Original Article

Comparison of seven videolaryngoscopes with the Macintosh laryngoscope in manikins by experienced and novice personnel

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Summary

Videolaryngoscopy is often reserved for 'anticipated' difficult airways, but thereby can result in a higher overall rate of complications. We observed 65 anaesthetists, 67 residents in anaesthesia, 56 paramedics and 65 medical students, intubating the trachea of a standardised manikin model with a normal airway using seven devices: Macintosh classic laryngoscope, Airtraq®, Storz C-MAC®, Coopdech VLP-100®, Storz C-MAC D-Blade®, GlideScope Cobalt®, McGrath Series5® and Pentax AWS®) in random order. Time to and proportion of successful intubation, complications and user satisfaction were compared. All groups were fastest using devices with a Macintosh-type blade. All groups needed significantly more attempts using the Airtraq and Pentax AWS (all $p < 0.05$). Devices with a Macintosh-type blade (classic laryngoscope and C-MAC) scored highest in user satisfaction. Our results underline the importance of variability in device performance across individuals and staff groups, which have important implications for which devices hospital providers should rationally purchase.

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Introduction

Good airway management can be life saving. 'Complexity factors' (e.g. circumstances, patients' characteristics, background and experience of the healthcare provider) are highly variable and influence the difficulty of airway management [1]. Considerable experience is required before one becomes proficient in direct laryngoscopy and tracheal intubation [2]. In most situations, having an airway management expert at the bedside for every tracheal intubation is not feasible and airway management must be delivered by practitioners from different specialty backgrounds. The incidence of difficult or failed tracheal intubation is up to ~15% outside the operating theatre, compared with up to ~9% in the elective theatre setting. Moreover, outside the operating theatre, it is more likely to lead to significant morbidity and mortality [3, 4].

Videolaryngoscopes are often seen as rescue devices. Yet, indirect videolaryngoscopy has proven advantageous over direct laryngoscopy using a classic Macintosh blade [5, 6]. But videolaryngoscopes differ and cannot be seen as a single entity. Similar to direct laryngoscopy, considerable experience is necessary [7]. The transferability of skills between different types of videolaryngoscopes and the level of adequate training has yet to be established.

Current videolaryngoscopes may be superior for difficult airways, but may increase the risk in routine tracheal intubations [8]. For a videolaryngoscope to be acceptable to clinicians for all forms of practice, it should offer advantages in difficult tracheal intubations while not jeopardising normal airway tracheal intubations [8, 9].

With the current range of indirect videolaryngoscopes available, it can be difficult to choose the most suitable videolaryngoscope for specific situations, patients or laryngoscopists.

The aim of this study is to give an indication on which device would be most suitable for which healthcare provider. We compared the time to successful tracheal intubation and several other factors which can affect tracheal intubation, when anaesthetists, residents in anaesthesia, paramedics and medical students intubate a standardised manikin model with a normal airway. Our hypothesis was that groups may perform differently for any given device, and also that devices may perform differently across the groups.

Methods

After obtaining Institutional Review Board approval at Maastricht University Medical Centre (MUMC; registration MEC 10-5-059), anaesthetists, residents in anaesthesia, paramedics and medical students were recruited from the MUMC, Catharina Hospital Eindhoven, University Medical Centre Utrecht (UMCU) and Regional Ambulance Service Limburg Noord between January 2011 and November 2012. All participants were volunteers, who could choose not to participate, withdraw at any time, and could not be identified from the data collected. Data were collected on paper forms and entered onto an SPSS spreadsheet. Only investigators had access to the data, which are stored in a de-identified form.

We used an Airway Trainer™ manikin (Laerdal Stavanger, Norway); a study by Jordan et al. using this manikin commented on the good anatomical proportions of the oral cavity [10].

Before the beginning of the trial, all participants received a standardised, 5 min demonstration by one of the investigators (BP, NW or MH) of the classic Macintosh laryngoscope and the different videolaryngoscopes and the use of optimisation manoeuvres (re-adjustment of head position, application of external laryngeal pressure and the use of a stylet). Practicing with the devices before the attempts was not allowed.

Each participant was asked to attempt tracheal intubation with each device in randomised order using the same normal airway scenario in the supine position. Photographs of the Cormack and Lehane grades in the manikin were displayed next to the manikin as a reference. A cuffed tracheal tube (Mallinckrodt™; Covidien, Dublin, Ireland) with 7.5 mm internal diameter was used for all attempts.

