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Original Article

A comparison of the McGrath videolaryngoscope with direct laryngoscopy for rapid sequence intubation in the operating theatre: a multicentre randomised controlled trial

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Summary

Aspiration of gastric contents is a recognised complication during all phases of anaesthesia. The risk of this event becomes more likely with repeated attempts at tracheal intubation. There is a lack of clinical data on the effectiveness of videolaryngoscopy relative to direct laryngoscopy rapid sequence intubation in the operating theatre. We hypothesised that the use of a videolaryngoscope during rapid sequence intubation would be associated with a higher first pass tracheal intubation success rate than conventional direct laryngoscopy. In this multicentre randomised controlled trial, 1000 adult patients requiring tracheal intubation for elective, urgent or emergency surgery were allocated randomly to airway management using a McGrath™ MAC videolaryngoscope (Medtronic, Minneapolis, MN, USA) or direct laryngoscopy. Both techniques used a Macintosh blade. First-pass tracheal intubation success was higher in patients allocated to the McGrath group (470/500, 94%) compared with those allocated to the direct laryngoscopy group (358/500, 71.6%), odds ratio (95%CI) 1.31 (1.23–1.39); $p < 0.001$. This advantage was observed in both trainees and consultants. Cormack and Lehane grade ≥ 3 view occurred less frequently in patients allocated to the McGrath group compared with those allocated to the direct laryngoscopy group (5/500, 1% vs. 94/500, 19%, respectively; $p < 0.001$). Tracheal intubation with a McGrath videolaryngoscope was associated with a lower rate of adverse events compared with direct laryngoscopy (13/500, 2.6% vs. 61/500, 12.2%, respectively; $p < 0.001$). These findings suggest that the McGrath videolaryngoscope is superior to a conventional direct laryngoscope for rapid sequence intubation in the operating theatre.

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Introduction

Aspirating gastric contents during general anaesthesia increases the risk of postoperative respiratory complications and mortality [1]. In the UK, 50% of deaths related to airway management in anaesthesia are associated with pulmonary aspiration [2]. The incidence of peri-operative pulmonary aspiration is 1 in 7103, with a morbidity rate of 1 in 16,573 and a mortality rate of 1 in 99,441 [3]. High-risk patients, such as those with a higher ASA physical status and those undergoing emergency surgery, have a significantly greater incidence of pulmonary aspiration associated with anaesthesia [3]. Repeated tracheal intubation attempts increase the risk of aspiration and hypoxaemia [4]. Guidelines recommend avoiding multiple attempts at rapid sequence intubation (RSI) [5]. Guidelines also recommend the routine use of a videolaryngoscope whenever feasible because of improved glottic view and reduction of oesophageal intubation [6].

Videolaryngoscopy is a preferred technique for tracheal intubation when direct laryngoscopy has failed [7]. It is recommended that the success of first pass tracheal intubation should be a primary outcome in airway management research, as it is associated with patient morbidity and mortality [6, 8]. However, the effectiveness of videolaryngoscopy in some settings is uncertain. It may take longer to perform tracheal intubation with a videolaryngoscope than with a direct laryngoscope (even without cricoid force) [9]. If cricoid force is applied, tracheal intubation using a videolaryngoscope may be even more challenging and time-consuming [10]. Anatomical factors can make videolaryngoscopy difficult, particularly when inserting the blade into patients with smaller mouths or in the presence of blood, vomitus or other obstacles in the oral cavity (such as tumours or large tongues). While a recent systematic review of 222 studies with 26,149 patients found that videolaryngoscopy of any design is likely to improve first pass tracheal intubation success and glottic view [6], many included studies had limitations including small sample sizes; differences in settings (operating theatre vs. emergency department); exclusion of patients at high risk of pulmonary aspiration; and inclusion of only experienced providers [6, 8, 11]. Due to the differences in methodological design, it is uncertain whether videolaryngoscopy makes first pass tracheal intubation more likely during RSI.

We hypothesised that using the McGrath™ MAC (Medtronic, Minneapolis, MN, USA) videolaryngoscope for tracheal intubation during RSI in the operating theatre would achieve a higher first pass tracheal success compared with standard direct laryngoscopy.

