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SCIENTIFIC ARTICLE

A randomised crossover trial comparing the Airtraq[®] NT, McGrath[®] MAC and Macintosh laryngoscopes for nasotracheal intubation of simulated easy and difficult airways in a manikin



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KEYWORDS

Intubation;
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Abstract

Objective: Several devices can aid nasotracheal intubation when managing difficult airways. The McGrath MAC and Airtraq NT were compared with a Macintosh laryngoscope when studying the performance of anaesthetists with different levels of experience, in a manikin model of easy or difficult airway scenarios.

Methods: Sixty-three anaesthetists were recruited into a randomised trial in which each performed nasotracheal intubation with all laryngoscopes, in both scenarios. The main endpoint was intubation time. Additional endpoints included laryngoscopic view, intubation success, number of optimisation manoeuvres, audible dental clicks and the force applied to the upper airway.

Results: Intubation time was significantly shorter using the McGrath MAC in both scenarios and using the Airtraq in the difficult scenario, when compared with the Macintosh laryngoscope. Both devices gave more Cormack and Lehane grade 1 or 2 views than the Macintosh in the difficult scenario ($p < 0.001$). The McGrath MAC had the best first-attempt success rate (98.4% vs. 96.8% and 95.8%, $p < 0.001$ for the Airtraq NT and Macintosh laryngoscopes respectively). The number of optimisation manoeuvres, audible dental clicks and subjective assessment of the degree of force applied were significantly lower for indirect laryngoscopes versus the Macintosh laryngoscope ($p < 0.001$).

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Conclusion: In a manikin, the Airtraq and the McGrath laryngoscopes appeared superior to the Macintosh laryngoscope when dealing with simulated airway scenarios. Both devices were associated with better views, intubation times and rates of success, especially in a simulated "difficult airway". Overall satisfaction was highest with the McGrath laryngoscope. Similar clinical studies are needed.

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PALAVRAS-CHAVE

Intubação;
Laringoscópios;
Manequim;
Estudo randômico e controlado

Estudo cruzado e randômico comparando os laringoscópios Airtraq® NT, McGrath® MAC e Macintosh para intubação nasotraqueal em simulação de via aérea fácil e difícil em manequim

Resumo

Objetivo: Vários dispositivos podem ajudar a intubação nasotraqueal no manejo de via aérea difícil. Os laringoscópios McGrath MAC e Airtraq NT foram comparados com um laringoscópio Macintosh em estudo do desempenho de anestesistas com diferentes níveis de experiência, em manequim com cenário de via aérea fácil ou difícil.

Métodos: Sessenta e três anestesistas foram recrutados para um estudo randômico, no qual cada um realizou intubação nasotraqueal com todos os laringoscópios, em ambos os cenários. O desfecho primário foi o tempo de intubação. Desfechos adicionais incluíram vista laringoscópica, sucesso na intubação, número de manobras de otimização, cliques dentais audíveis e força aplicada nas vias aéreas superiores.

Resultados: O tempo de intubação foi significativamente menor com o uso do laringoscópio McGrath MAC em ambos os cenários e com o uso do Airtraq no cenário difícil, em comparação com o laringoscópio Macintosh. Ambos os dispositivos obtiveram mais grau 1 ou 2 de Cormack e Lehane para visualização que o Macintosh em cenário difícil ($p < 0,001$). O McGrath MAC teve a melhor taxa de sucesso na primeira tentativa (98,4% vs. 96,8% e 95,8%, $p < 0,001$, para os laringoscópios Airtraq NT e Macintosh, respectivamente). O número de manobras de otimização, os cliques dentais audíveis e a avaliação subjetiva do grau de força aplicada foram significativamente menores para os laringoscópios indiretos *versus* o laringoscópio Macintosh ($p < 0,001$).

Conclusão: Em um manequim, os laringoscópios Airtraq e McGrath pareceram superiores ao laringoscópio Macintosh para lidar com cenários das vias aéreas simuladas. Ambos os dispositivos foram associados a melhores visibilidades, tempos de intubação e taxas de sucesso, especialmente em simulação de "via aérea difícil". A satisfação geral foi maior com o laringoscópio McGrath. Estudos clínicos similares são necessários.