The devices used for the study were: (a) a classic Macintosh laryngoscope (blade 3 (Karl Storz, Tuttlingen, Germany)); (b) Airtraq (size 3 (Prodol, Vizcaya, Spain)); (c) Storz C-MAC (Macintosh blade 3, 8402 ZX monitor (Karl Storz)); (d) Coopdech VLP-100 (BMAC-003 blade (Daiken Medical Co, Osaka, Japan); (e) Storz C-MAC, D-blade (8402 ZX monitor (Karl Storz)); (f) GlideScope Cobalt (blade 3 (Verathon Inc, Bothell, WA, USA)); (g) McGrath Series5 (blade middle setting (Aircraft Medical, Edinburgh, Scotland)); and (h) Pentax Airway Scope (Pentax Corporation, Tokyo, Japan; Fig. 1). All devices were property of the department or one of the investigators (AVZ).

It was left to the judgement of the participant whether or not they wanted to use a stylet. With the GlideScope, both rigid (GlideRite®; Verathon Inc) and malleable (Satin Slip®; Mallinckrodt, St. Louis, MO, USA) stylets have been proven to be equally effective [11]. Both stylets were available and participants were offered a choice of stylet when requested. When the participant chose to use a stylet, the stylet was placed within the tube from the start to shape the tube to the predesired form. As the Pentax AWS and the Airtraq have an integral guidance channel for the tracheal

Figure 1 Different videolaryngoscopes (obtained from publically accessible websites of the manufacturers): (a) Classic Macintosh laryngoscope (blade 3 (Karl Storz, Tuttlingen, Germany, www.karlstorz.com) (b) Airtraq® (size 3 (Prodol, Vizcaya, Spain, www.airtraq.com); (c) Storz C-MAC® (Macintosh blade 3, 8402 ZX monitor (Karl Storz, Tuttlingen, Germany, www.karlstorz.com); (d) Storz C-MAC, D-blade® (8402 ZX monitor (Karl Storz, Tuttlingen, Germany, www.karlstorz.com); (e) Coopdech VLP-100® (BMAC-003 blade (Daiken Medical Co, Osaka, Japan, www.daiken-iki.co.jp); (f) GlideScope Cobalt® (blade 3 (Verathon Inc, Bothell, WA, USA, www.verathon.com); (g) McGrath Series5® (blade middle setting (Aircraft Medical, Edinburgh, Scotland, www.aircraftmedical.com); (h) Pentax Airway Scope® (Pentax Corporation, Tokyo Japan, www.airway-scope.com).

tube, participants were instructed that a stylet could not be used with either of these two devices.

Participants used each of the eight different devices in a randomised order. Both participants and investigators were blinded to device order. Eight closed envelopes were used, each containing the name of one of the devices. The order of the devices used was determined for each participant separately by selecting these eight envelopes, one at a time. Demographic data collected included participants' clinical position and the, by the participant, estimated (by each individual) number of previous clinical tracheal intubations with each device.

The primary outcome was the time to successful tracheal intubation. The investigator started timing as soon as the blade of the scope was positioned between the teeth of the manikin. The time until the best view of the glottis was achieved (marked as picking up of the tube (or touching the tube in case of the Airtraq and Pentax AWS)) and success of tracheal intubation was also noted. Timing ended when the participant declared the trachea to be intubated. Tracheal intubations that took > 180 s were classified as unsuccessful. Failed tracheal intubation was also defined as oesophageal intubation (not recognised by the participant) and tracheal intubations that required > three attempts. When the participant did recognise the intubation as being oesophageal, it was counted as one attempt instead of an unsuccessful intubation. If, however, the participant opted against a second or third attempt after a failed attempt on the basis that further attempts would be futile, the tracheal intubation was registered as failed.

Secondary end-points included: the number of tracheal intubation attempts; the number of optimisation manoeuvres to aid tracheal intubation; the Cormack and Lehane grade scored by the participant and the number of audible click sounds from contact of the (video)laryngoscope with the teeth of the manikin: this was recorded as a method of evaluation of dental trauma.

At the end of the study, each participant was asked to rank all devices on the basis of satisfaction, using a chart (1–8, very satisfactory – would definitively purchase this device – to not satisfactory at all – would never purchase this device) [12].

