



## APPARATUS

# Comparison of the Glidescope<sup>®</sup>, the McGrath<sup>®</sup>, the Airtraq<sup>®</sup> and the Macintosh laryngoscopes in simulated difficult airways<sup>★</sup>

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### Summary

Several indirect laryngoscopes have recently been developed, but relatively few have been formally compared. In this study we evaluated the efficacy and the usability of the Macintosh, the Glidescope<sup>®</sup>, the McGrath<sup>®</sup> and the Airtraq<sup>®</sup> laryngoscopes. Sixty anaesthesia providers (20 staff, 20 residents, and 20 nurses) were enrolled into this study. The volunteers intubated the trachea of a Laerdal SimMan<sup>®</sup> manikin in three simulated difficult airway scenarios. In all scenarios, indirect laryngoscopes provided better laryngeal exposure than the Macintosh blade and appeared to produce less dental trauma. In the most difficult scenario (tongue oedema), the Macintosh blade was associated with a high rate of failure and prolonged intubation times whereas indirect laryngoscopes improved intubation time and rarely failed. Indirect laryngoscopes were judged easier to use than the Macintosh. Differences existed between indirect devices. The Airtraq<sup>®</sup> consistently provided the most rapid intubation. Laryngeal grade views were superior with the Airtraq<sup>®</sup> and McGrath<sup>®</sup> than with the Glidescope<sup>®</sup>.

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Direct laryngoscopy using a curved Macintosh blade remains the standard technique to facilitate tracheal intubation during routine anaesthesia. However, this method has several limitations. Firstly, it is a difficult skill to acquire and a long period of training is necessary to achieve competence [1]. Secondly, alignment of the oro-pharyngo-laryngeal axes is not always possible [2]. Finally, routine bedside screening-tests for predicting these difficulties have a limited power [3]. As a result, even the most experienced practitioner will experience difficult direct laryngoscopy (Cormack-Lehane grade 3/4 laryngeal view) in 1.5–8.5% of cases. Its occurrence is associated with intubation difficulties, morbidity, and mortality [4]. In fact, unanticipated difficulties during tracheal intuba-

tion and failure to intubate are among the leading causes of anaesthesia related morbidity and mortality [5, 6].

Many alternatives have been developed to facilitate intubation in cases of difficult direct laryngoscopy. Recently, several indirect laryngoscopes have been introduced. Visualisation of the vocal cords with these devices is achieved indirectly through either an optical or a video system. Three devices are becoming increasingly popular: the Glidescope<sup>®</sup> (Verathon Inc., Bothell, WA, USA) [7, 8], the McGrath<sup>®</sup> (Aircraft Medical Ltd, Edinburgh, UK) [9, 10] and the Airtraq<sup>®</sup> laryngoscopes (Airtraq<sup>®</sup>; Prodol Meditec S.A., Vizcaya, Spain) [11, 12].

The Glidescope and the Airtraq have been compared to the Macintosh blade in a simulated or clinical

environment [12, 13]. However, the comparison of the three devices with the Macintosh in a single study has been conducted only once with medical students as novice users [14].

The purpose of this study was to compare the efficacy and the usability of the Glidescope, McGrath, Airtraq, and Macintosh laryngoscopes in simulated difficult airway scenarios, when used by subjects experienced with direct laryngoscopy but inexperienced with using indirect laryngoscopes.

## Methods

Following ethical committee approval and written informed consent, we recruited 60 anaesthesia providers (staff anaesthetists, residents, and nurses). Participants were excluded if they had performed < 50 direct laryngoscopies, or if they had ever used any of the indirect laryngoscopes in a clinical practice.

The four intubating devices that we compared were the traditional Macintosh metal blade size 4, the Glidescope (adult large blade), the McGrath (mid-length position), and the Airtraq (regular size). All indirect laryngoscopes were used according to the manufacturers instructions. A rigid stylet (Glidescope®; Verathon Inc.) was used to facilitate intubation with the Glidescope and the McGrath. The Airtraq was used with a video-camera connected to an external screen. All intubations were performed using a size 7 tracheal tube (ETT).

Before starting the study, each participant was given individual standardised training by a single instructor. The training consisted of watching a 5-min computer-based presentation explaining the use of an indirect laryngoscope, this was followed by an practical demonstration. The participants were then allowed to practice five intubation attempts using a SimMan® manikin (Laerdal Medical Canada Ltd., Toronto, ON, Canada) with the normal airway setting. Constructive feedback was provided by the instructor. This training session was repeated for all indirect laryngoscopes. For the Macintosh blade no presentation or demonstration was provided but five hands-on intubations were permitted.