Methods

We conducted a randomised controlled trial across four hospitals in Germany: two tertiary hospitals (University Medical Centre, Mainz and University Medical Centre, Freiburg) and two general hospitals (Klinikum Mutterhaus der Borromäerinnen, Trier and Bundeswehrzentralkrankenhaus Koblenz). The study protocol has been published previously [12]. Before commencing recruitment, ethical approval was granted at each participating centre. After obtaining written informed consent, we enrolled adult patients (aged ≥ 18 y) who were scheduled for elective or emergency surgery (within 6–24 h of a decision to operate) and for whom RSI was indicated. Patients with a known or anticipated difficult airway; patients with an airway difficulty score ≥ 9 [13]; pregnant or breastfeeding women; and patients with life-threatening conditions requiring immediate surgery were not studied. Eligible patients at all four sites were assigned randomly to tracheal intubation using a McGrath MAC videolaryngoscope (McGrath group) or direct laryngoscopy group with an appropriately sized Macintosh blade [12] (direct laryngoscopy group) using a computer-generated list (QuickCalcs, GraphPad® Software, La Jolla, CA, USA). Patients were blinded to their group allocation.

Before induction of anaesthesia, all patients received standard monitoring, which included electrocardiography, pulse oximetry and blood pressure (invasive or non-invasive). In the McGrath group, the tracheal tube was prepared with a stylet, while in the direct laryngoscopy group, it was prepared according to the local practice of each study centre [12, 14]. No other airway adjuncts, such as a bougie, were permitted. Before starting, all patients were placed in a supine/reverse Trendelenburg (30° head up) position. After sufficient pre-oxygenation, balanced anaesthesia was induced and maintained according to local standards and practices. After complete neuromuscular blockade was confirmed (train-of-four count of 0/4 or after muscular fasciculation stopped when using succinylcholine), intubation of the patient's trachea was attempted.

The primary outcome was successful first pass tracheal intubation. This was defined as correct placement of the tracheal tube with a single blade insertion within 120 s and verified by waveform capnography [15]. If two attempts with the same device proved unsuccessful, the operator was changed and an alternative technique was applied. Secondary outcomes included: time to glottic view (from device insertion to glottic view); time to tracheal tube placement (from device insertion to tracheal tube passing through the vocal cords); time to ventilation (from device

insertion to first end-tidal capnography waveform); number of laryngoscopy attempts; use of external laryngeal manipulation; glottic view using Cormack and Lehane grading; percentage of glottic opening; intubation difficulty score [16]; incidence of peri-operative complications (defined as regurgitation and/or aspiration; desaturation on pulse oximetry to < 90%; or dental or soft tissue trauma); incidence of postoperative complications assessed after 24 h (such as hoarseness or dysphagia); and comparison of the level of training with tracheal intubation success rate. A research assistant, not involved in patient care, was present during anaesthesia induction to record peri-intubation variables and outcome parameters and was unblinded to group allocation. We also recorded the laryngoscopy technique used in patients allocated to the McGrath group (whether direct or indirect glottic visualisation was used).

In recent trials, tracheal intubation with videolaryngoscopy was successful in approximately 97% of first attempts. The trial power calculation therefore assumed first pass success rates of 97% and 92% for the McGrath [17] and direct laryngoscopy [18, 19] groups, respectively. To detect such a difference, we included 500 patients per group, assuming a drop-out rate of 5%. This yielded a study power of 96% to detect a 5% absolute difference between the two groups at significance level ($\alpha = 0.05$).

Binary data were analysed using the χ^2 test or by Fisher's exact test, if > 20% of expected values were < 5. Ordinal data were evaluated using the Wilcoxon-rank test. Kaplan–Meier curves and the log-rank test were used to compare comparative data. Continuous data were checked for normality by the Shapiro–Wilk W-test. Normal data were analysed by Student's unpaired t-test and non-normal data were analysed by an independent sample Kruskal–Wallis test. Multiple logistic regression analysis using age, sex, ASA physical status, BMI, airway difficulty score and provider experience as potential explanatory variables for successful tracheal intubation within 120 s was assessed using Cox regression. We considered two-tailed p-values < 0.05 to be significant. We used SPSS 9.4 (SAS® Institute Inc., Cary, NC, USA) for statistical analysis.