Based on the previous studies, taking into account the larger amount of devices used, we decided to perform an explorative study, including 65 participants per group [9]. The Friedman test was performed as non-parametric alternative to repeated measures ANOVA to analyse the difference in time until best view of the glottis and time until successful intubation between devices for each group of participants separately [13]. In addition, Wilcoxon signed-rank tests were used to assess pair-wise differences between devices. On the other hand, the post-hoc Mann–Whitney U-test was used to compare groups. Differences between groups in rate of successful tracheal intubation were analysed using a Chi-squared test, whereas differences between devices were analysed using the McNemar test.

For the secondary end-points, the Wilcoxon signed-ranked test was used when comparing devices within a group. When comparing groups for the same device, the Chi-squared test was used. A $p \leq 0.05$ was considered statistically significant.

All analyses were performed using SPSS (IBM SPSS 22; IBM Corporation, Armonk, NY, USA).

Results

A total of 253 participants (65 anaesthetists, 67 residents in anaesthesia, 56 paramedics and 65 medical students) completed the study. Their levels of experience with the different devices are shown in detail in Table 1.

The times until the best view of the glottis was achieved are graphically displayed in Fig. 2. All participants, except paramedics, took significantly longer to achieve the best view of the glottis when using the GlideScope (anaesthetists median (IQR [range]) 12 (11–18 [0–73] s; residents 15 (15–22 [0–78]) s; medical students 15 (15–26 [0–87]) s; $p < 0.017$ vs other devices). Medical students also took significantly longer than other groups using the classic Macintosh laryngoscope (21 (20–31 [0–78]) s; $p < 0.001$ vs other groups).

When comparing groups, paramedics achieved the best view of the glottis faster than all other groups for the C-MAC videolaryngoscope (4 (4–7 [2–22]) s;

Table 1 Self-reported estimates of previous experience per device (uses on patients). Data are reported as numbers, median (IQR [range]).

Device	Anaesthetists	Residents	Medical students	Paramedics
Classic Macintosh	6000 (6378–8847 [600–31400])	500 (325–492 [10–1000])	0 (0–2 [0–12])	50 (57–78 [0–150])
Airtraq	0 (0–3 [0–60])	0 (0–0 [0–0])	0 (0–0 [0–0])	0 (0–3 [0–50])
C-MAC	0 (0–49 [0–1000])	0 (0–8 [0–100])	0 (0–0 [0–1])	0 (0–0 [0–0])
Coopdech	0 (0–5 [0–100])	0 (0–0 [0–0])	0 (0–0 [0–0])	0 (0–0 [0–0])
C-MAC D-Blade	0 (0–0 [0–0])	0 (0–0 [0–0])	0 (0–0 [0–0])	0 (0–0 [0–0])
GlideScope	0 (0–50 [0–800])	0 (2–7 [0–80])	0 (0–0 [0–0])	0 (0–0 [0–3])
McGrath	0 (0–24 [0–500])	0 (0–5 [0–80])	0 (0–0 [0–0])	0 (0–0 [0–0])
Pentax AWS	0 (0–5 [0–75])	0 (0–0 [0–5])	0 (0–0 [0–0])	0 (0–2 [0–30])