The study was then undertaken using a randomised crossover design. The Macintosh metal blade size 4 was always the first device to be used by the participant. Thereafter, the sequence of use of the Glidescope, McGrath and Airtraq was randomly assigned and each participant kept the same sequence throughout the study. Randomisation was stratified according to participant's grade. After completing the training session, each participant performed intubation in the SimMan® manikin in three difficult airway scenarios: (i) pharyngeal obstruction,

(ii) pharyngeal obstruction and cervical rigidity, and (iii) tongue oedema.

The primary endpoints were the rate of successful intubation, the number of intubation attempts, the time taken to intubate and the Modified Cormack–Lehane grades as described by Yentis and Lee [15]. A failed intubation was defined as a failure to intubate in < 2 min and/or if > three attempts were required. An attempt was defined as a withdrawal of the device from the mouth followed by repositioning. The time taken to intubate was defined as the time from first insertion of the blade between the teeth until the achievement of chest inflation using a self-inflating bag.

Secondary endpoints included the difficulty of use of each laryngoscopes which was assessed following each scenario using a visual scale (from 0 = very easy to 100 = very difficult), and the severity of potential dental trauma visually graded by the pressure exerted on the upper teeth (0 = none, 1 = mild, 2 = moderate, 3 = severe) [13]. Following each scenario, the participants were asked to indicate their preferred laryngoscope. At the conclusion of the study, we asked the participants which they would like to incorporate into their clinical practice. Free comments from the participants pertaining to perceived advantages and disadvantages of the devices were also recorded.

Data for the rate of successful intubation were analysed using a chi-squared test. Data for the duration of intubation attempts, modified Cormack grades, severity of dental trauma and difficulty of use were analysed using paired non-parametric tests. The Friedman and Wilcoxon signed rank tests were used for multiple and post-hoc comparisons respectively. The preferred choice of laryngoscope was analysed using a chi-squared test. A Kruskal–Wallis analysis was performed to test for differences between the grade of the participants (staff, resident or nurse). For all statistical analysis a *p* value < 0.05 was considered significant.

## Results

### Participants' characteristics

A total of 60 anaesthesia providers, 20 staff, 20 residents and 20 nurse anaesthetists, completed the study. None of them had any prior clinical experience with any of the indirect laryngoscopes tested in this study. Their levels of experience in clinical anaesthesia and in fiberoptic intubation are detailed in Table 1.

### Scenario 1 – Pharyngeal obstruction

All participants successfully intubated the manikin on the first attempt using each laryngoscope. The durations of intubation are graphically displayed in Fig. 1a. Significant

| Position  | Number of participants | Mean age (year) | Experience in clinical anaesthesia (year) | Estimated no. fiberoptic intubation performed |
|-----------|------------------------|-----------------|-------------------------------------------|-----------------------------------------------|
| Staff     | 20                     | 43 (9)          | 13.4 (8)                                  | 25 (2–400)                                    |
| Residents | 20                     | 32 (3)          | 3.1 (1)                                   | 10 (0–30)                                     |
| Nurses    | 20                     | 41 (5)          | 10.5 (5)                                  | 0 (0–10)                                      |

**Table 1** Characteristics of the participants.

Data are reported as number, mean (SD) or median (range).

differences existed between the times taken to intubate the trachea using the devices ( $p < 0.001$ ). Post-hoc comparison revealed no difference between the Macintosh and the Airtraq laryngoscopes ( $p = 0.24$ ), both being more rapid than the McGrath and the Glidescope, whereas the latter two did not differ ( $p = 0.11$ ).

The quality of laryngeal exposure differed between the devices ( $p < 0.001$ ). Post-hoc analysis revealed that all three indirect laryngoscopes provided a better glottic view than the Macintosh blade. The Airtraq and the McGrath offered similar laryngeal views ( $p = 0.56$ ), with both offering better views than to the Glidescope (Fig. 2).

Comparisons of secondary outcomes measures for scenario 1 are detailed in Table 2. The severity of dental trauma and the difficulty of use were slightly lower with the indirect laryngoscopes compared to the Macintosh. The McGrath and the Airtraq conferred a greater advantage than the Glidescope. Despite a clear trend, there was no statistically significant difference in the device preferred by the participants.

