





ORIGINAL RESEARCH

Comparison of four methods of endotracheal tube passage in simulated airways: There is room for improved techniques

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Abstract

Objective: Endotracheal intubation requires laryngoscopy followed by passage of the endotracheal tube (ETT). Tube passage can be difficult, but there is little evidence to support which adjunct for tube passage is most effective.

Methods: The four tube passage adjuncts tested were the naked ETT, stylet ETT, railroaded bougie and preloaded bougie. Participants completed pre- and post-test surveys identifying demographics, experience and method preference. After instruction, participants completed eight intubations on manikins with 'easy' and 'difficult' airways.

Results: One hundred and seventeen practitioners who were experienced emergency medicine physicians, anaesthesiologists and out-of-hospital providers completed 936 total ETT attempts. For the 'difficult' airway, the percentage first pass success (95% confidence interval [CI]) for the naked ETT was 30.8% (23.1–39.7%). This was significantly lower than the stylet ETT (95.7% [86.6–100%]), the railroaded bougie (75.2% [63.8–86.6%]), or the preloaded bougie (89.7%

[79.7–99.7%]). On difficult airways, the median (interquartile range [IQR]) time-to-intubation was fastest in the stylet ETT (25.0 s [20.9–32.2 s]) with the railroaded bougie being the slowest (43.2 s [36.5–56.2 s]). Seventy-nine per cent of participants stated that they would change their practice based on participating in this study. Participants increased their preference for the preloaded bougie from 30.6% to 69.4%.

Conclusion: The data show that tube passage with a stylet ETT or a preloaded bougie is superior in terms of higher first pass success, faster time-to-intubation and higher post-test preference. The naked ETT is clearly inferior to other methods. This research supports the recommendation to use a stylet ETT or bougie for every predicted difficult intubation.

Key words: *difficult airway, simulation, tracheal intubation.*

Introduction

Endotracheal intubation is a complex procedure with two fundamental

Key findings

- Endotracheal intubation should not be routinely performed with a naked endotracheal tube.
- The use of a stylet or bougie for intubation has increased success, reduced time to intubation, and subjective preference of use by practitioners.

steps: laryngoscopy to view the glottis, and passage of the endotracheal tube (ETT). Although intubation is an essential component of airway management, there is little evidence to support which method of tube passage is most effective.

Four methods have been described for ETT passage: a 'naked' ETT alone, a stylet, bougie placement followed by railroaded an ETT ('railroaded bougie') or a bougie 'preloaded' in the ETT. A 'naked' ETT describes passing an ETT into the trachea without any other adjuncts. The 'stylet ETT' uses a semi-rigid stylet inside the ETT to increase rigidity and alter the shape of the ETT during tube passage.¹ A bougie (also termed a tracheal tube introducer) is a long, thin device with a *coude* tip, and can be used in two broad fashions. The most common method is the 'railroaded bougie', where the bougie is placed between the vocal cords and then an ETT is advanced over the bougie. The second method is the 'preloaded bougie' technique. The ETT is loaded onto

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the bougie and then the distal end of the bougie is passed through the vocal cords before singlehandedly advancing the ETT into the trachea.

The use of a bougie or stylet for potentially difficult airways is part of multiple guidelines.²⁻⁸ However, there is a paucity of evidence on the efficacy of different methods, and recommendations are primarily based on expert opinion. The present study aims to compare the performance of four ETT passage techniques in an airway model.

Methods

This is a prospective, cross-sectional, cross-over study involving qualified airway practitioners performing intubations on a standard airway model. Ethics approval was provided by the University of Cape Town Human Research Ethics Committee (UCT HREC 663/2015). Participants were recruited with written informed consent during education sessions at several institutions in the Western Cape Province, South Africa. Participants were practitioners experienced in advanced airway management as paramedics working out of hospital

or doctors working in emergency medicine or anaesthesia.

Data collection occurred from September 2015 to May 2016. Participants completed a pretest survey before watching a 6 min training video and then practiced the techniques (Appendix S1 and S2). An Airway Trainer (Laerdal, Stavanger, Norway) was used to simulate an 'easy' airway. The 'difficult' airway was simulated by placing a cervical collar on the manikin, which produced a Cormack-Lehane grade 2b/3 view. This method has been well described.⁹⁻¹² Participants performed each of the four techniques in the 'easy' and 'difficult' configurations in an order randomised using a Latin Square. Participants used a standard size 4 Macintosh laryngoscope, 7.5 mm cuffed RÜSCH® ETT (Duluth, GA, USA), intubating stylet (Mallinckrodt® Satin-Slip™, St Louis, MO, USA) and a bougie (Frova Intubating Introducer, Cook® Medical, Bloomington, IN, USA). In the present study, the preloaded bougie method evaluated was the 'Kiwi-D grip' as initially described by Dr James DuCanto (Fig. 1). Participants performed eight

intubations and then completed a post-test survey.