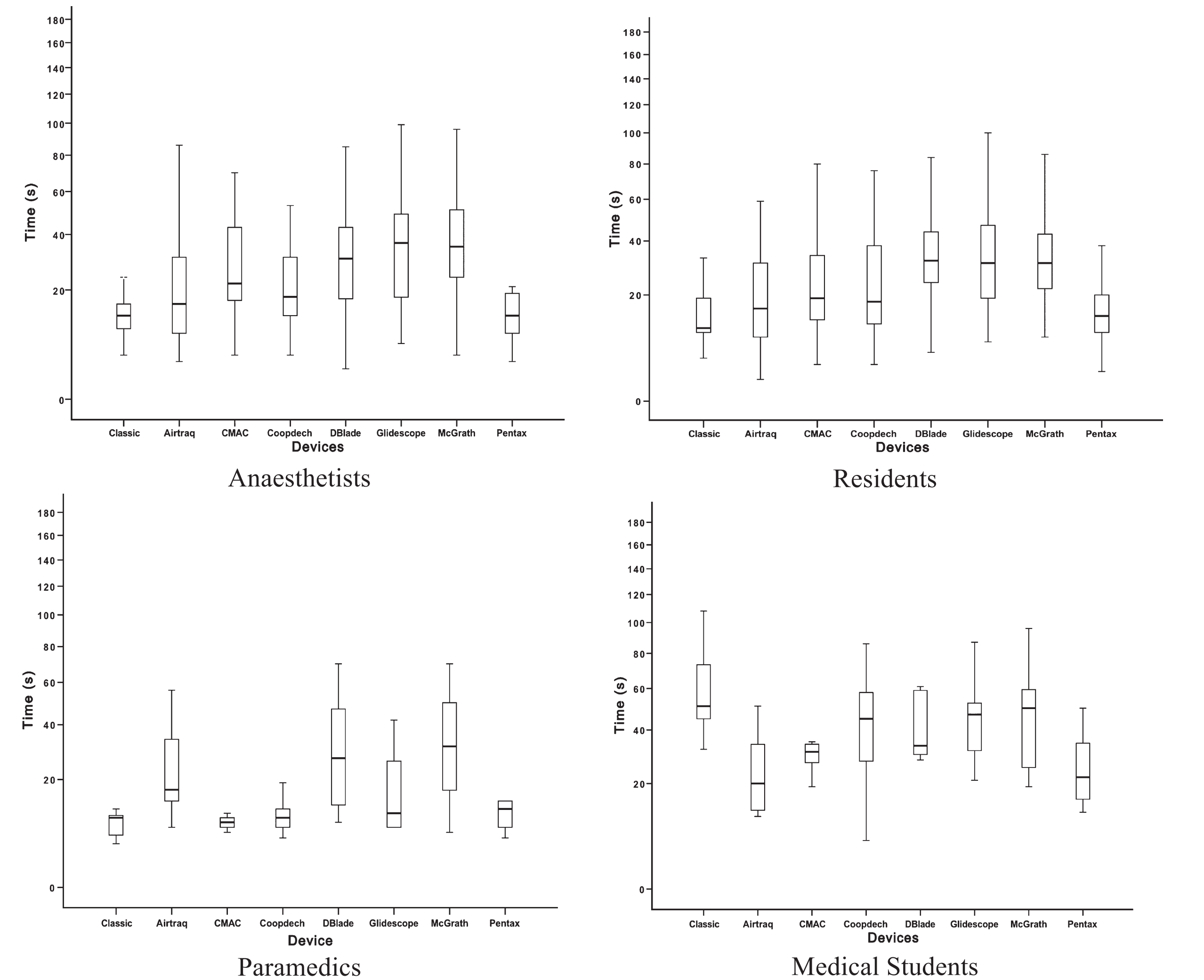

Figure 2 Boxplots representing the time to the best view of the glottis. The horizontal bars represent the median with edges of box being IQR; the whiskers are defined as 1.5 times the IQR. Thus, the bottom whiskers represent lower limits within 1.5 times IQR, top whiskers represent upper limits within 1.5 times IQR Outlier points were not studied for clarity.

$p < 0.001$ vs. other groups) and classic Macintosh laryngoscope (5 (5–7 [2–18]) s; $p < 0.036$ vs. other groups).

Times until successful tracheal intubation was achieved are graphically displayed in Fig. 3. Time to successful tracheal intubation was achieved fastest with the classic Macintosh laryngoscope by anaesthetists (12 (14–21 [5–84]) s; residents (13 (13–17 [5–58]) s and paramedics (11 (11–16 [4–45]) s; $p < 0.001$ vs. other devices). Medical students achieved successful tracheal intubation fastest when using the Coopdech videolaryngoscope (28 (26–37 [6–95]) s; however, this did not reach statistical significance ($p = 0.061$).

When comparing groups, medical students were slower compared with all other groups with the classic Macintosh laryngoscope (38 (38–57 [9–159]) s; $p < 0.001$ vs. other groups), Airtraq (32 (28–48 [5–175]) s; $p < 0.023$ vs. other groups), C-MAC (35 (34–45 [7–96]) s; $p < 0.019$ vs. other groups), and GlideScope (45 (45–62 [13–169]) s; $p < 0.047$ vs. other groups). For both the C-MAC (10 (10–19 [4–96]) s and the Coopdech (14 (14–20 [6–53]) s, paramedics were the fastest of all groups ($p < 0.002$ vs. other groups).