### Scenario 2 – Pharyngeal obstruction and cervical spine rigidity

All participants successfully intubated the manikin. On two occasions (once with the Macintosh and once with the Glidescope) two attempts were needed. The duration of intubation is graphically displayed in Fig. 1b. Significant differences existed between the times taken to intubate using the devices ( $p < 0.001$ ). Post-hoc comparison revealed no difference between the Macintosh and the Airtraq laryngoscopes ( $p = 0.21$ ), both being faster than the McGrath and the Glidescope laryngoscopes, whereas the latter two did not differ ( $p = 0.58$ ).

The quality of laryngeal exposure differed between the devices ( $p < 0.001$ ). Post-hoc analysis revealed that all three indirect laryngoscopes provided a better glottic view than the Macintosh. The Airtraq and the McGrath offered similar laryngeal views ( $p = 0.13$ ), with both offering better views than the Glidescope (Fig. 3).

Secondary outcomes measures for this scenario are detailed in Table 3. The severity of dental trauma was lower with the indirect laryngoscopes compared to the Macintosh. The McGrath was found to be the easiest to use and was also the preferred device in this scenario.

### Scenario 3 – Tongue oedema

In this scenario, the rate of failure was significantly different between the Macintosh and the indirect laryngoscopes ( $p < 0.001$ ). Failure rate was 37% with the Macintosh, 2% with the Glidescope, and 2% with the Airtraq. No failure was observed with the McGrath. Failures with the Macintosh laryngoscope were due to repeated oesophageal intubations, fatigue, and overrunning of the allowed time or the number of attempts permitted. The failure observed with the Glidescope was related to repeated difficulties in obtaining a good view and guiding the tracheal tube. The failure seen with the Airtraq was due to difficulties in inserting the device into the mouth forcing the participant to give up.

Only successful intubations were used to compare the durations of intubation attempts. These are graphically displayed in Fig. 1c. Significant differences existed between the time taken to intubate the trachea using the devices ( $p < 0.001$ ). The most rapid intubation was achieved using the Airtraq and the slowest with the Macintosh.

The quality of laryngeal exposure differed between the devices ( $p < 0.001$ ). Post-hoc analysis showed that all three indirect laryngoscopes provided better glottic view than the Macintosh blade. The Airtraq and the McGrath offered similar views ( $p = 0.41$ ), with both offering better views than the Glidescope (Fig. 4).

Secondary outcomes measures for the tongue oedema scenario are detailed in Table 4. The severity of dental trauma was always greatest with the Macintosh. In comparison, the use of the Glidescope caused less dental pressure but more than the use of the McGrath or the Airtraq. In this scenario, the participants found the Macintosh very difficult to use, the Glidescope was judged to be of intermediate difficulty, whereas the McGrath and the Glidescope were found easy to use. The vast majority of the participants preferred either the McGrath or the Airtraq to intubate the manikin in this scenario.

### Overall preference

After completing the three scenarios, all participants indicated that they would like to incorporate an indirect laryngoscope into their clinical practice. Fifty-two

