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RESPIRATION AND THE AIRWAY

Randomized controlled trial of the A.P. Advance, McGrath, and Macintosh laryngoscopes in normal and difficult intubation scenarios: a manikin study

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Editor's key points

- There is a need to develop techniques and equipment to facilitate difficult intubation.
- Manikin use can assist in reliable, standardized evaluation of new equipment or techniques.
- The clinical utility of several laryngoscopes was assessed by studying different components of tracheal intubation.
- The performance of different laryngoscopes was dependent on the type of clinical scenario.

Background. Several videolaryngoscopes are available which may facilitate tracheal intubation in difficult airways. We compared the McGrath® Series 5 and the Venner™ A.P. Advance™ (APA) videolaryngoscopes with a Macintosh laryngoscope by studying the performance of experienced anaesthetists using manikins in normal and difficult airway scenarios.

Methods. We recruited 48 anaesthetists into a randomized trial. Each performed tracheal intubation with each laryngoscope in one easy and one difficult laryngoscopy scenario. The primary endpoint was time to intubation. Other endpoints were time to best glottic visualization, grade of view, and number of glottic advances.

Results. There were no dropouts. In the easy scenario, the time to intubation was greater using the McGrath [median time 40.7 s, inter-quartile range (IQR) 31.0, 57.4, $P<0.001$] than the other devices. In the difficult scenario, the time to intubation using the APA with Difficult Airway Blade (DAB) was less (median time 23.2 s, IQR 19.8, 29.0, $P<0.001$) than the other devices. Time to glottic visualization was reduced using the McGrath and the APA with DAB. Glottic advances were fewer using the APA with DAB.

Conclusions. Experienced anaesthetists required a longer time for intubation in a standard manikin using a McGrath compared with other laryngoscopes, but a shorter time for intubation in a difficult manikin using an APA with DAB, and with fewer glottic advances, compared with other laryngoscopes.

Keywords: intubation; intratracheal; laryngoscopes; manikins; randomized controlled trial

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Difficult and failed laryngoscopy and tracheal intubation cause morbidity and mortality.[1] The Macintosh laryngoscope necessitates alignment of the oropharyngeal–laryngeal axes to visualize the glottic opening and intubate the trachea. This is often difficult in patients with abnormal airway anatomy. Several videolaryngoscopes are available which use fibreoptic or camera technology to provide indirect laryngeal visualization. Clinical studies have suggested that videolaryngoscopy improves the glottic view,[2] but some authors have questioned whether an improved view necessarily facilitates easier tracheal intubation.[3] Passage of the tracheal tube (TT) may be more difficult so a paradoxically longer intubation time may be necessary with some devices despite an improved view.[4]

There are three main types of videolaryngoscopes in common clinical use; a Macintosh-style blade, an angulated blade with a delivery channel for the TT, and an angulated blade without a delivery channel.[5] The techniques required to use each of these are different.[6] Angulated blades with no delivery channel mandate the use of a stylet, which has been associated with airway trauma.[7–10]

The McGrath® Series 5 videolaryngoscope (Aircraft Medical, UK) and the Venner™ A.P. Advance™ (APA; Intavent Direct, UK) are both commercially available videolaryngoscopes. Both have camera sticks with an integrated light source, LCD screens topping the handles, and single-use transparent blades which cover the camera sticks (Fig. 1A and B). The McGrath has been clinically available since 2006 and has a small LCD screen (1.7 in.) and a single choice of blade: a slim acrylic cover with a 60° angulation to provide an indirect view of the glottis. Conventional direct laryngoscopy is not possible using the McGrath device. The manufacturers recommend that intubation is performed with a TT loaded onto a stylet.[11]

In contrast, the APA has recently been approved for use in Europe and the USA and has a larger, higher resolution LCD

screen (3.5 in.). It is a hybrid videolaryngoscope with a choice of two types of blade, the conventional size 3 or 4 Macintosh blade for standard laryngoscopy, and the Difficult Airway Blade (DAB) which is angulated to provide an indirect view and has a guiding channel to facilitate tracheal intubation once a view is obtained. A stylet is not required.[12]

We wished to evaluate the efficacy of these laryngoscopes compared with a Macintosh laryngoscope, when used by experienced anaesthetists unfamiliar with these videolaryngoscopes, in a randomized controlled manikin study in a normal airway and in a difficult airway scenario. We chose a manikin study because the APA is a new device whose performance has not been examined in a randomized trial in the peer-reviewed literature.

