation attempt; s	18.5 (10.5)	18.0 (14.2)
No. of intubation attempts; %		
1	25 (100)	23 (92)
2	0	1 (4)
3	0	1 (4)
No. of optimisation manoeuvres; %		
0	21 (84)	24 (96)
1	3 (12)	0
≥ 2	1 (4)	1 (4)
Severity of dental trauma; teeth clicks		
0	17	22
1	5	1
≥ 2	3	2

Data are reported as mean (SD) or as number (percentage).

Table 5 Data from tongue oedema scenario in SimMan® Manikin.

Parameter assessed	Macintosh	Airtraq®
Overall success rate; %	11 (44)	23 (92)*
Duration of 1st intubation attempt; s	74.3 (37.0)	40.6 (39.4)*
No. of intubation attempts; %		
1	6 (24)	16 (64)*
2	4 (16)	6 (24)
3	15 (60)	3 (12)
No. of optimisation manoeuvres; %		
0	1 (4)	24 (96)*
1	8 (32)	1 (4)
≥ 2	16 (64)	0
Severity of dental trauma; teeth compression		
0	1 (4)	6 (24)*
1	0	14 (56)
≥ 2	24 (96)	5 (20)

Data are reported as mean (SD) or as number (percentage).
*Significantly ($p < 0.01$) different compared to the Macintosh laryngoscope.

Table 6 Data from cervical spine rigidity scenario in SimMan® Manikin.

Parameter assessed	Macintosh	Airtraq®
Overall success rate; %	25 (100)	23 (92)
Duration of 1st intubation attempt; s	27.2 (21.6)	25.6 (28.0)
No. of intubation attempts; %		
1	21 (84)	23 (92)
2	4 (16)	0
3	0	2 (8)
No. of optimisation manoeuvres; %		
0	11 (44)	21 (84)*
1	12 (48)	3 (12)
≥ 2	2 (8)	1 (4)
Severity of dental trauma; teeth compression		
0	2 (8)	14 (56)†
1	5 (20)	8 (32)
≥ 2	18 (72)	3 (12)

Data are reported as mean (SD) or as number (percentage).
*Significantly ($p < 0.05$) different compared to the Macintosh laryngoscope.
†Significantly ($p < 0.01$) different compared to the Macintosh laryngoscope.

Scenario 3 – normal airway with cervical immobilisation

The Airtraq® device performed comparably to the Macintosh Laryngoscope in this scenario. All anaesthetists successfully intubated the trachea with both devices (Table 4). One anaesthetist required two attempts and another three attempts with the Airtraq®. However, the duration of tracheal intubation was similar with both devices (Fig. 3). Although the number of optimisation manoeuvres and incidence of dental trauma was higher in the Macintosh group, this difference was not statistically significant (Table 4). There was no difference in the degree of difficulty of use of each device (Fig. 4).

Scenario 4 – difficult airway due to tongue oedema

The performance of the Airtraq® device was superior to that of the Macintosh Laryngoscope in this scenario (Table 5). The rate of successful intubation of the trachea with the Airtraq® device was twice that seen with the Macintosh laryngoscope (Table 5). The duration of tracheal intubation was significantly shorter with the Airtraq® (Fig. 3), and the number of intubation attempts, the number of optimisation manoeuvres and the dental compression scores were all significantly lower (Table 5). The anaesthetists found the Airtraq® significantly easier to use in this scenario (Fig. 4).

Scenario 5 – difficult airway with cervical spine rigidity

The Airtraq® device performed similarly to the Macintosh Laryngoscope in this scenario (Table 6). The overall success rate, the duration of tracheal intubation and the number of intubation attempts were similar in both groups (Table 6 and Fig. 3). However, the number of optimisation manoeuvres and the severity of dental compression were all significantly lower with the Airtraq® (Table 6). There was no difference in the degree of difficulty of use of each device (Fig. 4).

Scenario 6 – difficult airway with pharyngeal obstruction

The performance of the Airtraq® device was superior to that of the Macintosh Laryngoscope in this scenario (Table 7). All anaesthetists successfully intubated the

Table 7 Data from pharyngeal obstruction scenario in SimMan® Manikin.