Success was defined as confirmed placement of the ETT within the model trachea on the first pass in the difficult airway model. Failure was defined as termination of efforts without success, oesophageal intubation or inability to intubate the trachea within 60 s. Time-to-intubation was measured from picking up the laryngoscope until the first ventilation. Instances of manikin teeth clicks (induced by excess pressure of the laryngoscope on the manikin teeth) were recorded.

The pretest survey assessed practitioner specialty, previous airway experience, frequency of intubation in daily practice, personal preference and availability of a stylet or bougie in their practice environment. The post-test survey identified post-test preference and participant's opinions on the study experience.

Power calculations

Based on our literature review (Table 1), we hypothesised a first pass success (FPS) rate of 60% for naked ETT, 75% for stylet ETT, 90% for railroaded bougie and 90% for preloaded bougie techniques. Power analysis indicated that 97 participants were required to detect a 30% difference in FPS on the 'difficult' airway model between the worst- and best-performing methods. Using the cross-over design, we calculated the sample size for a nominal power of 0.85 and Type I error of 0.05. A minimum of 30 participants per specialty were required to conduct a subgroup analysis.

Statistical analysis

The FPS and teeth click rates were calculated for different tube passage methods. The 95% confidence interval (CI) and relative risk (RR) for FPS and teeth clicks were reported compared to the naked ETT. A logistic mixed-regression model was used for both rates, where correlation introduced from the cross-over design was accounted for by adding subject variations using a random intercept.

All mixed-effect models were tested for the intubation methods. FPS rate, teeth click rate and time-to-intubation.

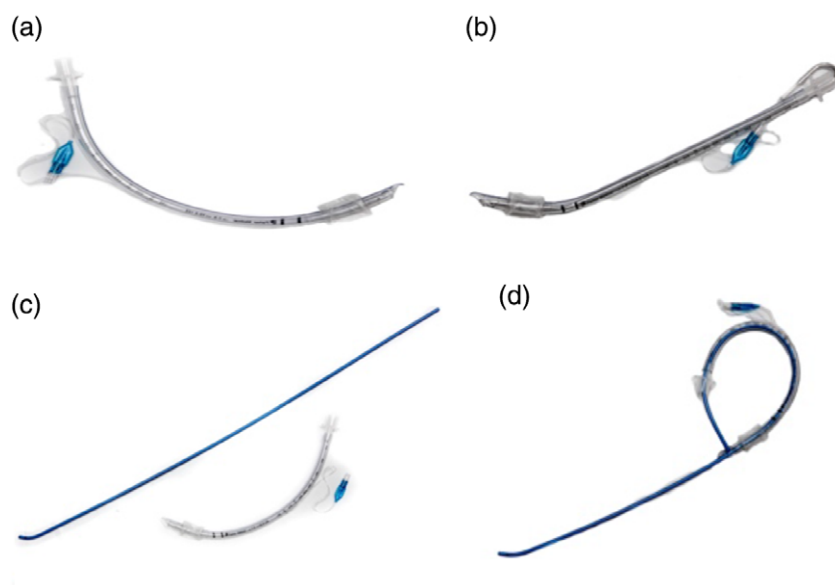


Figure 1. Examples of four tube passage methods. (a) Naked ETT – ETT without any adjuncts. (b) Stylet ETT – ETT loaded on a stylet and is shaped straight-to-cuff, with 30° bend at cuff. (c) Railroaded bougie – bougie and an ETT. (d) Preloaded bougie – The ETT is loaded onto the bougie. The proximal end of the bougie is then placed through Murphy's Eye. The bougie is adjusted so that more than 10 cm of distal end protrudes past the distal end of the ETT.

TABLE 1. Review of previous literature from 1996 to 2016 on tube passage techniques that include first pass success and/or time-to-intubation