Several trials have demonstrated an improved glottic view using videolaryngoscopy compared with Macintosh laryngoscopy in manikin difficult airway scenarios[2] and in patients with predicted difficult airways.[4 13] There is little evidence that videolaryngoscopy is advantageous when used by experienced anaesthetists in normal airways or simulated normal airways.[14–17] We hypothesized that the intubation time would be shorter using the videolaryngoscopes in a difficult airway. On the basis of the differences between the McGrath and the APA, we further hypothesized that the APA would be associated with less glottic trauma than the McGrath in both situations, as measured by a number of 'glottic advances'—unsuccessful attempts at inserting the TT into the trachea which potentially abut the tube onto glottic structures before intubation was accomplished.

Methods

Study design

An ethical waiver was provided by the Institutional Research Ethics Board. After the study of trials with similar methodology, we aimed to recruit at least 48 anaesthetists with at least 2 yr experience in anaesthesia who had performed more than 250 intubations using a Macintosh laryngoscope. Participation was voluntary, informed written consent was obtained, and all data were anonymized. Data were collected from participants regarding previous experience with videolaryngoscopes. Anaesthetists who had used either the APA or the McGrath videolaryngoscope more than 10 times were excluded.

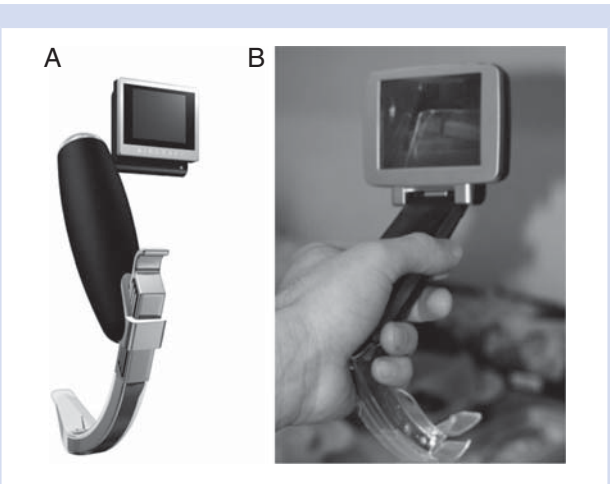

Fig 1 (A) The McGrath videolaryngoscope (with permission, Aircraft Medical, UK) and (B) the APA videolaryngoscope with DAB (with permission, Intavent Direct, UK).

Each participant was given a standardized demonstration of both the APA and McGrath devices by the investigators who had performed laryngoscopy in patients and manikins using both of the devices, and who had read the relevant product literature. This included an explanation of the devices, oral instructions on how to use each laryngoscope, and a run-through of intubation using each laryngoscope. Participants then practised laryngoscopy with each of the laryngoscopes until tracheal intubation had been achieved, in a VBM 'Bill' manikin™ (VBM Medizintech).

The study was a four-group, two-stage randomized crossover trial. Each anaesthetist performed tracheal intubation with each device in one easy and then one difficult laryngoscopy scenario. The order of use of the laryngoscopes by each participant was randomized (www.random.org) and participants used the same order in both scenarios. The easy scenario was a SimMan® Manikin in the normal setting. The difficult scenario was a Laerdel® Airway Trainer with occipital immobilization and neck fixation applied using a non-elastic adhesive tape to simulate a fixed cervical spine with reduced neck extension.

The primary endpoint was time to intubation. The secondary endpoints were as follows: time to best glottic view; the Cormack and Lehane grade at laryngoscopy; a surrogate marker of potential glottic trauma—glottic advances (defined as the number of forward advances of the TT followed by a withdrawal of the TT, before successful intubation); a visual analogue scale (VAS) of perceived difficulty of tracheal intubation after the use of each device; participant preference for quickest and safest intubation after each scenario. An additional endpoint was measured in the difficult scenario, namely, dental trauma, defined as the number of teeth clicks on the Laerdel manikin during the intubation attempt.