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Introduction

Airway management for oral and maxillofacial surgery can be a major challenge. The high incidence of difficult intubation compared to within the general population is due to congenital variations or pathology of the oral and the upper airway anatomy secondary to infection, tumour, surgery or radiotherapy.^{1,2} Nasotracheal intubation (NTI) is generally needed to allow unrestricted surgical access and is usually performed using a Macintosh laryngoscope and Magill forceps. This necessitates alignment of the oropharyngeal-laryngeal axes for visualisation of the glottis and tracheal intubation³; and may fail or be poorly tolerated by an awake patient with a 'difficult airway', resulting in morbidity and even mortality.⁴ Use of a fiberoptic bronchoscope has

been recommended in this scenario, but this device is often unavailable and the technique is less familiar and requires additional skill and training to be used effectively,^{5,6} making alternatives necessary.

Advances in optic and video technology have led to production of new intubation devices such as the Airtraq® NT (Prodol Meditec S.A., Vizcaya, Spain) and the McGrath® MAC (Aircraft Medical Ltd, Edinburgh, UK). A defining characteristic of these devices is that the glottic view is achieved indirectly instead of by direct line-of-sight, thus improving the view and reducing intubation time compared with direct laryngoscopes.⁷ The efficacy and safety of these devices for NTI have received little attention.

The aim of this study was to evaluate the efficacy of these laryngoscopes, compared with a Macintosh laryngoscope,

when used by anaesthetists of different levels of experience in direct laryngoscopy. The anaesthetists were unfamiliar with these new devices and participated in a randomised controlled manikin study involving management of both a normal airway and a difficult airway. We chose a manikin study because the McGrath MAC is a new device, the performance of which has not been examined in a trial published in the peer-reviewed literature.

We hypothesised that the time to correct endotracheal tube (ETT) placement through the nose would be shorter with the Airtraq NT and McGrath devices, compared with the Macintosh laryngoscope. The primary aim of the trial was to assess the time to successful intubation when using these different devices.

Methods

The Clinical Research Ethics Committee of Galicia approved the trial (Ref: 2010/486), which adhered to the standards of the International Conference on Harmonization Good Clinical Practice. The trial (NCT01311284) was registered at ClinicalTrials.gov before inclusion of participants. The participants were eligible if they were members of Department of Anaesthesiology of University Hospital Complex of A Coruña. Participation was voluntary and all participants gave written informed consent.

Trial protocol

A randomised crossover trial was performed in the Training Technology Center of University Hospital Complex of A Coruña. Sixty-three anaesthetists were recruited, comprising 21 residents (minimal exposure to NTI, 'resident group'), 21 consultants (anaesthetists familiar with a NTI technique but who only performed it occasionally, 'trained group') and 21 expert consultants (who performed the technique regularly, 'expert group'). Standardised instructions were provided about each device, including a demonstration of the intubation method and verbal information. The use of optimisation manoeuvres to facilitate intubation, such as readjustment of head position, application of external laryngeal force, use of Magill forceps, use of a stylet or the Frova airway intubation catheter (Cook Critical Care, Letchworth, United Kingdom), and the use of an assistant, were also demonstrated. Before the study, each anaesthetist tested the different devices until they achieved successful intubation of the manikin.

The Airtraq® NT optical laryngoscope, the McGrath® MAC videolaryngoscope and the Macintosh laryngoscope, size 3, were tested in this trial (Fig. 1).

All intubations were performed with a Portex Polar Preformed tracheal tube (Smith Medical Internacional Ltd Hythe, Kent, UK; internal diameter 7.0 mm) on a standard training manikin (AirSim Advance, Trucorp, Belfast, Northern Ireland). Each subject performed a NTI in normal and difficult airways using the three devices. The difficult airway was obtained by the inflation of the tongue of the manikin with 25 mL of air, simulating limited access to the oropharyngeal cavity.