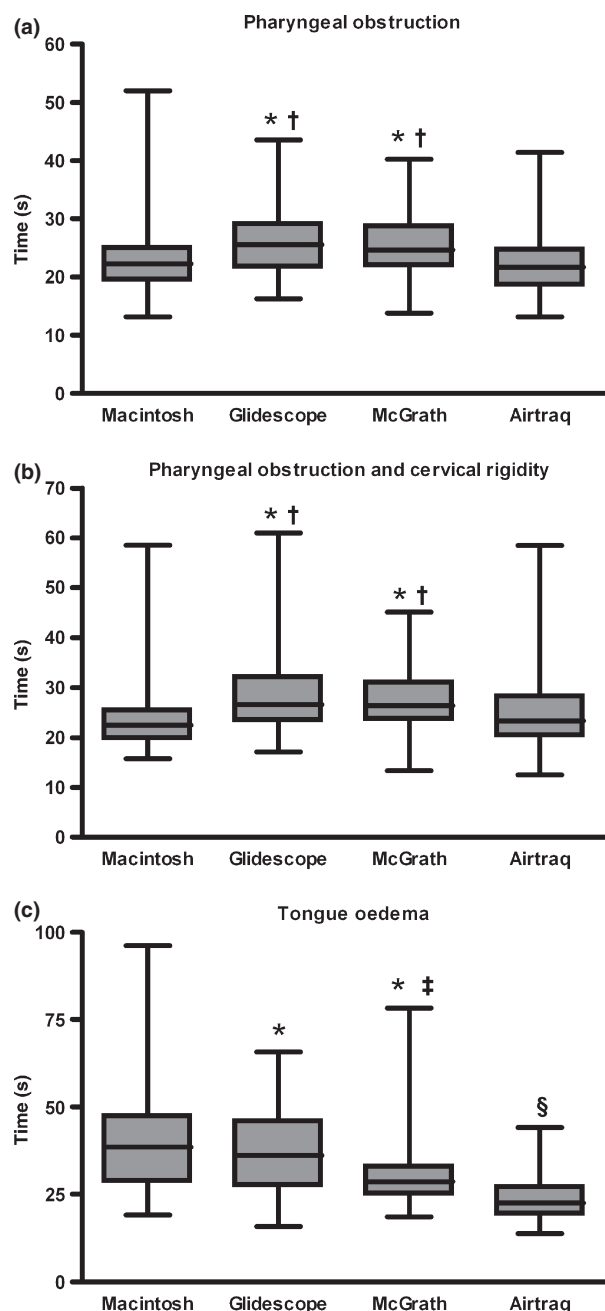


**Figure 1** Box plot representing the time taken to successfully intubate the trachea with each laryngoscope in scenario 1, 2 and 3 (graph a, b and c respectively). \* $p < 0.01$  compared with Macintosh. † $p < 0.01$  compared with Airtraq. ‡ $p < 0.01$  compared with Glidescope. § $p < 0.01$  compared with Macintosh, Glidescope and Airtraq.

per cent preferred the Airtraq, 45% the McGrath and only 3% The Glidescope. Thirty per cent wished to have access to only one type of indirect laryngoscope whereas 70% indicated that they would like to have more than one type of indirect laryngoscope, Airtraq and McGrath for

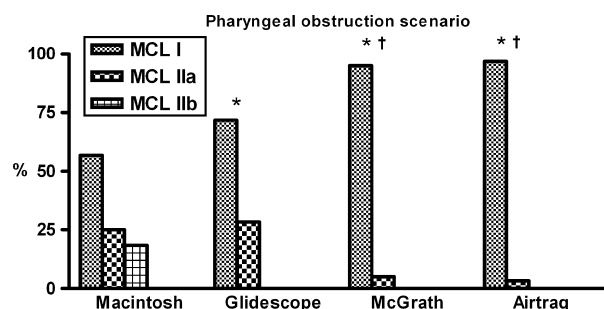


**Figure 2** Distributions of laryngeal views (MCL = Modified Cormack–Lehane grades) for each laryngoscope in scenario 1. \* $p < 0.001$  compared with Macintosh. † $p < 0.001$  compared with Glidescope.

the vast majority, mostly because they thought these techniques were complementary.

### Influence of the grade of the participants

In scenario 1, the grade of the participants did not influence the study endpoints. In scenario 2, the time required to intubate the manikin using the Macintosh was shorter for staff anaesthetists in comparison to nurses ( $p < 0.01$ ) and residents ( $p = 0.05$ ). In scenario 3, successful intubation with direct laryngoscopy was achieved by 100%, 50% and 60% of the staff, residents and nurses respectively ( $p < 0.001$ ). Similarly, staff anaesthetists intubated the trachea faster with the Macintosh in comparison to residents and nurses (both  $p < 0.001$ ) and obtained superior laryngeal exposure (both  $p < 0.01$ ). In the three scenarios, performances with the indirect laryngoscopes did not differ with the grade of the participants. Similarly, the preferred device (in the scenarios and overall) was not influenced by the grade of the participants.

### Discussion

Our study demonstrates that, in comparison with the traditional Macintosh blade, indirect laryngoscopes provide superior intubating conditions and facilitate tracheal intubation in all manikin simulated difficult airway scenarios. Indirect laryngoscopes also appear to produce less dental trauma and are easier to use than the Macintosh even when used by practitioners experienced with the latter. These advantages increased with the level of difficulty of the scenario and were most pronounced in the 'tongue oedema scenario'. In this scenario we observed many intubation failures with the Macintosh whereas only one was observed with Glidescope and one with the Airtraq.