Before each intubation attempt, the manikin, laryngoscope blade, and TT were lubricated. The participants had a choice of two identical TTs, internal diameter 7.0 mm (Portex, Kent, UK), one of which was preloaded with a rigid stylet formed in the shape of a hockey stick with a 90° bend, optimized for use with videolaryngoscopes (GlideScope Rigid Stylet, BC, Canada). A gum elastic bougie was also available. The participants were encouraged to choose whichever TT and intubation aid that they thought would maximize the chances of successful tracheal intubation. The anaesthetists were free to choose either the styletted or the unstyletted TT or use the bougie at any time during attempts.

Timing began when the laryngoscope entered the mouth, an interim time was recorded when the participant stated the grade of best glottic view, and timing stopped when there was successful lung expansion using a self-inflating

bag. Participants were asked to rate each device using a 10 cm VAS where a higher number indicated greater difficulty, and to choose which device they would use in each scenario to give the safest intubating conditions.

Data analysis

Results were analysed using Stata version 11.1 (StataCorp, TX, USA). Outcomes from the same participant were expected to be more similar than outcomes from different participants and not independent from each other. Therefore, the analysis was performed using multilevel statistics. Two-level models were used with individual results nested within participants. Continuous data were analysed using multilevel linear regression and integer data by the Poisson regression. Log transformation was used to transform the skewed data to normal. The results were summarized by median and inter-quartile range for each method. The difference between groups is presented as a ratio.

Results

Participant characteristics

Forty-eight anaesthetists were successfully recruited (26 males and 22 females; mean age 38 yr); with no dropouts. Forty-six (96%) were right-handed. All had at least 3 yr experience in direct laryngoscopy (mean 10.4 yr, SD 5.8). Forty-seven (98%) had used videolaryngoscopy previously, with almost all (94%) familiar with the GlideScope® and half (48%) familiar with the Airtraq. Of the study videolaryngoscopes, 12 (25%) anaesthetists had used the McGrath previously and five (10%) had used the APA previously.

Easy scenario

There was no significant difference in time to intubation between the APA DAB, APA Mac, and the Macintosh, but intubation was significantly faster in the Macintosh [median time 26.1 s, inter-quartile range (IQR) 19.9, 33.5] and APA DAB (median time 27.7 s, IQR 22.5, 38.0) than the McGrath (median time 40.7 s, IQR 31.0, 57.4). There were statistically significant differences between the devices for the secondary endpoints: time taken to view the vocal cords and number of glottic advances. Time to view the vocal cords: there was no difference between the Macintosh and the APA Mac, but both the McGrath and the Macintosh were significantly faster than the APA DAB. Glottic advances: these were significantly reduced in the APA DAB compared with the McGrath and the Macintosh, and also in the APA Mac compared with the Macintosh. Other outcomes: there was no overall difference between the four methods for the VAS score or for the Cormack and Lehane grade of the glottic view. Participants were asked to state their preference for quickest and safest intubation if faced with the same scenarios again. In the easy scenario, the preference was for the Macintosh laryngoscope (52%).

The results for time to intubation are shown in Figure 2. Table 1 shows the analysis of time to view and time to intubation. Glottic advances are shown in Table 2.

Difficult airway scenario

The APA DAB (median time 23.2 s, IQR 19.8, 29.0) was significantly faster for the primary endpoint (time to intubation) than both the Macintosh (median time 39.2 s, IQR 27.0, 50.9) and the McGrath (median time 35.6 s, IQR 25.5, 49.6). In the difficult scenario, the results showed a statistically significant difference overall between the four devices for the time taken to view the vocal cords, number of glottic advances, and dental clicks. Time to view the vocal cords: both videolaryngoscopes were significantly faster than the Macintosh. Glottic advances: the APA DAB caused significantly fewer glottic advances than the Macintosh and the McGrath. Dental clicks: there were significantly more dental clicks using the Macintosh and the APA Mac compared with the McGrath and the APA DAB, with the McGrath causing the fewest number of clicks (Table 2).