The order of selection of the device and the airway scenario at each attempt were randomised, based on a list



Figure 1 The Airtraq® NT optical laryngoscope, the Macintosh laryngoscope and the new McGrath® MAC Videolaryngoscope.

created using the Epidat program, version 3.1. In addition, the participants were blinded to level of difficulty of the airway until their attempt to intubation.

A total of three intubation attempts were allowed with each laryngoscope in each scenario. An unsuccessful NTI, removal of the device from the oral cavity due to a poor view or NTI taking more than 120 s were considered a failed intubation. The correct location of the ETT was corroborated by an investigator at all intubation attempts.

The main endpoint was the time taken to achieve successful NTI. Additional endpoints included time to and grade of glottic view (Cormack and Lehane grades 1–4), incidence of successful NTI, number of attempts, number of optimisation manoeuvres during NTI, number of audible dental clicks due to touching the teeth, severity of force applied to the upper airway and time to ventilation of the lungs.

Time intervals were measured by the same investigator, using a stopwatch, for all intubations. Timing began when the blade of the intubation device was inserted between the teeth; interim times were when the vocal cords were visualised, when the ETT was inserted into the trachea; and timing finished at the first ventilation of the lungs. Time to view the glottis was when the investigator saw the glottis on the viewing device for the McGrath MAC and by verbal notification from the participant for the Airtraq NT and Macintosh laryngoscopes. The time to tracheal intubation was defined as the time from insertion of the blade between the teeth until the ETT was deemed to be correctly positioned. The time to inflation of the lungs was defined as the time from insertion of the blade between the teeth to the time when the ETT was connected to the manual ventilation device (Laerdal Medical, Stavanger, Norway) and successful ventilation was verified by the investigator.

The count of audible dental click sounds of the manikin (0, 1, 2 or >2) was made as an assessment of potential dental trauma. An investigator subjectively assessed the degree of force (absent, slight, moderate or severe) exerted during each intubation. Once the study was completed, each participant evaluated the clinical utility of each laryngoscope using a visual analogue scale (VAS) from 0 (extremely poor) to 10 (extremely high) for criteria of ease of use, field of view and preference in an emergency.

Statistical analysis

The main outcome measure was the time needed for to achieve successful NTI in the scenario of a difficult airway.

Table 1 Characteristics and intubation experience of participants. Numerical values represent median.

	Residents	Trained	Experts
Number	21	21	21
Male:female ratio	9:12	5:16	6:15
Experience (yr)	2.5 ± 1.2	16.7 ± 7.1	11.6 ± 5.5
Number of previous Macintosh NTI	2	15	All >50
Number of previous Airtraq® NT NTI	0	0	0
Number of previous McGrath® MAC NTI	0	0	0

From experience we considered that the time expected for NTI in a manikin would be 12–70 s, depending on the operator's experience and the difficulty of the scenario. We reasoned that a reduction to 7 s with one of the scopes was meaningful in a simulator study. Sixty-three participants would provide at least an 80% power to detect this difference, at a significance level of 0.05. The statistical analysis was conducted using SPSS 20.0 (SPSS Inc., Chicago, IL, USA). The data were expressed as mean ± SD for continuous or discrete variables and as frequency and percentage for categorical variables. The normal distribution of quantitative variables was evaluated by the Kolmogorov–Smirnov test. The between-group comparisons were performed using the Mann–Whitney *U*-test for non-parametric variables and the independent Student *t*-test for parametric variables. The analysis of variance by Friedman and Kruskal–Wallis multiple-comparison tests were applied for comparison between groups. The Wilcoxon test was used for post hoc comparisons. *p*-Values of <0.05 were considered statistically significant.

Results

Participants' characteristics

Sixty-three anaesthesia providers – 21 residents, 21 consultants and 21 experts – were recruited (20 males, 43 females; mean age 37 years) and there were no dropouts. No participant had previous experience with either of the indirect laryngoscopes tested. The average experience in direct laryngoscopy was a mean of 10.2 (SD 7.8) years. Characteristics of the participants are presented in Table 1.

