Comparison of the performance of four laryngoscopes in a high-fidelity simulator using normal and difficult airway

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Background. Novel laryngoscopes may demonstrate advantages over the traditional Macintosh laryngoscope for difficult airways. Our study compared Glidescope® laryngoscope, Bonfils fibrescope, and CTrach™ intubating laryngeal mask airway with the Macintosh laryngoscope in a simulated normal and difficult airway, considering the additional effect of previous intubation experience.

Methods. Twenty-two non-anaesthetists, 21 trainees, and 20 consultant anaesthetists attempted tracheal intubation of a Laerdal® SimMan manikin, comparing a normal with a difficult airway scenario for each intubation device. The time taken to view the vocal cords and time to intubate were recorded. Also success rate and ease of use for each device were scored, alongside scope preference for each scenario.

Results. Time to intubate was significantly shorter with the Macintosh compared with all three novel devices. All the devices had a high first-attempt success rate, but the Glidescope® had a 100% first time successful intubation for all participants in both a normal and a difficult airway. Non-anaesthetists took significantly longer time to intubate compared with consultant anaesthetists, but there was no difference between trainee and consultant anaesthetists. Higher proportions of participants found the Glidescope® easy to use, compared with other devices. For the normal airway, the Macintosh was the preferred device, but for the difficult airway, the Glidescope® was favoured.

Conclusions. In this study, the Macintosh laryngoscope outperformed the other devices. However, the Glidescope® was considered easy to use regardless of previous experience and was the preferred device for the simulated difficult airway.


Keywords: equipment; Macintosh laryngoscope, Glidescope® laryngoscope, Bonfils fibreoptic scope, CTrach™ ILMA, manikin; tracheal intubation, difficult airway

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Tracheal intubation is a core skill essential to the practice of general anaesthesia. It is estimated that the difficult intubation scenario may occur in about 2% of routine anaesthetics.1 2 Despite predictive tests, unexpected difficult intubations are still encountered.3 The potential consequences to the patient of a failed intubation are death or serious morbidity.1

Traditional teaching paradigms of clinical skills necessitated regular exposure to clinical scenarios to maintain psychomotor skills.4 However, in the absence of exposure to clinical scenarios, there is a rapid decay in performance. The reduction in trainee hours under the European working time directive necessitates the development of alternative teaching paradigms, particularly where clinical events occur rarely.

High-fidelity simulators are increasingly being used to test anaesthesia skills and measure performance. Simulation of clinical skills provides a measurement of competence and translates into improvements in clinical performance. The application of simulators to compare the
performance of aids with intubation is not common. Yet, commercial claims of new intubation aids maintain that they provide an improvement in performance over the traditional Macintosh laryngoscope. A high-fidelity simulator has the potential to test such claims.

In this study, we compared three fibreoptic aids with intubation (Glidescope®, Bonfils, and CTrachTM) against the standard Macintosh laryngoscope, in a Laerdal SimMan® (Laerdal®, Kent, UK) manikin designed to reproduce a difficult airway. We also considered additional variables that may influence performance—the performance of non-anaesthetists and anaesthetists according to their level of experience.

Methods

After local Ethics Committee approval and obtaining written informed consent, a total of 63 participants were enrolled into this study. These included 22 non-anaesthetists (20 operating department practitioners and two paramedics forming a ‘novice’ group), 21 anaesthetic trainees (‘trainee’ group), and 20 consultants (‘senior’ group). The anaesthetic trainees had at least 1 yr experience in anaesthesia. Participation was voluntary and all data collected were anonymized.

Each participant was given an individual standardized demonstration of each laryngoscope by one of the investigators. This included oral instructions on how to use each device and a demonstration of the intubation technique with each device. After this, each participant was allowed a practice achieving one successful tracheal intubation with each intubation aid on a SimMan® Manikin, with a ‘normal airway’ setting. Study volunteers participated with only the investigator(s) present.