Cormack and Lehane views obtained: the APA Mac gave more Grade 1 or 2 views in the difficult scenario than the Macintosh. Neither the McGrath nor the APA DAB elicited Grade 3 or 4 views in either scenario (Table 3).

Participants were asked to state their preference for quickest and safest intubation if faced with the same scenarios again. In the difficult scenario, the preference was for the APA DAB (58%) (Fig. 3).

In the difficult scenario, the use of stylet was as follows: 47 (98%) used a stylet with the McGrath, 4 (8%) with APA Mac, and 1 (2%) with each of the APA DAB and Macintosh.

Discussion

We aimed to evaluate the effectiveness of the Macintosh, McGrath, and APA laryngoscopes when used by experienced anaesthetists in manikins in two airway scenarios. Time to intubation using an APA Mac and an APA DAB in an easy intubation manikin scenario is comparable with the Macintosh, and significantly faster than the McGrath. In a difficult intubation scenario, time to intubation is significantly faster using the APA DAB than the McGrath or Macintosh blades.

Our expectation was that intubation time using videolaryngoscopy and direct laryngoscopy would not differ in an easy airway scenario and that videolaryngoscopy would result in a reduced time to intubation in a difficult airway scenario. This expectation was only partially supported by the results. We suggest that this is because anaesthetists who are experienced in direct laryngoscopy are expert at tracheal intubation using a Macintosh laryngoscope, and therefore, the different skills necessary to effectively perform McGrath videolaryngoscopy outweigh the advantages that the new technology may offer. Other studies have found that novices find the MacGrath easier to use than the Macintosh,[18] but that experienced anaesthetists find the MacGrath harder.[3] The technique required to effectively use the APA videolaryngoscope is very similar to the Macintosh; therefore, the learning curve may be shorter.

During laryngoscopy, an adequate view of the glottis is important but not sufficient. Our study showed that while the use of the McGrath enabled the participant to have a

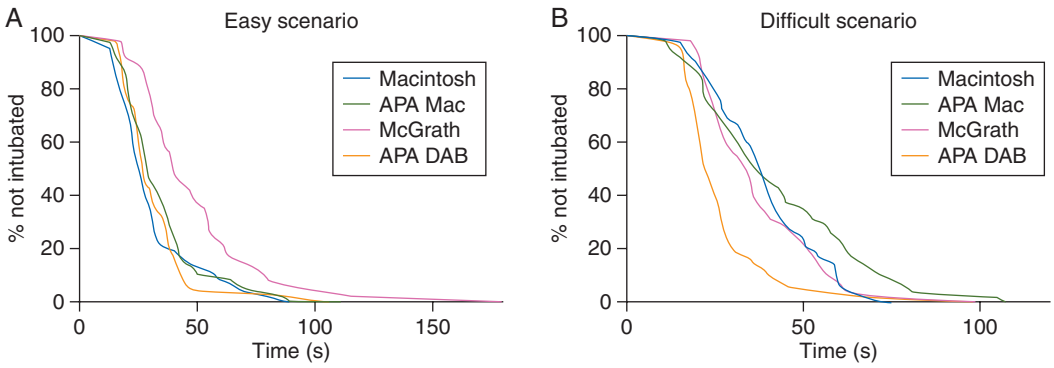

Fig 2 Graphical representations of percentage of manikins in each scenario whose tracheas are not yet successfully intubated. (A) Easy scenario. (B) Difficult scenario.

Table 1 Time to view vocal cords and time to intubate (s). Timings are expressed as median (IQR). The data were positively skewed, and therefore, a log transformation was performed and the differences between groups presented as ratios. The ratios represent the time taken for each scope method relative to the time taken for the Macintosh laryngoscope. The *P*-values for multilevel linear regression are shown