Easy airway scenario

The values of the different variables for both scenarios are shown in Table 2. There was significant difference in time to intubation between the McGrath MAC, Airtraq NT and the Macintosh ($p=0.002$). There was no difference between the Macintosh and the Airtraq NT, but intubation time was significantly shorter with the McGrath MAC compared with the Airtraq NT ($p=0.001$) and the Macintosh laryngoscopes ($p=0.016$).

The results for time to view the cords and time to intubate in both scenarios are graphically represented (Fig. 2).

There were statistically significant differences between the devices for several secondary endpoints ($p<0.001$). These were the number of audible dental click sounds, the

severity of force applied to the upper airway, the Cormack and Lehane grade of view and the number of optimisation manoeuvres to aid NTI; the latter were readjustment of head position ($p<0.001$), application of external laryngeal force ($p=0.011$) and use of Magill forceps ($p<0.001$). These endpoints were significantly reduced in both the McGrath MAC and Airtraq NT groups compared with the Macintosh group. A significant difference between devices was observed for the time taken from visualisation of the vocal cords to correct placement of the ETT (Fig. 3A).

There were no significant differences between groups for the time taken to view the vocal cords, the incidence of successful ETT placement in the trachea or the number of intubation attempts.

Difficult airway scenario

A significant difference between the three intubation devices ($p<0.001$) was detected for the endpoints of time to view the vocal cords and intubation time (Fig. 2). However, there was no significant difference between the McGrath MAC and the Airtraq NT ($p=0.082$). Nevertheless, the time with both devices was significantly shorter than with the Macintosh ($p=0.001$ and $p<0.001$ respectively) (Fig. 2).

The post hoc analysis for the time to intubate demonstrated a significant difference between the McGrath MAC and the Airtraq NT when compared with the Macintosh ($p<0.001$) but no significant difference between the McGrath MAC and the Airtraq NT ($p=0.125$).

There was a significant difference in time required to intubate associated with operator experience when using the Macintosh laryngoscope ($p=0.004$).

There were also statistically significant differences ($p<0.001$) between the three devices for the number of intubation attempts, the number of additional manoeuvres used, the number of audible dental clicks, the severity of force applied to the upper airway and the grade of the glottic view. The McGrath MAC needed fewer attempts to intubate and also had the highest intubation success rate (98.4%) versus the other laryngoscopes (96.8% and 95.8%, $p<0.001$ for the Airtraq NT and Macintosh laryngoscopes respectively), although successful intubation at the first attempt was more than 90% for all participants with all devices. The number of optimisation manoeuvres, including the use of Magill forceps, was significantly reduced in both the McGrath MAC and Airtraq NT compared with the Macintosh groups ($p<0.001$). There were significantly more dental clicks when using the Macintosh compared with the McGrath MAC and the Airtraq NT ($p<0.001$) (Table 2). The McGrath MAC and the Airtraq NT

Table 2 Intubation success rates and variables. Values are mean ± SD or number (percentage) or percentage.

Airway scenario	Easy			Difficult		
	ML	ANT	McG	ML	ANT	McG
Success NTI (n)	63 (100)	61 (96.8)	63 (100)	58 (92)	59 (93.6)	62 (98.4)
<i>Times</i>						
View glottis (s)	15.1 ± 7.5	15.4 ± 10.0	13.1 ± 6.5	30.6 ± 12.0	22.9 ± 14.8	18.1 ± 9.7
Intubation (s)	31.3 ± 14.2	34.7 ± 19.2	25.4 ± 14.4	51.7 ± 17.2	41.0 ± 21.7	37.4 ± 21.8
Ventilation (s)	45.6 ± 17.3	45.8 ± 20.3	37.4 ± 16.4	71.4 ± 62.9	53.6 ± 24.3	50.7 ± 22.4
<i>Manoeuvres</i>						
Head	76.2	38.1	49.2	90.3	51.6	53.2
BURP	19.0	3.2	9.5	61.3	8.1	14.5
Forceps	60.3	12.7	19.0	79.0	16.1	7.7
Stylet	0	0	3.2	1.6	3.2	1.6
Assistant	7.9	1.6	7.9	32.3	4.8	11.3
<i>Dental clicks (%)</i>						
0	44.4	73.0	76.2	9.5	61.9	60.3
1	38.1	19.0	20.6	46.0	33.3	38.1
2	14.3	7.9	3.2	30.2	1.6	1.6
>2	3.2	0	0	12.7	3.2	0
<i>Pressure exerted on airway (%)</i>						
None	9.5	36.5	52.4	0	23.8	15.9
Minor	41.3	57.1	44.4	1.6	68.3	60.3
Moderate	46.0	6.3	3.2	17.5	4.8	22.2
Severe	3.2	0	0	81.0	3.2	1.6
<i>Grade of glottic view (%)</i>						
1	68.3	96.8	93.7	0	87.1	87.1
2	31.7	3.2	6.3	19.4	12.9	11.3
3	0	0	0	77.4	0	1.6
4	0	0	0	3.2	0	0