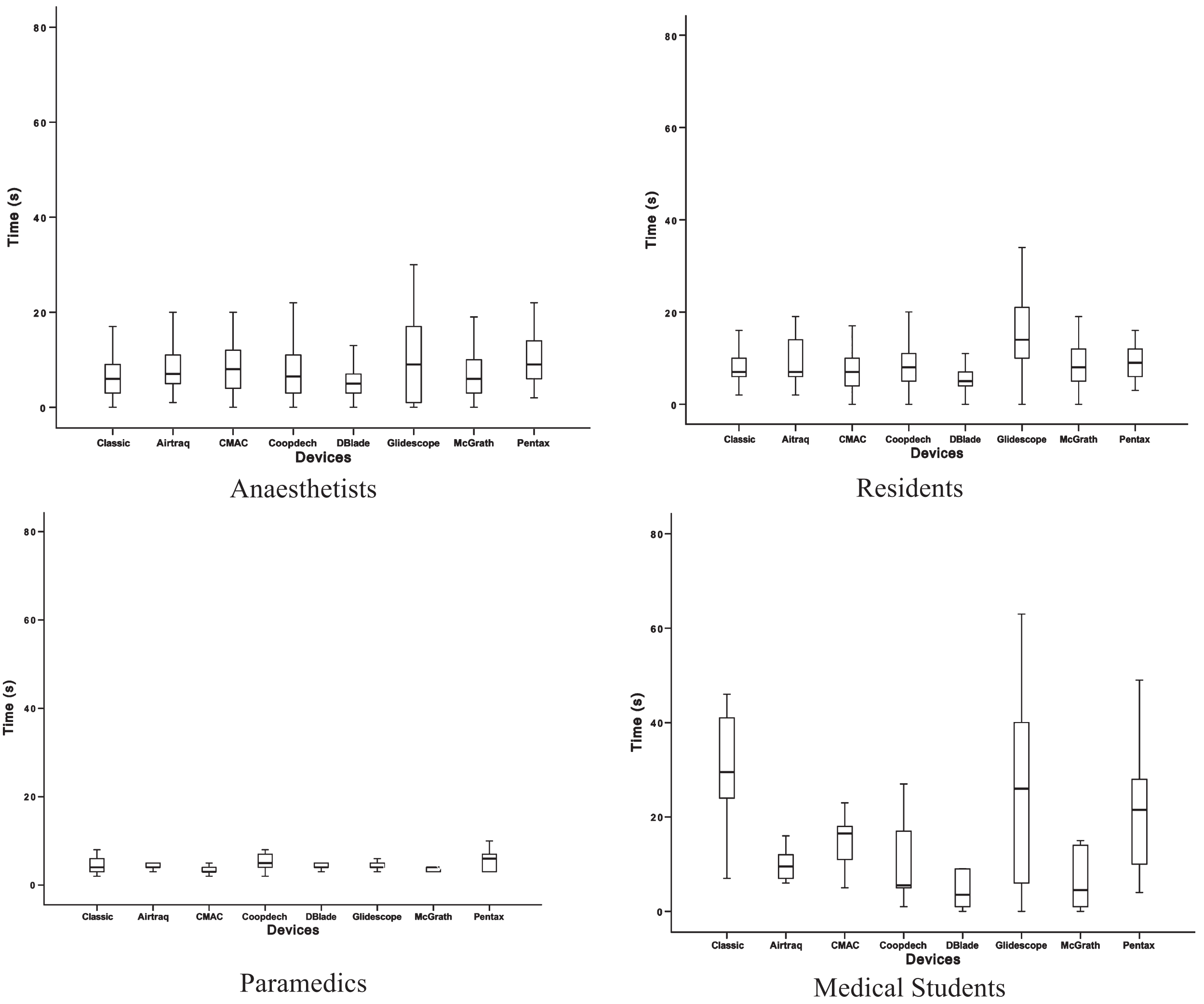

Figure 3 Boxplots representing the time to successful tracheal intubation (details as for Fig. 2).

Tracheal intubation success rates and variables are displayed in Table 2. Anaesthetists, residents and paramedics (all $p < 0.001$) were significantly less successful when using the Airtraq videolaryngoscope. Anaesthetists ($p = 0.04$) and paramedics ($p = 0.003$) also performed significantly worse when using the McGrath. Medical students were most successful when using the C-MAC, Coopdech and C-MAC D-Blade.