The previous experience with each device was variable among the three different groups. Hence, patient characteristic data collected included: gender, anaesthetic grade, number of years experience in anaesthesia, and number of previous intubations with each device (Table 1).

The study design was a randomized crossover trial. Each participant performed tracheal intubation with each device in a normal and difficult airway. The difficult airway was achieved with the ‘neck immobilization’ setting on the SimMan® manikin and the presence of a hard collar, simulating limited neck extension and mouth opening.

The laryngoscope order was randomized for each scenario using a Latin square. A Latin square is a numerical matrix that ensures that the order of treatments is presented equally often to all of the subjects, balancing the experiment with respect to any carry-over effect.

The primary endpoints were the time to view the vocal cords and the time taken for successful intubation, and the number of attempts at intubation (a failed attempt was classed as failure to intubate the trachea or removal of the intubation device from the mouth due to a poor view). Timing commenced when the intubation device entered the ‘mouth’, an interim time was recorded when the vocal cords were seen (time to vocal cords), and the time ended when there was chest expansion with lung inflation via a self-inflating bag. The ‘time to vocal cords’ was recorded when seen by the investigator on the viewing device for the Bonfils, Glidescope®, and CTrachTM and by verbal indication from the subject for the Macintosh. A failed intubation was classed as inability to intubate the trachea. No time limit was placed on the time to complete the task.

Secondary subjective endpoints were recorded that considered the usability of the devices. Ease of intubation (1, easy; 2, moderate; 3, difficult) was graded by the participant at the conclusion of the trial. Participants were also asked to commend an intubating device for the two clinical scenarios tested (normal and difficult airway).

Sample size estimation considered the potential improvement in intubation time with the test devices compared with the Macintosh laryngoscope. Previous studies estimate intubation times for a Macintosh laryngoscope in a manikin of 12–70 s depending on the experience of the operator and the degree of difficulty.5–8 The time to intubation can be improved by 5–47 s using an alternative intubation aid.89 These disparate values prevent precise sample size calculation. However, if we consider an α-value of 0.05 and a β-value of 0.1, then finding a difference between the intubation times of 10 s with a standard deviation of 10 s would require 12 subjects. Since no patients were to be placed at risk by this study, we accepted 20 subjects per group. This sample size would detect a 7 s difference in intubation time.

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

<table>
<thead>
<tr>
<th></th>
<th>Novice</th>
<th>Trainee</th>
<th>Senior</th>
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<tbody>
<tr>
<td>Number per group</td>
<td>21</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>Male:female ratio</td>
<td>9:12</td>
<td>14:8</td>
<td>13:7</td>
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<tr>
<td>Experience as anaesthetist (yr)</td>
<td>0</td>
<td>5 (1–20)</td>
<td>15 (9–30)</td>
</tr>
<tr>
<td>Number of previous Macintosh intubations</td>
<td>0 (0–20)</td>
<td>All &gt;50</td>
<td>All &gt;50</td>
</tr>
<tr>
<td>Number previous Glidescope® intubations</td>
<td>0 (0–5)</td>
<td>2 (0–20)</td>
<td>2 (0–50)</td>
</tr>
<tr>
<td>Number of previous Bonfils intubations</td>
<td>0 (0–5)</td>
<td>0 (0–5)</td>
<td>0 (0–50)</td>
</tr>
<tr>
<td>Number of previous uses of CTrachTM</td>
<td>0 (0)</td>
<td>0 (0–5)</td>
<td>0 (0–5)</td>
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Statistics

The statistics package SPSS was used for the analysis and the production of graphical images. The general linear regression model considered the strength of the relationship between the dependent variables (time to view the ‘vocal cords’ and time to intubate) against the factors such as intubation aid, operator experience, and intubation difficulty. Bonferroni’s post hoc analysis considered the difference between the four intubation aids. The relationship between the dependent variables, operator experience, and intubation aid was measured. A P-value of <0.05 was considered significant.
For ordinal data (subjective performance of the intubation aids and the preferred intubation aid), the Kruskal–Wallis one-way analysis of variance was applied, and \( P<0.05 \) was considered significant.