	Time to view of vocal cords	Ratio (95% CI)	Time to intubate	Ratio (95% CI)
Easy scenario				
Macintosh	11.5 (8.4, 17.0)	1	26.1 (19.9, 33.5)	1
APA Mac	12.2 (8.0, 18.5)	1.08 (0.92, 1.28)	29.4 (22.7, 41.5)	1.14 (0.98, 1.33)
McGrath	9.1 (7.0, 12.0)	0.79 (0.67, 0.94)	40.7 (31.0, 57.4)	1.60 (1.37, 1.87)
APA DAB	14.5 (9.8, 20.6)	1.23 (1.04, 1.46)	27.7 (22.5, 38.0)	1.07 (0.92, 1.25)
Overall *P*-value		<0.001		<0.001
Difficult scenario				
Macintosh	14.0 (11.1, 20.2)	1	39.2 (27.0, 50.9)	1
APA Mac	17.5 (10.6, 23.9)	1.09 (0.92, 1.28)	38.5 (23.5, 60.5)	1.03 (0.89, 1.20)
McGrath	10.0 (7.1, 14.3)	0.68 (0.58, 0.81)	35.6 (25.5, 49.6)	0.95 (0.82, 1.12)
APA DAB	10.4 (8.3, 15.7)	0.75 (0.64, 0.89)	23.2 (19.8, 29.0)	0.69 (0.59, 0.80)
Overall *P*-value		<0.001		<0.001

rapid and adequate view of the glottis, this did not translate into quick intubation. Indeed, while the Cormack and Lehane[19] grade of the laryngoscopic view is an accurate predictor of success in direct laryngoscopy, its use in videolaryngoscopy has been called into question.[20] This is because a good view of the glottis on a screen does not guarantee easy passage of the TT into the larynx, since hand-eye coordination may be impaired by the indirect view.

Despite having a bulkier blade, the APA DAB seems to facilitate intubation in a difficult airway scenario. This may be due to the channel built into the DAB which guides the TT directly through the glottic opening and allows easier intubation. A similar phenomenon was reported in a comparison of the Pentax AWS videolaryngoscope with the McGrath in a manikin study.[17]

During conventional direct laryngoscopy, a stylet is seldom used at the first attempt. In contrast, the routine use of a styletted TT is advocated by the manufacturers of the McGrath videolaryngoscope.[11] In previous studies of the McGrath, the use of a stylet was considered mandatory to facilitate tracheal intubation, and a thicker more rigid stylet facilitated intubation better than a malleable one.[6] This may be because the narrow blade of the McGrath means tissues are not displaced as far anteriorly as with conventional laryngoscopy. The use of the stylet has been associated with airway complications,[7–10] perhaps due to the blind gap that the styletted TT must travel after it disappears from direct vision and before it is visible on the LCD screen. The tip of the styletted tube can catch on the vocal cords as it enters the larynx. The use of a stylet is not necessary for intubation using the APA DAB. The authors speculate that this may reduce the problem of airway trauma that has been described with the use of a styletted TT during videolaryngoscopy.[10]

The APA can be used as a direct or indirect laryngoscope. As the APA can incorporate a Macintosh blade, proficiency with the device may be easier to acquire than with other videolaryngoscopes as our anaesthetists experienced. This

Table 2 Glottic advances and dental clicks presented as median (IQR). *P*-values from multilevel linear regression are shown

	Easy scenario		Difficult scenario			
	Glottic advances	Ratio (95% CI)	Glottic advances	Ratio (95% CI)	Dental Clicks	Ratio (95% CI)
Macintosh	1 (0, 2)	1	1 (0, 2.5)	1	2 (1, 5.5)	1
APA Mac	1 (0, 2)	0.69 (0.50, 0.93)	1 (0, 2)	0.76 (0.57, 1.03)	2.5 (1, 5.5)	0.99 (0.80, 1.22)
McGrath	3 (1, 4.5)	2.30 (1.82, 2.92)	2 (1, 7)	2.24 (1.77, 2.83)	0 (0, 0.5)	0.17 (0.11, 0.25)
APA DAB	1 (0, 1)	0.39 (0.27, 0.56)	1 (0, 1)	0.31 (0.21, 0.46)	1 (0, 2)	0.35 (0.26, 0.47)
Overall *P*-value		<0.001		<0.001		<0.001

Table 3 Grade of laryngoscopy (Cormack and Lehane). Values are *n* (%)