All groups needed significantly more attempts when using the Airtraq and Pentax AWS VLS (all $p < 0.047$). Paramedics needed significantly more attempts than residents when using the Airtraq videolaryngoscopy ($p = 0.006$). They also needed more attempts than medical students when using the McGrath ($p < 0.001$) and Pentax AWS ($p = 0.026$).

All participants, except medical students, needed significantly more optimisation manoeuvres when using the McGrath videolaryngoscope (all $p < 0.010$).

Residents and paramedics also needed significantly more optimisation manoeuvres when using the GlideScope (all $p < 0.008$) and D-Blade (all $p < 0.026$) VLS.

The Cormack and Lehane grade was scored significantly worse by all participants when they used the GlideScope videolaryngoscope (all $p < 0.001$). Anaesthetists (all $p < 0.014$), residents (all $p < 0.006$) and medical students (all $p < 0.001$) also got a worse view of the glottis using the classic Macintosh laryngoscope. Comparing groups, anaesthetists and paramedics

Table 2 Tracheal intubation success rates across staff groups. Values are numbers (proportion).

Device	Anaesthetists n = 65	Residents n = 67	Medical Students n = 65	Paramedics n = 56
Classic Macintosh	65 (100%)	67 (100%)	51 (79%)†	56 (100%)
Airtraq	54 (83%)*	55 (82%)*	45 (69%)†	44 (79%)*
C-MAC	65 (100%)	67 (100%)	65 (100%)	50 (100%)
Coopdech	65 (100%)	55 (100%)	52 (98%)	52 (100%)
C-MAC D-Blade	51 (98%)	46 (98%)	31 (100%)	15 (100%)
GlideScope	63 (97%)	63 (94%)	58 (89%)†	55 (98%)
McGrath	59 (91%)**	60 (95%)	48 (87%)†	44 (85%)***
Pentax AWS	63 (97%)	63 (94%)	59 (91%)†	56 (100%)

*p < 0.01, **p < 0.05, ***p < 0.001 compared with the classic Macintosh.
†p < 0.01, p < 0.05 and p < 0.001 compared with the C-MAC.

scored the Cormack and Lehane grade lower than medical students when respectively using the classic Macintosh laryngoscope ($p = 0.030$) and Airtraq videolaryngoscope ($p < 0.001$).

All participants, except paramedics, caused significantly more audible dental clicks when using the GlideScope videolaryngoscope (all $p < 0.029$). Of these participants, 19 (29%) anaesthetists, 11 (17%) residents and 39 (70%) medical students caused audible dental clicks. Audible dental clicks were also caused by anaesthetists ($p < 0.041$) and medical students ($p < 0.038$) significantly more when using the Coopdech videolaryngoscope. Paramedics (n = 9, 17%) caused significantly more audible dental clicks when using the McGrath videolaryngoscope ($p < 0.034$). Comparing groups, paramedics caused less audible dental clicks compared with anaesthetists when using the classic Macintosh laryngoscope ($p < 0.001$); however, they caused more audible dental clicks than residents when using the Airtraq videolaryngoscope ($p < 0.001$). Medical students caused more audible dental clicks when using the Pentax AWS than anaesthetists ($p < 0.001$) and paramedics ($p = 0.005$).

Regarding preference of devices, 22 anaesthetists (34%) and 15 residents (22%) rated the classic Macintosh laryngoscope highest. Paramedics and medical students most often rated the C-MAC highest (21 paramedics (38%) and 18 medical students (28%)). The Airtraq was rated lowest most often by anaesthetists (n = 26; 40%), paramedics (n = 23; 41%) and medical students (n = 28; 43%). Residents most often rated the McGrath videolaryngoscope lowest (n = 15; 22%).

Discussion

Our main observation is that, for the very wide range of devices we tested, across all key groups, there was not one single device that was best for all caregivers.

For anaesthetists, residents and paramedics, the time to successful tracheal intubation was shortest when using the classic Macintosh laryngoscope. Previous experience with this device in day-to-day practice should therefore be highly valued. The learning curve for videolaryngoscopes may be relevant [7]. A longer time to tracheal intubation when using the GlideScope and McGrath videolaryngoscopes has been reported in the literature in both manikins and patients [8, 14–17]. The potential advantages of this new technology may be outweighed by the lack of familiarity with the new technique.