MLT = Macintosh, ANT = Airtraq NT, McG = McGrath MAC. NTI = nasotracheal intubation. BURP = backwards, upwards, right, pressure. Glottic view based on Cormack and Lehane classification.

appeared to require less force on the upper airway compared with use of the Macintosh laryngoscope ($p < 0.001$).

In the difficult airway scenario, both the McGrath MAC and the Airtraq NT were more likely to provide a grade 1 or 2 view than the Macintosh ($p < 0.001$), with almost no Grade 3 or 4 views. The post hoc analysis demonstrated significantly better views from the McGrath MAC than from the Airtraq NT ($p = 0.013$). There were no significant differences between devices for the time taken from visualisation of the vocal cords to correct placement of the ETT (Fig. 3B). There were several intubation failures with the Macintosh (five) and the Airtraq NT (four) and one with the McGrath MAC.

The VAS score for ease of use of the Macintosh laryngoscope was significantly higher than the VAS score of the Airtraq NT and McGrath MAC videolaryngoscopes ($p < 0.001$). Participants rated the indirect laryngoscopes well, as their hypothetically preferred laryngoscope in an emergency setting, but post hoc analysis showed no significant differences between groups (Fig. 4).

Discussion

Although many studies have compared indirect versus conventional laryngoscopy,^{8–10} none have compared the Airtraq

and McGrath MAC with the Macintosh laryngoscope for NTI. This study in a simulated manikin model, evaluating the performance of practitioners experienced in direct laryngoscopy but inexperienced with these indirect laryngoscopes, the time to NTI was significantly shorter using the McGrath MAC in the easy and difficult airway settings and the Airtraq in the difficult scenario. Indirect laryngoscopes also offered superior views of the glottis before additional optimisation strategies. Secondary endpoints suggested that they might also reduce the risk of dental injury and high upper airway forces. These advantages were most evident in the 'limited oropharyngeal cavity' or difficult scenario.

The reduced intubation time found in the McGrath MAC group corroborates a preliminary clinical study that compared the Macintosh with the McGrath series 5.¹¹ However, the results obtained in previous studies for oral intubation with the McGrath series 5 contrast with our findings.^{12–14} This difference may reflect the fact that the current version of the McGrath incorporates a Macintosh blade,¹⁵ which might have modified user characteristics compared with other devices with blades with a more pronounced curvature.

The Airtraq NT provided more grade 1 laryngoscopic views than the other two devices, yet intubation times