	Grade 1	Grade 2	Grade 3	Grade 4
Easy scenario				
Macintosh	23 (48)	21 (44)	4 (8)	0
APA Mac	23 (48)	22 (46)	3 (6)	0
McGrath	44 (92)	4 (8)	0	0
APA DAB	45 (94)	3 (6)	0	0
Difficult scenario				
Macintosh	2 (4)	24 (50)	21 (44)	1 (2)
APA Mac	3 (6)	33 (69)	12 (25)	0
McGrath	30 (62)	18 (38)	0	0
APA DAB	31 (65)	17 (35)	0	0

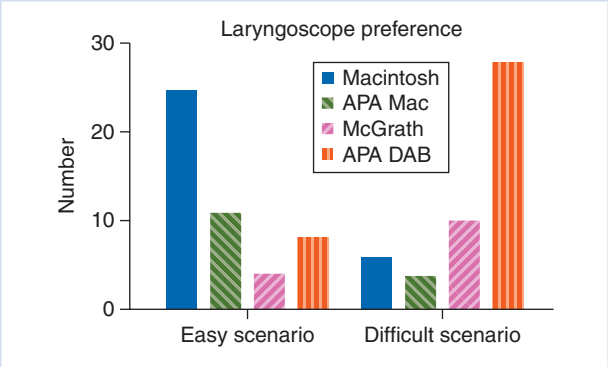

Fig 3 Anaesthetist preference for the laryngoscope they would choose for safest and quickest intubation if faced with the same scenario again.

may allow for a quicker learning curve compared with other devices and may account for the improved degree of satisfaction that the participants felt when using the APA.

To our knowledge, this is the first randomized comparison of the Macintosh, APA, and McGrath laryngoscopes. Our aim was to evaluate the APA in manikin scenarios in comparison with the standard of care (Macintosh) and a videolaryngoscope which is in common clinical use (McGrath). There are no published trials of the APA in patient populations. Manikin studies are necessary in this context to protect patients from harm from untested medical devices. Recent studies have demonstrated that laryngoscopy using high-fidelity manikins is similar when repeated on patients;[15] however, data from manikin studies cannot be directly extrapolated into clinical practice.[21] We cannot be sure of the clinical implications of our results.

While there are major differences between intubation of manikins and patients, we believe that this trial contributes to our understanding in this area; videolaryngoscopes vary in their ability to facilitate tracheal intubation. The use of manikins in simulation is widespread in many areas of anaesthesia and is an accepted way to train novices in laryngoscopy.[22] While manikins have been demonstrated to be unreliable in the assessment of supraglottic airway devices,[23] the same is not true for the assessment of videolaryngoscopes.

Ideally, this study would have been performed in clinical conditions, but recruiting patients with known or suspected difficult airways for adequately powered comparative trials is a lengthy process; many years will pass before any useful data are available on any airway device if this is the only form of trial available. In the meantime, the anaesthetist should be aware of the best available evidence.

This study has several other limitations. It was not blinded either to the participants or the assessors, which may have introduced bias. Our study does not provide information about the use of these devices by novices or by those familiar with the McGrath and the APA in the clinical setting. There are other videolaryngoscopes available which we did not investigate. We used a Portex size 7.0 mm internal diameter TT, but the results may have been different using a different size or brand of TT. The anaesthetists were aware that their actions were being timed, which could lead to altered performance as a result of the Hawthorne effect.[24] One of our secondary outcomes required the anaesthetist to say the Cormack and Lehane view as soon as they thought they had the best view. This was subjective and prone to bias. There is likely to have been some period effect between the easy and difficult scenarios, but this was balanced between the laryngoscopes order of use which was randomized. There is unlikely to have been any carryover effect. The difficult airway scenario that we simulated was that of a fixed cervical spine. Other authors have used different scenarios,[15] which may affect the performance of the devices. Finally, a formal sample size calculation was not performed for this study; rather, the literature was reviewed for trials

of a similar methodology before a target was agreed. However, as significant differences were observed between the different laryngoscopes for the primary outcome, the study seems to have been sufficiently powered.

In conclusion, the APA is an effective videolaryngoscope and is likely to be safe for use in humans. In our trial, both the McGrath and the APA with DAB possess advantages over the Macintosh, and in a difficult airway scenario, the APA facilitates more rapid intubation compared with the McGrath and Macintosh devices.

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Conflict of interest

None declared.

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