Results

Between 1 July 2021 and 31 August 2023, we assessed 1351 patients for eligibility, and 1037 patients were enrolled and allocated randomly (Fig. 1). In total, 37 patients were excluded after allocation because they failed to meet the inclusion criteria: 19 patients did not receive the allocated intervention as they had a predicted difficult airway with airway difficulty score ≥ 9 and 18 patients were lost to follow-up (surgery cancelled or postponed or organisational reasons). Thus, a total of 1000 patients were analysed in the McGrath (n = 500) and direct laryngoscopy groups (n = 500). Patient baseline characteristics and distribution of RSI indications were comparable between groups (Table 1).

There was a significantly higher first pass tracheal intubation success rate in patients allocated to the McGrath group (470/500, 94%) compared with those allocated to the direct laryngoscopy group (358/500, 71.6%; Table 2); odds ratio (95%CI) 1.31 (1.23–1.39); p < 0.001. In patients allocated to the McGrath group, the majority of failed first tracheal intubation attempts (25/30, 83.3%) resulted from exceeding the maximum allowed tracheal intubation time of 120 s, while 5/30 (16.7%) were related to inadequate glottic view (Cormack and Lehane ≥ 3). In 3/500 (0.6%) patients in the McGrath group both tracheal intubation attempts were unsuccessful, all due to a prolonged tracheal intubation time > 120 s. In 142/500 (28.4%) patients allocated to the direct laryngoscopy group, the first attempt at tracheal intubation was unsuccessful. These were related to poor glottic view with Cormack and Lehane ≥ 3 in 94/142 (66%); 7/142 (4.9%) oesophageal intubation; and 41/142 (29.1%) from exceeding the tracheal intubation time limit. In 30/500 (6%) patients allocated to the direct laryngoscopy group both tracheal intubation attempts were unsuccessful. These were due to an insufficient glottic view and exceeding the allowed tracheal intubation time. Rescue techniques after the second failed attempt for both devices are outlined in the online Supporting Information Table S1.

Technical problems were reported in 2/500 (0.4%) patients allocated to the McGrath group, most often fogging of the camera lens. No technical problems with direct laryngoscopy were noted. Subgroup analyses showed that first-pass tracheal intubation success among trainees was significantly higher using the McGrath videolaryngoscope compared with direct laryngoscopy (239/258, 92.6% vs. 180/255, 70.5%; p < 0.001). This equates to an absolute risk reduction (95%CI) of 15.8% (10.2–21.6%) for unsuccessful tracheal intubation at the first attempt. Successful first pass tracheal intubation among consultants was also significantly higher with the McGrath videolaryngoscope compared with direct laryngoscopy (231/242, 95% vs. 179/245, 73%; p < 0.001), absolute risk reduction (95%CI) 19.3% (13.8–25.0%).

Multiple logistic regression analysis showed both instrument (p < 0.001) and experience (p = 0.002) were associated with first pass tracheal intubation success (online Supporting Information Table S2). Experience with the instrument before the study was not associated with a higher success rate (p = 0.06). Higher patient BMI