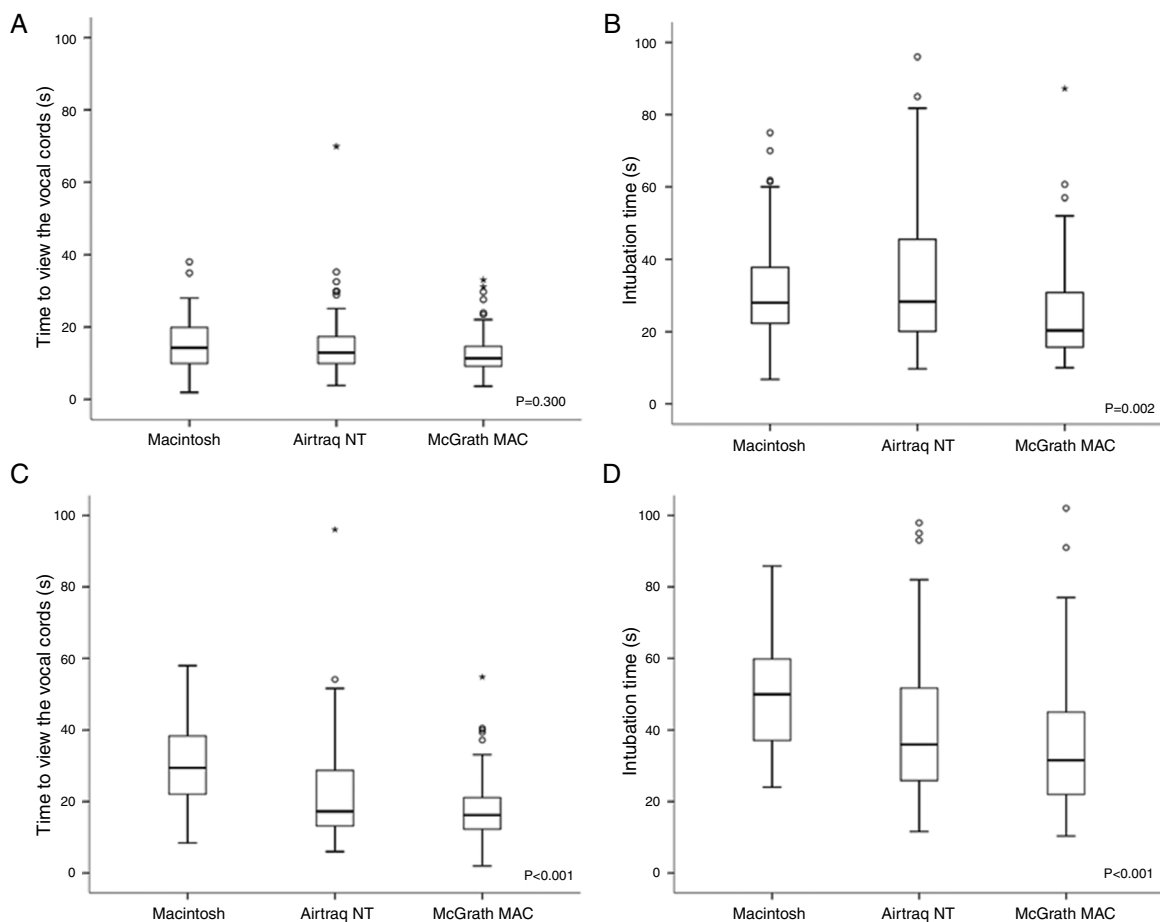


Figure 2 Boxplots depicting the time to view the vocal cords and the time to intubate in easy (A and B) and difficult (C and D) airway simulations.

were longer and more attempts were required to intubate when compared with the McGrath MAC. By contrast, the speed of oral intubation with the standard Airtraq was faster than other devices.^{16,17} This may be because of the side-channel that guides the ETT through the glottis.^{7,18} The Airtraq NT lacks an ETT channel, preserving the angulated blade, but consequently the view with the Airtraq

NT does not necessarily correspond with the path followed by the ETT, making it more difficult to pass the tracheal tube. Extra manoeuvres may be necessary and the four intubation failures we observed occurred because participants had difficulty placing the ETT into the glottis. This is considered a general limitation of indirect laryngoscopes.¹⁹