**Results**

The results for time to view the cords and time to intubate are graphically represented (Fig. 1).

A significant difference between the four intubation aids \( (P<0.001) \) was observed for the two dependent variables (time to view the vocal cords and intubation time). The *post hoc* analysis (Bonferroni) for the dependent variable, time to view the vocal cords (Fig. 1A), demonstrated no significant difference between the Macintosh and the Glidescope\(^\circledR\) \( (P=0.19) \). However, there was a significant difference between the Macintosh and the Glidescope\(^\circledR\) when compared with the Bonfils or the CTrach\(^\text{TM}\) \( (P<0.001) \) (Fig. 1A). There was a significant difference between the Glidescope and the Bonfils \( (P=0.005) \), but not between the Glidescope and the CTrach \( (P=0.1) \).

For the dependent variable, time to intubate (Fig. 1B), there was a significant difference between the Macintosh and the Glidescope\(^\circledR\) \( (P=0.02) \) and the Macintosh and the Bonfils, and the Macintosh and the CTrach\(^\text{TM}\) \( (P=0.005) \) (Fig. 1B). There was a significant difference between the Glidescope and the Bonfils \( (P<0.05) \). Although the differences between the medians of time to view the cords and time to intubate were small in the boxplot images, there were large numbers of extreme outliers (>3 times the IQR; Fig. 1) in both the CTrach and the Bonfils.

A significant difference \( (P<0.001) \) was observed between the two dependent variables and operator experience (Fig. 2A and B). The *post hoc* analysis showed the difference between the novice and the senior operator \( (P<0.001) \). There was no significant difference between the trainee and the senior operator \( (P=0.056) \).

A significant difference \( (P=0.04) \) was observed between the dependent variables and the degree of intubation difficulty (Fig. 2C and D).

The rate of successful intubation at first attempt was more than 90% for all participants with all devices. (The Glidescope\(^\circledR\) had the highest intubation success rate with 100% of participants intubating successfully at first attempt both with the normal and with the difficult airway settings.) Overall, the majority found the Macintosh and Glidescope easy to use (Fig. 3), whereas a greater proportion of operators rated the Bonfils and CTrach\(^\text{TM}\) as moderate or difficult to use.

A significant difference \( (P<0.001) \) was observed for the subjective opinion of the operators, when they were asked to describe the ease of use of the intubation aids. For the normal airway (Fig. 4A), the Bonfils was considered more difficult to use \( (P<0.001) \) when compared with the other devices. For the difficult airway (Fig. 4B), both the Bonfils \( (P<0.001) \) and the CTrach \( (P=0.02) \) were considered difficult to use compared with the other devices.

The subjects were asked at the conclusion of the trial which intubation aid they would prefer for the two simulated airway conditions. For the simulated normal airway, the preference of the senior anaesthetists was for the Macintosh, but the novice subjects preferred the Glidescope\(^\circledR\). For the difficult airway, the preference of the novice operators was for the Glidescope\(^\circledR\), and the proportion of operators that preferred the Glidescope\(^\circledR\) among the experienced operators was greater than when compared with the easy airway.

**Discussion**

Laryngoscopy is a complex psychomotor skill, performed in a potentially hazardous environment, requiring several
years to acquire a skill level where the ‘difficult intubation’ can be successfully managed.\(^4\) Previously, the novice anaesthetist would acquire these skills through prolonged and regular exposure to clinical cases over several years of training. However, the difficult intubation is an infrequent event requiring several years experience. When encountering a difficult intubation in training, the instructor may feel obliged to take over because of time constraints or concerns for patient safety. Recent changes to anaesthesia trainee programmes in the UK, with a reduction in trainee hours, may compromise these traditional learning paradigms for airway skills, forcing instructors to consider alternative teaching methods.