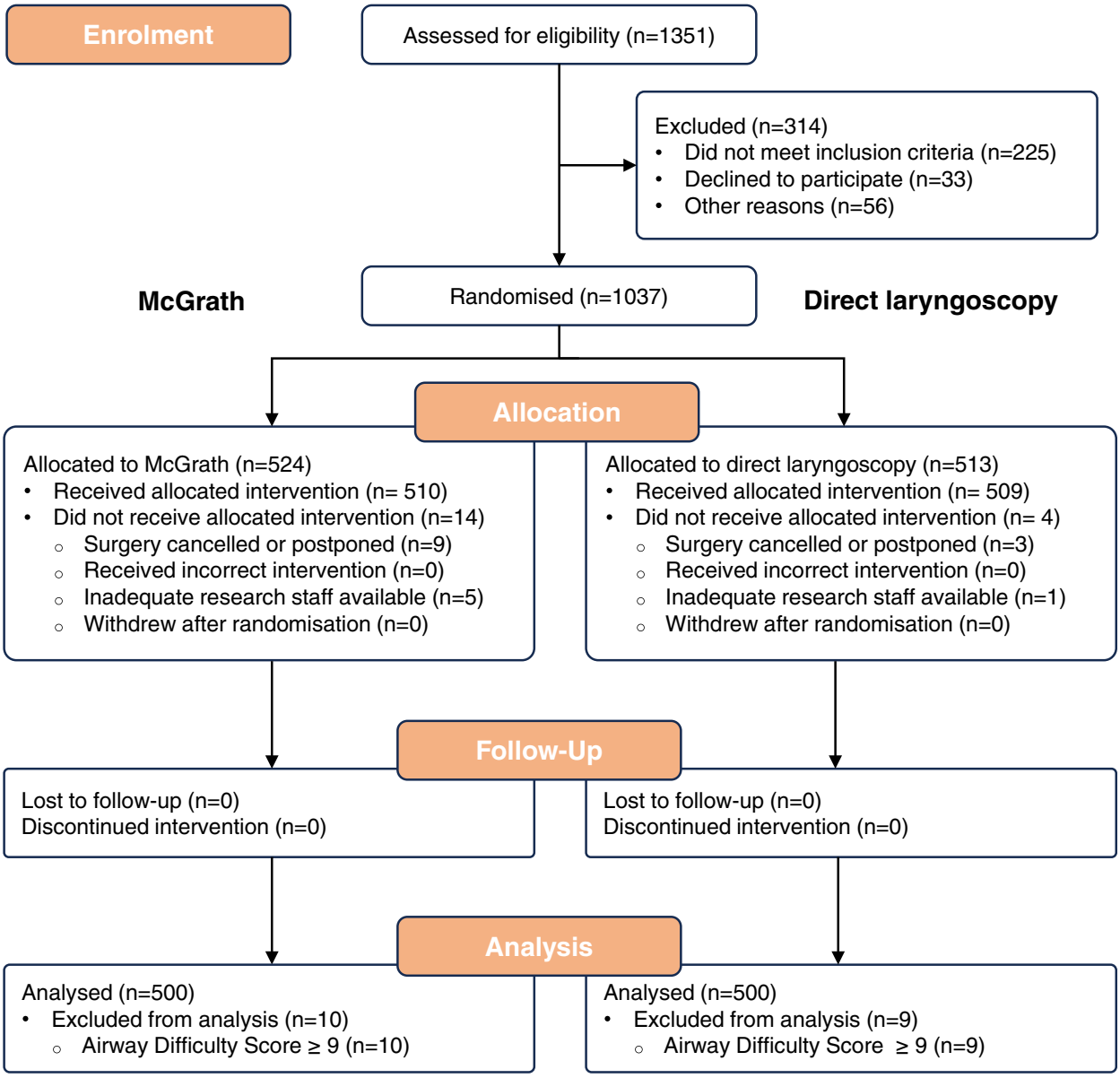

Figure 1 Study flowchart.

(> 35 kg.m^2) decreased the odds of first pass success (OR (95%CI) 0.87 (0.84–0.93) per 1 kg.m^2 increase). Patient age, sex, ASA physical status and airway difficulty score did not affect first pass success tracheal intubation rate.

There was a significantly lower incidence of peri-operative complications related to tracheal intubation in patients allocated to the McGrath group compared with the direct laryngoscopy group (13/500, 2.4% vs. 61/500, 12.2%, respectively; $p < 0.001$). This remained consistent when assessed 24 h postoperatively (59/500, 11.8% vs. 135/500, 27%; $p < 0.001$). The most frequent adverse event was dental injury (Table 3). Factors associated with adverse events are reported in online Supporting Information Table S3.