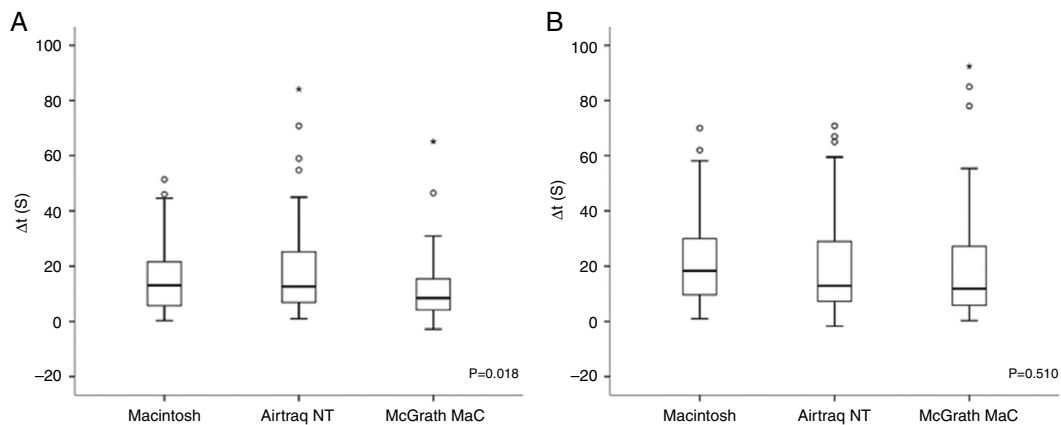


Figure 3 Boxplots depicting the time taken from visualisation of the vocal cords to placement of the endotracheal tube (ETT) in the trachea in easy (A) and difficult (B) airway simulations.