The results of the speed of tracheal intubation, display greater differences; in the first two scenarios (pharyngeal

| Endpoints                 | Macintosh | Glidescope | McGrath     | Airtraq     | p (overall) |
|---------------------------|-----------|------------|-------------|-------------|-------------|
| Dental trauma             | 2.2 (0.6) | 1.7 (0.5)* | 0.9 (0.5)*† | 0.8 (0.4)*† | < 0.001     |
| Difficulty of use (0–100) | 29 (23)   | 24 (17)    | 20 (15)*‡   | 18 (12)*‡   | = 0.03      |
| Favorite laryngoscope (%) | 12        | 23         | 32          | 33          | = 0.07      |

$n = 60$ , Data reported as mean (SD) or %. Significant post-hoc comparisons are detailed using the following footnotes: \* $p < 0.001$  compared with Macintosh; † $p < 0.001$  compared with Glidescope; ‡ $p < 0.05$  compared with Glidescope.

**Table 2** Secondary outcome measures from the pharyngeal obstruction scenario.

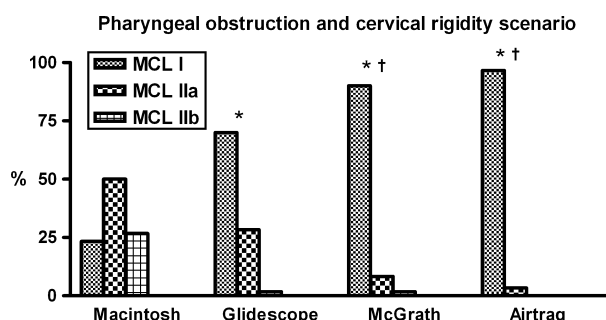


**Figure 3** Distributions of laryngeal views (MCL = Modified Cormack–Lehane grades) for each laryngoscope in scenario 2. \* $p < 0.001$  compared with Macintosh. † $p < 0.001$  compared with Glidescope.

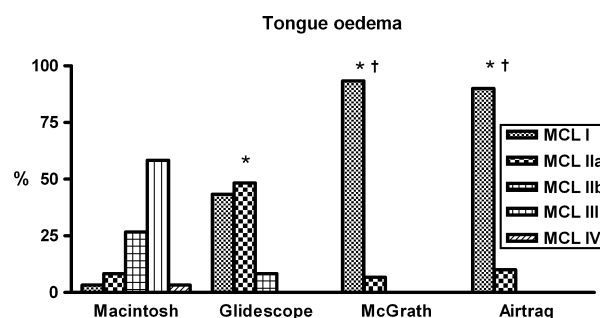


**Figure 4** Distributions of laryngeal views (MCL = Modified Cormack–Lehane grades) for each laryngoscope in scenario 3. \* $p < 0.001$  compared with Macintosh. † $p < 0.001$  compared with Glidescope.

| Endpoints                 | Macintosh | Glidescope | McGrath     | Airtraq      | p (overall) |
|---------------------------|-----------|------------|-------------|--------------|-------------|
| Dental trauma             | 2.6 (0.5) | 2.1 (0.6)* | 1.5 (0.5)*† | 1.3 (0.5)*†‡ | < 0.001     |
| Difficulty of use (0–100) | 35 (25)   | 28 (18)    | 24 (18)*    | 32 (22)‡     | < 0.01      |
| Favorite laryngoscope (%) | 12        | 23         | 43          | 22           | < 0.01      |

$n = 60$ , Data reported as mean (SD) or %. Significant post-hoc comparisons are detailed using the following footnotes: \* $p < 0.001$  compared with Macintosh; † $p < 0.001$  compared with Glidescope; ‡ $p < 0.01$  compared with McGrath.

**Table 3** Secondary outcome measures from the pharyngeal obstruction and cervical rigidity scenario.

| Endpoints                 | Macintosh | Glidescope | McGrath     | Airtraq      | p (overall) |
|---------------------------|-----------|------------|-------------|--------------|-------------|
| Dental trauma             | 3 (0)     | 2.4 (0.6)* | 1.4 (0.7)*† | 1.0 (0.5)*†‡ | < 0.001     |
| Difficulty of use (0–100) | 72 (26)   | 48 (23)*   | 25 (19)*†   | 23 (18)*†    | < 0.001     |
| Favorite laryngoscope (%) | 2         | 2          | 46          | 46           | < 0.001     |

$n = 60$ , Data reported as mean (SD) or %. Significant post-hoc comparisons are detailed using the following footnotes: \* $p < 0.001$  compared with Macintosh; † $p < 0.001$  compared with Glidescope; ‡ $p < 0.001$  compared with McGrath.