Discussion

In this multicentre, randomised controlled trial, we compared the effectiveness of the McGrath videolaryngoscope with a Macintosh blade to direct laryngoscopy with a Macintosh blade in surgical patients at increased risk of regurgitation and pulmonary aspiration. We found that a higher first pass success rate for tracheal intubation in patients allocated to the McGrath group compared with those allocated to the direct laryngoscopy group.

Table 1 Baseline characteristics of patients allocated to tracheal intubation using a McGrath MAC videolaryngoscope or direct laryngoscope with a Macintosh blade. Values are number (proportion), mean (SD) or number.

	McGrath group n = 500	Direct laryngoscopy group n = 500
Patient characteristics		
Sex; female	246 (49%)	239 (48%)
Age; y	52.4 (16.7)	51.8 (17.1)
BMI; kg.m^2	28 (6.9)	28.1 (7.1)
ASA physical status 1/2/3/4/5	18/157/139/185/1	20/158/114 /206/2
Airway difficulty score 5/6/7/8	50/139/85/226	51/141/107/201
Indications for RSI		
Full stomach	19 (4%)	18 (4%)
Increased abdominal pressure	193 (39%)	202 (40%)
Gastrointestinal pathology	89 (18%)	71 (14%)
Symptomatic GORD	199 (40%)	209 (44%)
Level of training		
Trainees*	260 (52%)	254 (51%)
Consultants†	240 (48%)	246 (49%)
Trainee experience with direct laryngoscopy (number of tracheal intubations)		
< 100		52 (21%)
101–500		54 (21%)
501–1000		125 (49%)
> 1000		3 (9%)
Trainee experience with McGrath videolaryngoscope (number of tracheal intubations)		
< 10	10 (4%)	
11–50	42 (16%)	
51–100	109 (42%)	
> 100	99 (38%)	

RSI, rapid sequence intubation; GORD, gastro-oesophageal reflux disease.
*< 6 years of anaesthetic experience.
†≥ 6 years of anaesthetic experience.

Before this study, there has been a lack of data comparing these two devices in patients with an increased risk of pulmonary aspiration. Some studies have compared the McGrath videolaryngoscope with direct laryngoscopy in different environments but have done so with lower statistical power and with different operators (e.g. prehospital physicians, novice operators or non-anaesthetists) in different clinical settings (e.g. prehospital environment, emergency departments and intensive care units) [20–23]. Rapid sequence intubation aims to reduce the number of tracheal intubation attempts and the time interval between the loss of protective airway reflexes and tracheal intubation. In a study conducted by Sulser et al., the C-MAC® (Karl-Storz GmbH, Tuttlingen, Germany) videolaryngoscope with a Macintosh blade had a first pass tracheal intubation success rate of 98%, which was not significantly different from the 100% success rate using direct laryngoscopy achieved by three experienced consultants (defined as ≥ 7 years of anaesthesia experience) [21]. Prekker et al. found that the use of different C-MAC blades resulted in a first pass tracheal intubation success rate of 79% compared with 73% with direct laryngoscopy [24]. Emergency residents were most frequently responsible for performing tracheal intubations in this study.

In our study, the use of the McGrath videolaryngoscope resulted in a median reduction of 5 s for the duration of tracheal intubation attempts. While longer times have been correlated with complications such as hypoxaemia or cardiac arrest [22], this small difference is unlikely to have a significant clinical impact, and similar differences have been reported previously [7, 21, 25]. However, other studies have reported a median tracheal intubation time difference of 8–20 s between the McGrath videolaryngoscope and direct laryngoscopy [24, 26, 27], which might be attributed to differences in time measurement definitions, operator experience and study settings [6, 21, 23, 24, 26, 27]. Given

Table 2 Outcome parameters for patients allocated to tracheal intubation using a McGrath MAC videolaryngoscope or direct laryngoscope with a Macintosh blade. Values are number (proportion) or median (IQR [range]).