When using the classic Macintosh laryngoscope, the laryngeal, pharyngeal and oral axes have to be aligned to achieve the best possible view of the glottis [18]. The passage of the tracheal tube through the upper airway is then usually easily done. This could explain why participants experienced with the classic Macintosh laryngoscope were significantly slower when using the acutely angled videolaryngoscopes (D-Blade, GlideScope and McGrath). Participants experienced with direct tracheal intubation may be subconsciously convinced that the axes should always be in one line when intubating.

A balance between the advantages of videolaryngoscopes and the disadvantage of new skill requirements can be found in videolaryngoscopes with a classic-shaped Macintosh blade (e.g. C-MAC and Coopdech VLS). Ideally, one is able to choose between direct and indirect laryngoscopy while in the middle of the act of tracheal intubation, changing the technique dependent on the (oral-laryngeal) situation encountered. Being familiar with the technique of direct laryngoscopy should not be a handicap, as bringing the axes into line is not perceived to hamper the effectiveness of the videolaryngoscope [14].

It may be argued that the difference of a few seconds is not clinically relevant. However, those few extra seconds taken to try and manipulate the tracheal tube once more may result in oedema, cause more trauma and make future attempts more difficult. More attempts are likely to result in even more trauma. The concept of 'time is brain', should not be underestimated as in our view 'every second counts'.

Medical students needed significantly more attempts when using the classic Macintosh laryngoscope. This reflects the results shown in previous studies; an average of 57 attempts is needed to achieve a 90% success rate of intubation with direct laryngoscopy [19].

Medical students produced significantly more audible clicks when using the classic Macintosh laryngoscope compared with the Airtraq, C-MAC, D-Blade, McGrath and Pentax AWS videolaryngoscopes. Being of a generation used to playing video-games, they may have better indirect eye-hand co-ordination than some experienced participants of an older generation [20]. They are, however, not used to the technique of direct laryngoscopy and are more likely to use the maxillary incisors as a fulcrum. Although the C-MAC videolaryngoscope also has a classic Macintosh blade, our results for the C-MAC are consistent with our previous findings that, even for experienced anaesthetists, the use of the C-MAC results in less pressure applied to the maxillary incisors [21–23].

Our study has several limitations, notably that it is a manikin study. Findings are not directly transferable to acute clinical care, but manikins can provide reliable, standardised comparative evaluation of new equipment or techniques [24, 25]. Due to the large numbers of participants and devices, we wanted to ensure standardised, consistent, true laryngoscopy each time to allow adequate device comparison. Ethically, it is preferable to limit patient risk, especially with so many inexperienced participants: we were able to include 56 paramedics (86%) because they work in small units and are en-route a lot during a shift. Paramedics may have performed better than expected because they were more familiar with regular manikin training. This does not invalidate the present study as there was a positive result, but it may mean that some comparisons that were not significant might in fact have been significant with a larger sample size.

We note that not all the devices we studied are always readily available elsewhere. The decision to use a stylet was left to the intubator, whereas manufacturers of GlideScope and McGrath VLS advocate routine use. The absence of an external monitor may influence the users' preference (e.g. the Airtraq does not have a video screen). Our study was not blinded, which could have led to altered performance as a result of the Hawthorne effect (individuals improve or modify their behaviour because of their awareness of being observed) [26]. We appreciate that the Cormack and Lehane grade has been described for direct laryngoscopy, not videolaryngoscopy. The percentage of glottic opening may be better for documentation of videolaryngoscopy, but we do not think our results would greatly differ if an alternative scale had been applied [25].

In conclusion, while there are major differences between tracheal intubation in manikins and in patients, we believe this trial contributes to the understanding as to how videolaryngoscopes vary in their ability to facilitate tracheal intubation for different caregivers.

The choice of a laryngoscope should be made based on requirements of the device and the person using it. This has implications for hospital providers. While they might sensibly take advice from their core staff as to the choice of main device to purchase (ideally, in turn, based on published evidence [27]), they should also rationally stock a range of devices to account for differences in performance across individuals and staff groups, as we have demonstrated. Failing to acknowledge this reality might compromise patient safety.

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