**Table 4** Secondary outcome measures from the tongue oedema scenario.

obstruction with or without cervical rigidity) anaesthetists took less time with the Macintosh and the Airtraq when compared to the Glidescope and the McGrath. This can be explained by the fact that our subjects were very familiar with the Macintosh and therefore obtained good laryngeal views (modified Cormack–Lehane grade I to IIb) with direct laryngoscopy. Therefore, it was faster for them to position the tracheal tube under direct vision

than to manipulate it whilst looking at a video screen. By contrast, intubation speed with the Airtraq was similar to the Macintosh. Rapid intubation with the Airtraq can be explained by the presence of a side-channel that guides the ETT through the glottis once an optimal view has been obtained. These explanations are supported by previous studies conducted on manikins that have compared the Macintosh either with the Glidescope

[16, 17] or with the Airtraq [13]. The results obtained in the tongue oedema scenario strengthen these explanations. In this scenario, laryngeal exposure with the Macintosh was very poor and, for the 63% of the participants who were successful, intubation speed was the slowest of the four laryngoscopes. Once again the Airtraq was the fastest followed by the McGrath and the Glidescope.

To our knowledge, Maharaj et al. [14] are the only authors who have published a study comparing the four laryngoscopes studied here. In their study they compared six devices, the same four laryngoscopes that we have compared plus the McCoy and the intubating LMA® (ILMA). They enrolled 30 medical students without previous airway management experience and presented them with two simulated airway scenarios (normal and cervical spine immobilisation). Their results revealed that the Airtraq, the McCoy and the ILMA reduced the number of intubation attempts, the Airtraq and the ILMA also reduced the severity of dental trauma, whereas the performance of other devices was more variable. Our study differs in several ways and therefore provides new information. We used three difficult airway scenarios and a larger study sample drawn from a population of anaesthetists familiar with the Macintosh but unfamiliar with indirect laryngoscopy. This may explain why we found slightly different results. In particular, the McGrath and the Glidescope showed superior performances than in Maharaj's study. In fact, several participants commented that they appreciated the McGrath precisely because it resembles the Macintosh. Our results may therefore be more relevant to the anaesthesia community, whereas Maharaj's results provide important information for health care providers who are less frequently exposed to endotracheal intubation.

In order to compare the quality of laryngeal exposure we used a modified Cormack–Lehane scoring system described by Yentis and Lee [15]. In this system, the traditional grade 2 view is further divided in grade IIa (part of the cords visible) and grade IIb (arytenoids only or very posterior origin of the cords visible). This classification offers two advantages. First, it distinguishes a view (grade IIb) associated with potential difficult intubation that would otherwise be mistakenly classified as grade II or III. Second, subtle differences between the devices can be uncovered because the breadth of the scale is increased. We have indeed shown differences between indirect laryngoscopes in terms of laryngeal exposure. We found that the Glidescope was less efficient than the other two devices. Although these differences were highly significant, their clinical impact is unknown. Nevertheless, the participants clearly expressed their overall preference either for the Airtraq or for the McGrath. We are not

aware of previous studies demonstrating differences in the quality of laryngeal view obtained with various indirect laryngoscopes.

The major limitation of this study is that it was performed using a high fidelity simulator and not in patients. Similar studies on real patients are extremely difficult to conduct. The simulation laboratory creates a safe, controllable and reproducible environment. It also offers a unique learning opportunity before bringing new devices into clinical practice. On the other hand, the predictive validity of the scenarios can always be questioned. In other words, can we apply the results to the clinical arena? The question remains open and clinical studies comparing these devices are clearly needed. However, the results of recent clinical studies that have compared the Macintosh to the Airtraq [11, 12] or to the Glidescope [18, 19] on patients with difficult airways indirectly support the validity of our model. Furthermore, in our study, staff anaesthetists performed better than residents and nurses when using the Macintosh blade to intubate the more difficult scenarios. This also clearly supports the construct validity of the model. Interestingly, the grade of the participant did not influence the performance with the indirect laryngoscopes. This also corroborates previous laboratory and clinical studies suggesting that modern indirect laryngoscopes are easy to use and have a steep learning curve [7, 9, 20, 21].

In conclusion, in this simulated manikin study, the Airtraq, the Glidescope and the McGrath laryngoscopes appear to possess advantages over the traditional Macintosh blade for the management of difficult airways. Indirect laryngoscopes differed in terms of speed of intubation, laryngeal exposure, potential dental trauma and easiness of use. These differences are further reflected in the participants' willingness to incorporate either the Airtraq or the McGrath into their clinical practice. Similar comparative studies on real patients are needed to further delineate the advantages and the limitations of indirect laryngoscopes and to better define their place in airway management strategies.

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