	McGrath group n = 500	Direct laryngoscopy group n = 500	p value
Tracheal intubation success			
First attempt	470 (94%)	358 (72%)	< 0.001
Second attempt	27 (5%)	112 (22%)	< 0.001
Failure (> 2 attempts)	3 (1%)	30 (6%)	< 0.001
Tracheal intubation times			
Time to glottic view; s	10 (7–14 [2–98])	14 (8–20 [2–99])	< 0.001
Time to tracheal tube placement; s	20 (16–28 [5–112])	27 (20–40 [4–112])	< 0.001
Time to ventilation; s	37 (30–46 [20–119])	42 (34–55 [20–119])	< 0.001
Glottic view			
Cormack and Lehane grade 1/2/3/4	398/97/4/1	189/217/68/26	< 0.001
Percentage of glottic opening	100 (100–100 [0–100])	70 (20–100 [0–100])	< 0.001
Epiglottic lifting	101 (20%)	30 (6%)	< 0.001
Intubation difficulty score	0 (0–1 [0–8])	1 (0–2 [0–10])	< 0.001
Intubation difficulty score > 5	3 (1%)	66 (13%)	< 0.001

Table 3 Peri-intubation variables of patients allocated to tracheal intubation using a McGrath MAC videolaryngoscope or direct laryngoscope with a Macintosh blade. Values are number (proportion).

	McGrath group n = 500	Direct laryngoscopy group n = 500	p value
External laryngeal manipulation			
BURP	38 (8%)	185 (37%)	< 0.001
Adjustment of head and neck	4 (1%)	51 (10%)	< 0.001
Use of a stylet at first attempt	500/500 (100%)	199/500 (40%)	< 0.001
First-pass tracheal intubation success rate with stylet	470/500 (94%)	150/199 (75%)	< 0.001
Neuromuscular blocking drug			
Succinylcholine	42/500 (8%)	44/500 (9%)	0.82
Rocuronium 0.9 $mg.kg^{-1}$	169/500 (34%)	155/500 (31%)	0.34
Rocuronium ≥ 1 $mg.kg^{-1}$	289/500 (58%)	302/500 (60%)	0.40
Immediate complications			
Total	13 (3%)	61 (12%)	< 0.001
Desaturation (SpO_2 < 90%)	4 (1%)	14 (3%)	0.02
Dental injury	3 (1%)	25 (5%)	< 0.001
Soft tissue lesion	6 (1%)	15 (3%)	0.07
Oesophageal intubation	0	7 (1%)	0.01
Late complications*			
Total	59 (12%)	135 (27%)	< 0.001
Sore throat	46 (9%)	103 (21%)	< 0.001
Hoarseness	8 (2%)	14 (3%)	0.28
Difficulty swallowing	5 (1%)	18 (4%)	0.009

BURP, backwards-upwards-rightward pressure.
*Assessed > 24 h postoperatively.

the lack of a clear clinical endpoint and variability in time measurement definitions, this outcome parameter does not provide meaningful information about laryngoscope performance. While longer tracheal intubation times can lead to increased morbidity, unsuccessful and multiple attempts are more consequential [4].

Unrecognised oesophageal intubation can result in disastrous patient outcomes, including severe desaturation, aspiration of gastric contents or bradycardia [22, 24, 27]. Even a single instance of recognised oesophageal intubation is associated with a higher incidence of hypoxaemia, aspiration, cardiac arrhythmias and cardiac arrest [4]. Interestingly, we observed seven cases of oesophageal intubation in patients allocated to the direct laryngoscope group (all with a Cormack and Lehane class ≥ 3), whereas there were no cases in those in the McGrath group. Oesophageal intubation can occur in both straightforward and challenging intubations, regardless of the experience of airway practitioners [28]. The low incidence of oesophageal intubation in patients allocated to the McGrath group was likely due to the magnified and improved visibility provided by videolaryngoscopy, which enables operators to identify the appropriate laryngeal anatomy and tracheal tube placement more accurately. Consequently, the recent recommendations from the Project for Universal Management of Airways (PUMA) advocate the routine use of videolaryngoscopy [5].