First author	Year	Journal	Type of study	n	CL grade	First pass success (%) and time (s)			
						Naked ETT	Stylet ETT	Railroad Bougie	Preloaded Bougie
Gataure <i>et al.</i> ¹³	1996	<i>Anaesthesia</i>	Human	100	1				
					3	48% (24/50)		82% (41/50)	
						15.1 (0.6)		14.4 (0.3)	
Phelan <i>et al.</i> ¹⁴	2003	<i>Prehosp. Emerg. Care</i>	Manikin	96	1				
					4	67%		72%	
Nielsen <i>et al.</i> ¹⁵	2010	<i>West. J. Emerg. Med.</i>	Manikin	21	1		20 (mean, both groups)	20 (mean, both groups)	
					3		24 (mean, both groups)	24 (mean, both groups)	
Messa <i>et al.</i> ¹¹	2011	<i>Prehosp. Emerg. Care</i>	Manikin	35	1				
					3	16.7 (SD 9.6)		20.4 (SD 9.1)	
Brazil <i>et al.</i> ¹⁰	2012	<i>Emerg. Med. Australas.</i>	Manikin	26	1	98%		100%	
					3	14 (approx.)		23 (approx.)	
					3	18 (approx.)		25 (approx.)	
Walsh <i>et al.</i> ¹²	2014	<i>Emerg. Med. Australas.</i>	Manikin	29	1	93%		93%	
						45		47.5	
					3	57.1		98	
Batuwitage <i>et al.</i> ⁹	2015	<i>Eur. J. Anaesthesiol.</i>	Manikin	24	1	87%		100%	100%
						11 (7–31.5)	8.5 (7–11)	13 (11–14.5)	12 (11–13.5)
					3	46%	96%	16.5 (14–21)	16.5 (15.5–20.5)
						60 (26.5–60)	14 (12–22)		
Baker <i>et al.</i> ¹⁶	2015	<i>West. J. Emerg. Med.</i>	Manikin	24	1			95.7%	95.7%
					3			29.7 (16.0–70.2)	29.4 (15.7–110.9)

CL, Cormack–Lehane; ETT, endotracheal tube; s, seconds.

TABLE 2. Characteristics of participants, most frequently used technique and availability of technique before intervention

Specialty	Number of participants	Average years of ETT experience	Average number of ETTs per month†	Most frequently used technique in a difficult airway				Immediate availability	
				Naked ETT	Stylet ETT	Railroaded bougie	Preloaded bougie	Stylet	Bougie
Total	117 (100%)	7 (6.1%)	15 (21.8%)	13 (11%)	20 (17%)	50 (43%)	25 (21%)	100 (85%)	69 (59%)
Anaesthesia	54 (46%)	8 (7.3%)	29 (25.7%)	12 (22.2%)	4 (7.4%)	27 (50%)	8 (14.8%)	52 (96%)	18 (33%)
EM	33 (28%)	6 (4.4%)	3 (3.8%)	1 (3.03%)	7 (21.2%)	14 (42.4%)	6 (18.2%)	26 (79%)	21 (64%)
OOH	30 (25%)	7 (5.3%)	2 (2.8%)	0 (0%)	9 (30%)	9 (30%)	11 (36.7%)	22 (73%)	30 (100%)

†Maximum reportable number of ETTs per month in electronic questionnaire was 100. EM, emergency medicine; ETT, endotracheal tube; OOH, out-of-hospital.

The confounders included were type of practitioner, practitioner experience, method preference and method availability. Interactions between the airway difficulty and each of the four methods, and order effects of the method applied, were also tested. The final model had the optimal Akaike Information Criterion (AIC) and all variables that were significant at the $P < 0.05$ level.

The FPS and teeth click rates were calculated for different tube passage methods. The 95% CI and RR for FPS and teeth clicks were reported compared to the naked ETT. Mixed effect logistic regression models were used for FPS and teeth click rates, where random intercepts of subjects are included. The random intercepts are used to account for correlations within subjects in the cross-over study.

Results

Data were collected for 117 participants with a mean of 7 years' experience. Participants perform an average of 15 intubations per month (anaesthesia 29, emergency medicine 3 and out of hospital 2). On initial survey, participants reported the railroaded bougie to be the most frequently used technique for difficult airways (43%), whereas a naked ETT was still used in 11% of these cases. A stylet and bougie were immediately available for 85% and 59% of respondents, respectively (Table 2).

There were no dropouts or protocol violations (Appendix S3). There were 936 ETT attempts, including both easy and difficult airway models (Fig. 2).

Time-to-intubation had a right-skewed distribution and was log-transformed in the generalised linear mixed model. For difficult airways, the median time (interquartile range [IQR]) was fastest in the stylet ETT (25.0 s [20.9–32.2 s]) with the railroaded bougie the slowest (43.2 s [36.5–56.2 s]). Intubation with the naked ETT (37.5 s [23.0–58.9 s]) had the largest IQR. On the difficult airways, compared to the naked ETT, the stylet ETT was 33% faster, the railroaded bougie was 15% slower and the preloaded bougie 20% faster. There was no significant

difference in FPS and time-to-intubation between anaesthesia, emergency medicine and out-of-hospital practitioners for both the 'easy' and 'difficult' airways (Table 3).