New paradigms are therefore required to teach complex psychomotor skills that are not reliant upon patients, particularly where they may be placed at risk. The acquisition and retention of psychomotor skills can be enhanced through the application of a high-fidelity simulator.\(^{10–12}\) This study utilized this model of training, to test the performance of four intubation aids and to consider the effect of experience level upon performance and ‘usability’ of these devices.

This study builds upon the many previous studies comparing intubation aids. We have observed that the learning curve for the Macintosh and the Glidescope\(^\circ\) is short, even where previous intubation experience is absent. Operators showed a preference for the Macintosh and the Glidescope\(^\circ\) videolaryngoscopes over the CTrach\(^\text{TM}\) and the Bonfils. The reduced intubation time in the simulated difficult and easy airway of the Macintosh and Glidescope\(^\circ\), when compared with the other two devices, attests to the value of the traditional laryngoscope design. The addition of a distal camera is a benefit to the original Macintosh design, with the ‘instructor’ able to observe the trainee during laryngoscopy with a reduction in training time and an increase in the likelihood of a successful intubation.

The Bonfils\(^{13}\) is an example of an optical stylet and is designed for retromolar placement and minimal neck movement. As such, the use of the Bonfils is unfamiliar to most anaesthetists. Operators did not demonstrate a preference for the Bonfils in either the simulated easy or difficult airway. The instructors observed that several attempts at intubation were required before the operator was confident.
The difficulty users experienced is reflected by the boxplots for time to view the vocal cords and intubate with several mild and extreme outliers. The long learning curve of the Bonfils Scope has previously been reported, with 20–25 intubations being a recommended minimum to achieve confidence. However, once the learning curve is overcome, users are impressed with the performance of the Bonfils in the difficult airway. The Bonfils does not have wide application as a rescue device when the Macintosh laryngoscope fails, but for the enthusiast has practical application in the difficult intubation or where neck movement is not desirable.

Unlike the Bonfils, the learning curve for the laryngeal mask airway (LMA) is short, and may be suited for the novice subject or where intubation skills cannot be regularly updated such as the paramedic or members of a trauma team. The intubating LMA (ILMA) has been adopted by the UK difficult airway society as the device of choice when tracheal intubation fails. The CTrach™ should therefore be an advance upon the ILMA, allowing the user the ability to confirm the position of the larynx during intubation. However, our study group did not indicate an inclination towards the CTrach™ LMA. The simplicity and the high success rate of the traditional Macintosh laryngoscope and the Glidescope videolaryngoscope were preferable to our study group. The CTrach™ LMA has demonstrated a high success rate in small clinical trials, but a longer time is required to intubate, and operators experienced occasional difficulty gaining a view of the vocal cords and the additional steps required to place the tracheal tube and remove the LMA occasionally dislodged the tracheal tube.

A manikin study is only of practical benefit, if the study results can be translated into clinical practice. This manikin study is comparable with other clinical studies in demonstrating that the Macintosh laryngoscope is simple to teach, and achieves a high first intubation rate. The Glidescope® compares favourably with the Macintosh in the simulated easy airway and is the preferred device in the subjective reports of the operators during the simulated difficult airway. The design of the Glidescope® is perhaps comparable with other video or optical laryngoscopes.
(Airtraq, C Max, McGrath, etc.) and could therefore be considered as a practical second or rescue device for the failed intubation drill. The short learning curve makes videolaryngoscopy suitable for teaching to a regularly changing population of trainees.

The Bonfils may remain accessible to enthusiasts who appreciate its application to the difficult airway and can maintain their skills through regular use on normal airways. The CTrach™ may have a role in the difficult intubation. However, the cost of intubation aids needs to be considered, if a department is to adopt these devices on a difficult intubation trolley. The cost of the CTrach™ is significantly more than the other devices, and this may limit its widespread application.

Acknowledgements

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