Parameter assessed	Macintosh	Airtraq®
Overall success rate; %	25 (100)	25 (100)
Duration of 1st intubation attempt; s	23.6 (15.2)	11.5 (10.1)†
No. of intubation attempts; %		
1	25 (100)	25 (100)
2	0	0
3	0	0
No. of optimisation manoeuvres; %		
0	15 (60)	24 (96)*
1	10 (40)	1 (4)
≥ 2	0	0
Severity of dental trauma; teeth compression		
0	5 (20)	19 (76)†
1	8 (32)	6 (24)
≥ 2	12 (48)	0

Data are reported as mean (SD) or as number (percentage).
*Significantly ($p < 0.05$) different compared to the Macintosh laryngoscope.
†Significantly ($p < 0.01$) different compared to the Macintosh laryngoscope.

trachea with both devices. The duration of tracheal intubation was approximately 50% shorter with the Airtraq® (Fig. 3), and the number of optimisation manoeuvres and dental compression scores were significantly lower (Table 7). The instrument difficulty score was also approximately 50% lower with the Airtraq® (Fig. 4).

Scenario 7 – difficult airway with cervical rigidity and pharyngeal obstruction

The performance of the Airtraq® device was superior to that of the Macintosh Laryngoscope in this scenario (Table 8). All anaesthetists successfully intubated the trachea with both devices. One anaesthetist required two attempts with the Macintosh to intubate the trachea successfully. However, the duration of tracheal intubation was similar with both devices (Fig. 3). The number of optimisation manoeuvres, severity of dental compression, and the instrument difficulty score were significantly lower with the Airtraq® (Table 8 and Fig. 4).

Table 8 Data from combined cervical rigidity and pharyngeal obstruction scenarios in SimMan® Manikin.

Parameter assessed	Macintosh	Airtraq®
Overall success rate; %	25 (100)	25 (100)
Duration of 1st intubation attempt; s	22.9 (20.1)	16.3 (12.5)
No. of intubation attempts; %		
1	23 (92)	25 (100)
2	2 (8)	0
3	0	0
No. of optimisation manoeuvres; %		
0	8 (32)	23 (92)†
1	15 (60)	2 (8)
≥ 2	2 (8)	0
Severity of dental trauma; teeth compression		
0	0	13 (52)†
1	4 (16)	12 (48)
≥ 2	21 (84)	0

Data are reported as mean (SD) or as number (percentage).
†Significantly ($p < 0.01$) different compared to the Macintosh laryngoscope.

Scenario 8 – Difficult airway with jaw trismus

The performance of the Airtraq® device was superior to that of the Macintosh Laryngoscope in this scenario (Table 9). One anaesthetist failed to intubate the trachea with the Macintosh laryngoscope. The duration of tracheal intubation was similar with both devices (Fig. 3). The number of intubation attempts was similar in both groups, whereas the number of optimisation manoeuvres, severity of dental compression, and the instrument difficulty score were significantly lower with the Airtraq® (Table 9 and Fig. 4).

Table 9 Data from trismus scenario in SimMan® Manikin.

Parameter assessed	Macintosh	Airtraq®
Overall success rate; %	24 (96)	25 (100)
Duration of 1st intubation attempt; s	22.8 (14.4)	23.8 (27.2)
No. of intubation attempts; %		
1	23 (92)	23 (92)
2	1 (4)	1 (4)
3	1 (4)	1 (4)
No. of optimisation manoeuvres; %		
0	8 (32)	23 (92)†
1	15 (60)	2 (8)
≥ 2	2 (8)	0
Severity of dental trauma; teeth compression		
0	0	7 (28)†
1	2 (8)	15 (60)
≥ 2	23 (92)	3 (12)

Data are reported as mean (SD) or as number (percentage).
†Significantly ($p < 0.01$) different compared to the Macintosh laryngoscope.

Discussion

The curved laryngoscope blade described by Macintosh in 1943 remains the most popular device used to facilitate tracheal intubation, notwithstanding recent developments in airway device technologies, and therefore constitutes the gold standard [5]. We therefore decided to compare the utility of the Airtraq® to the Macintosh laryngoscope in anatomically correct manikins. Laryngoscopy was performed by experienced anaesthetists on two different manikins in a variety of scenarios simulating easy and difficult laryngoscopy and intubation. The simulation of intubation scenarios in anatomically correct manikins has been widely used for similar studies in the past. It has

yielded considerable insights into the relative utilities of intubating devices, and has proven a reliable surrogate for the clinical context [6–23].