While videolaryngoscopy can improve glottic visualisation, it does not always lead to increased first pass success rates due to difficulties passing the tracheal tube through the glottic opening [9]. In our trial, 27/30 (90%) of failed first-pass tracheal intubation attempts were classified as Cormack and Lehane class 1 or 2 (percentage of glottic opening 80–100%) when using the McGrath videolaryngoscope. Other trials comparing the McGrath videolaryngoscope to direct laryngoscopy in the prehospital setting [20], emergency room [21, 24] and intensive care unit [22, 24] have reported similar improvements in glottic visualisation without a corresponding increase in successful tracheal intubation rates.

Tracheal tube placement with a videolaryngoscope is a more technically demanding procedure, as the tracheal tube must be navigated through the upper airway, positioned in front of the vocal cords and then directed into the trachea [9, 14]. Using a stylet with a 90° curvature at the distal tip during videolaryngoscopy can reduce the number of tracheal intubation attempts and time to tracheal intubation [6, 11, 14]. In our study, the 90° stylet was used for all attempts with McGrath videolaryngoscope but in only 40% of patients allocated to the direct laryngoscopy group. The incidence of adverse events in our trial is comparable to previous work [6, 7]. Notably, in both groups, adverse events were more likely to occur with > 2 tracheal intubation attempts. Studies have shown that multiple intubation attempts increase the risk of tissue or dental injuries [7, 11].

This study involved a heterogeneous group of anaesthesia providers with varying levels of experience in tracheal intubation. Our findings show that the McGrath videolaryngscope was particularly useful for less experienced anaesthetists, as evidenced by this subgroup's greater disparity in first pass success rates between the two devices. Being skilled in direct laryngoscopy does not necessarily translate to success with a videolaryngoscope. This could explain why earlier trials conducted in prehospital or emergency room settings found no discernible difference between the McGrath videolaryngscope and direct laryngoscopy [20, 21]. We concur with a recent editorial [29] that additional airway trials are needed to make a definitive statement on this crucial research question. It is imperative that future research focuses on clinically relevant core outcomes while also considering factors such as blade design (Macintosh blade vs. hyperangulated blade), limiting time for laryngoscopy attempts and varying levels of experience between physicians.

This study has several limitations. The results may not be applicable to other settings or situations, such as non-operating theatre settings, patients with known or anticipated difficult airways or non-anaesthetist operators [21, 22, 24, 26, 27]. This study specifically looked at one type of videolaryngoscope with a Macintosh blade, and the results may not be generalisable to other videolaryngoscopes, especially those with different blade designs (such as hyperangulated or channelled blades). Furthermore, the benefits of videolaryngoscopy in patients with predicted normal airways may become more pronounced in those with difficult airways. A study conducted exclusively in such a population may yield a different result. Critically, a malleable stylet was always used in the patients allocated to McGrath group but not in all patients in the direct laryngoscopy group, and additional airway adjuncts, such as bougies, were not permitted as a part of the study protocol. Both observations could lead to unmeasured confounding. Due to the nature of the trial, it was not possible to blind the operators or assessors. The presence of a research assistant during the intervention could have led to altered operator performance due to the Hawthorne effect [30]. Finally, we recruited more than the planned number of patients to this trial (1037 participants rather than the planned 1000); that is, recruitment continued until 1000 participants completed the trial protocol (with 37 participants excluded after enrolment) rather than continuing until 1000 participants were enrolled (with the exclusions subtracted subsequently). There are multiple possible explanations for this error, including a reliance on inexperienced recruiters

and a lack of communication/randomisation control between the coordinating study centre during the COVID-19 pandemic. We do not believe this error will have appreciably affected the trial results.

To conclude, we have shown that tracheal intubation with a McGrath videolaryngoscope with a Macintosh blade resulted in a higher first-pass success rate than direct laryngoscopy for both elective and urgent surgeries in patients at increased risk of pulmonary aspiration. The use of videolaryngoscopy was particularly advantageous for trainees. We recommend the routine use of videolaryngoscopy in patients undergoing RSI with an expected normal airway.

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Supporting Information

Additional supporting information may be found online via the journal website.

Table S1. Rescue techniques after the second failed attempt.

Table S2. Logistic regression analysis to assess factors for first pass success tracheal intubation rate.

Table S3. Factors associated with adverse events.