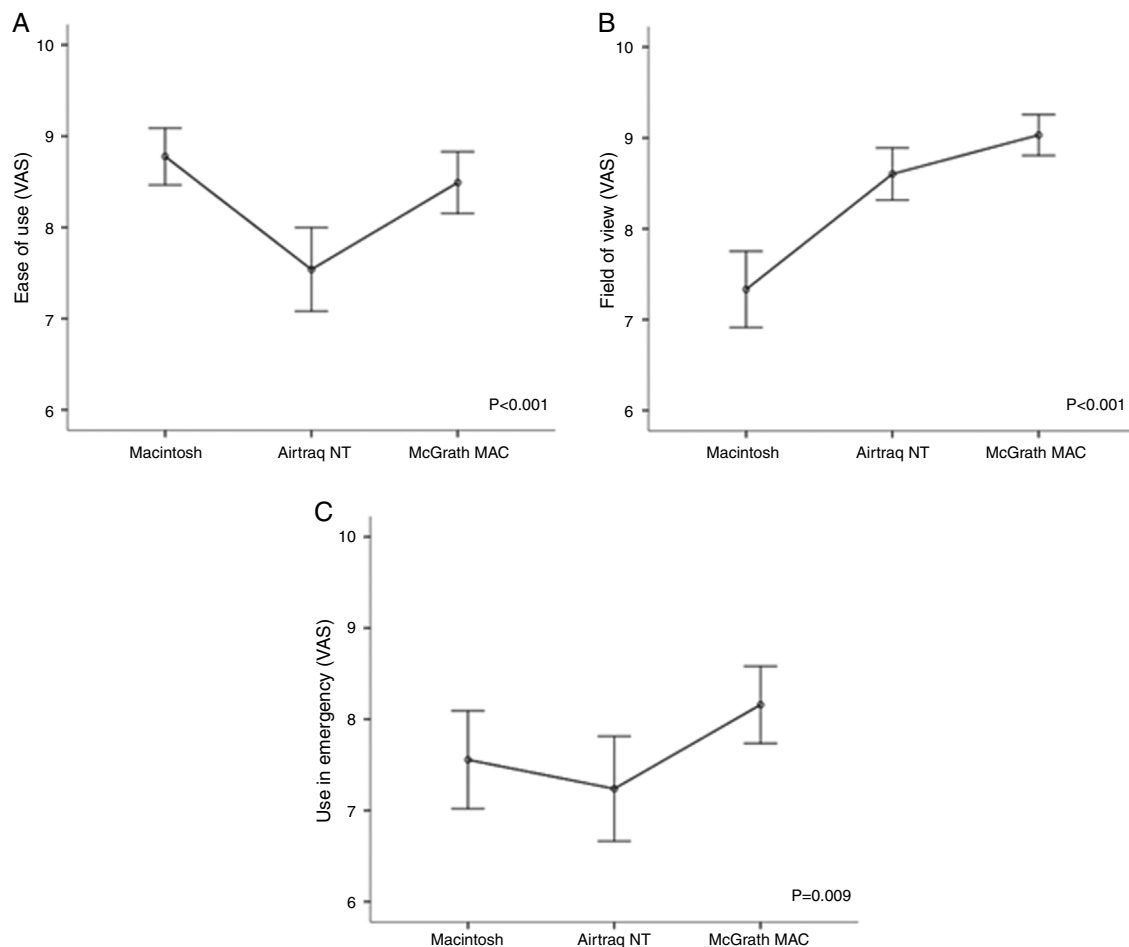


Figure 4 Graphs representing the visual analogue scale (VAS) score of participants' subjective evaluations of the devices.

During NTI, in contrast with oral intubation, the intubation time depends less upon the time required to expose the glottis and more on the time needed to advance the ETT from the nasopharynx towards the glottis.²⁰ The time taken from visualisation of the vocal cords to insertion of the ETT was shorter with the McGrath MAC than with the Airtraq NT and Macintosh laryngoscope in both scenarios, probably because fewer optimisation manoeuvres were required.

Airtraq NT and McGrath MAC appeared to reduce forces and the risk of dental trauma compared with the Macintosh, which is consistent with previous studies using indirect laryngoscopes.^{21–24} In conventional laryngoscopy, significant force is required to align the glottis, pharyngeal, and laryngeal axes,²⁵ but this is not required when using an indirect laryngoscope.^{7,19} The literature does not describe dental or upper airway injury due to these devices.

Familiarity with the Macintosh laryngoscope for routine tracheal intubation could have introduced bias in this study. However, there was no relationship between the experience of the operator and the time taken for NTI with indirect laryngoscopes. This corroborates previous trials indicating that novel optical and video laryngoscopes are easy to use and have a similar learning curve for both resident and staff anaesthetists.^{14,18,26}

The results of this study indicate that indirect laryngoscopes may be advantageous in the management of difficult

airway secondary to reduced oropharyngeal space (presence of tumour, infection or muscle flap after reconstructive surgery). Few publications have addressed this topic,^{27–29} although two recent clinical studies suggest that the Airtraq NT may be more useful than the Macintosh.^{20,30} This study differs in several points and provides additional information.

Our study has several limitations. The major limitation is that we used a manikin instead of patients. An airway simulator does not reproduce clinical intubating conditions exactly, with real-life differences including the appearance of humidified gas, secretions or blood, which add to difficulty. However manikin studies allow well-controlled and reproducible conditions, especially for untested medical devices. This avoids harm to patients and maintains strict standardisation of study conditions compared to the variability of differing patient airway anatomy. In addition, we only used one approach to a difficult airway scenario and other scenarios may result in alternative performance by the device. Nevertheless, recent clinical studies support the main findings in this simulation model.^{11,20,30} In a study of this design it is not possible to blind participants and investigators to the devices, which may also introduce bias. We attempted to control this by predetermining clear and consistent endpoints and using a randomised crossover design. The sample size was calculated based on the time to intubation, so our secondary endpoint and subgroup analyses may

have been underpowered. The ‘‘airway force’’ estimation was a subjective opinion that did not involve a measurement system and may not be valid with respect to reproducibility. Finally, there are a number of other videolaryngoscopes available, so our study only contributes to general understanding in this area.

In conclusion, in this manikin study, the Airtraq and the McGrath laryngoscopes appeared more useful than the conventional Macintosh laryngoscope under simulated conditions. Both devices were associated with shorter intubation times and fewer attempts and greater satisfaction, possibly because of the better view which appeared to result from fewer additional manoeuvres to improve the view. The clinical relevance is unknown until similar comparative clinical studies have been conducted to establish the benefits and the disadvantages of these devices during nasotracheal intubation.

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Conflicts of interest

The authors declare no conflicts of interest.

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