Our study demonstrates that, in comparison with the Macintosh laryngoscope, the Airtraq® provides comparable intubating conditions in the normal airway. Furthermore, the acquisition of skill with the device proved rapid, as evidenced by the fact that, by the end of the protocol, successful tracheal intubation of the normal airway was significantly shorter than intubation with either the Macintosh or Airtraq® laryngoscope at the start of the protocol. In the left lateral position, one anaesthetist failed to intubate the trachea of the manikin, possibly due to their relative lack of experience with this device at this early stage in the study. In the simulated difficult airway scenarios, in general, the Airtraq® provided better intubating conditions, required fewer airway optimisation manoeuvres, caused less dental trauma, and had greater overall success in tracheal intubation than the Macintosh laryngoscope.

There appears to be less potential for trauma to the teeth and upper airway with the Airtraq®. Dental trauma scores, as measured by the number of dental clicks and/or the severity of dental compression, were lower with the Airtraq® laryngoscope, particularly in the difficult airway scenarios. This is due to the fact that the Airtraq® provides a high quality view of the glottis (Fig. 5) without a need to align the oral, pharyngeal and tracheal axes, and therefore means that less force has to be applied during laryngoscopy. The importance of this finding is underlined by the fact that actual trauma to the oral tissues has been reported in 6.9% of patients undergoing conventional laryngoscopy and tracheal intubation [24].

Figure 5 Photograph of the image of the glottis seen through the proximal lens of the Airtraq® laryngoscope in the Laerdal® Airway Trainer manikin.

The Airtraq® proved easier to use than the more familiar Macintosh laryngoscope, particularly in the difficult airway scenarios. The Airtraq® may require less operator skill and it therefore may prove easier to teach personnel who perform tracheal intubation infrequently, such as emergency room staff. Although this study does not directly examine this issue, the rapid learning curve supports this contention. All anaesthetists were skilled in the use of the Macintosh laryngoscope and were given a deliberately brief – 2 min – demonstration of the device prior to the evaluation of the device. They were then allowed a maximum of two practice attempts at intubation with this device before they proceeded with the study. Despite their experience and familiarity with the Macintosh laryngoscope, they preferred the Airtraq®, as reflected in the instrument difficulty scores, particularly in the difficult airway scenarios. These findings support the ease of use and the rapid learning curve associated with this device.

An important potential advantage of the Airtraq® is that it is a single-use device, reducing the chance of prion transfer [25, 26]. These concerns arise from the difficulties in ensuring that all proteinaceous material has been removed from reusable laryngoscope blades during cleaning and sterilisation [27, 28]. 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 wherever possible [29]. However, studies have reported that certain single use laryngoscope blades provide inferior intubating conditions compared to reusable blades, such as the Macintosh [30, 31]. These findings raise concern regarding the safety of single use conventional laryngoscope blades. Our study demonstrates that the Airtraq® is at least as effective as the reusable Macintosh bladed laryngoscope, attesting to its safety in this regard.

In conclusion, the Airtraq® laryngoscope offers a new approach for the management of the normal and the difficult airway. In these manikin studies, the performance of the Airtraq® laryngoscope was similar to that of the Macintosh laryngoscope for tracheal intubation in the normal airway and was superior in the management of the difficult airway. Further studies, in both manikins and in the clinical context, are necessary to confirm these initial positive findings.

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Conflict of Interest

The authors have no conflict of interest with regard to the Airtraq® device.

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Appendix 1 – Instructions for use of Airtraq® Device

1 Apply lubricant to the outside of the ETT
2 Insert ETT into the channel of the Airtraq® so that the tip of the ETT is at the tip of the channel
3 Switch on the Airtraq® light
4 Hold the device in your left hand
5 Insert the device into the mouth in the midline and pull towards you so that the tip of the device slides over the base of the tongue.
6 Look through the viewfinder to optimise the view by advancing, retracting and/or lifting the device blade as necessary
7 Ensure that the view of the vocal cords is in the centre of the viewfinder before attempting to advance the ETT.