All methods were more likely to achieve higher FPS than the naked tube. In the difficult airway, the RR (95% CI) for FPS with the stylet ETT was 3.1 (2.4–4.1), the railroaded bougie 2.4 (1.8–3.3) and the preloaded bougie 2.9 (2.2–3.9) (Table 3).

Overall, the most common cause of failure was oesophageal placement or declared inability to intubate (12% of attempts), followed by exceeding the 60 s allowed time (5.9%). Teeth clicks were the most common with the naked ETT (38.1% of attempts at naked ETT) and the least common with the preloaded bougie (19.3%). The RR of teeth clicks with difficult airways when compared to the naked ETT was 0.55 for the stylet ETT, 0.60 for the railroaded bougie and 0.49 for the preloaded bougie (Table 3).

The order of the ETT technique and difficulty level had a significant impact on the results. Order effects have been included in the regression to derive the final adjusted RR.

On comparison of the pre- and post-test surveys, 79% of participants stated that they would change their difficult airway practice based on their experience during the present study. There was an increase in preference towards the preloaded bougie, from 30.6% to 69.4%. Although the stylet ETT was shown to have the fastest time-to-intubation, there was a small decrease in preference, from 22.7% to 17.1%. The railroaded bougie showed a reduction in preference from 39.5% to 11.7%. Nearly all the participants chose to avoid the naked ETT (from 9.0% to 1.8%) (Fig. 3).

There were 83 comments in the post-test survey; 72% changed their preference to the preloaded bougie. Participants reflected that the preloaded bougie was easier and quicker to perform and should be used regardless of predicted airway difficulty. Some participants stated that they favoured the preloaded bougie over stylet ETT technique as the latter 'feels too rigid' and 'may cause soft tissue airway trauma'.

TABLE 3. FPS, time-to-intubation and teeth clicks of four methods of tube passage on 'easy' and 'difficult' airway manikins

	'Easy' (total trials = 468)						'Difficult' (total trials = 468)					
	FPS (%)			Time (s)			FPS (%)			Time (s)		
	Rate (95% CI)	RR (95% CI)	RD (%)	Median (IQR)	Rate (95% CI)	RR (95% CI)	Rate (95% CI)	RR (95% CI)	RD (%)	Median (IQR)	Rate (95% CI)	RR (95% CI)
Naked ETT	77.8 (69.4–84.4)	—	—	25.3 (18.0–36.2)	12.0 (7.2–19.2)	—	30.8 (23.1–39.7)	—	—	37.5 (23.0–58.9)	45.3 (36.6–54.3)	—
Stylet ETT	99.2 (94.9–100)	1.28 (1.16–1.41)	–12.3 (18.4–26.4)	22.2 (18.4–26.4)	7.8 (4.0–14.3)	0.65 (0.29–1.44)	95.7 (90.1–98.4)	3.11 (2.36–4.09)	–33.3 (20.9–32.2)	25.0 (20.9–32.2)	24.8 (17.8–33.4)	0.55 (0.38–0.79)
Railroaded bougie	91.5 (84.8–95.5)	1.18 (1.05–1.32)	52.6 (30.3–45.3)	38.6 (30.3–45.3)	4.3 (1.6–9.9)	0.36 (0.14–0.96)	75.2 (66.6–82.2)	2.44 (1.83–3.27)	15.2 (36.5–56.2)	43.2 (36.5–56.2)	27.4 (20.1–36.1)	0.60 (0.42–0.86)
Preloaded bougie	96.6 (91.3–99.0)	1.24 (1.12–1.38)	–4.7 (19.7–28.3)	24.1 (19.7–28.3)	6.8 (3.3–13.1)	0.57 (0.25–1.31)	89.8 (82.8–94.2)	2.92 (2.21–3.85)	–19.7 (23.8–38.6)	30.1 (23.8–38.6)	22.2 (15.6–30.6)	0.49 (0.33–0.73)

—, inconclusive results; % time, % of time, in seconds, relative to naked ETT; CI, confidence interval compared to naked ETT; ETT, endotracheal tube; IQR, interquartile range; RD, relative difference in median time compared to naked ETT (negative numbers are faster); RR, relative risk compared to naked ETT.

Discussion

Difficult laryngoscopy or intubation due to anatomical and/or physiological abnormalities is common in emergency medicine.^{17,18} Ideal positioning, lighting and equipment is not ubiquitous, and patient pathology often prevents or reduces the efficacy of pre-oxygenation. In these settings, successful and rapid intubation on the first attempt is critical. The use of adjuncts such as stylets and bougies for intubation is well established in the literature, but few studies exist to elucidate the optimal strategy to enhance FPS.

A literature review showed eight studies on the performance of bougies and stylets.^{9–16} One manikin study with 24 participants investigated FPS of the naked ETT, achieving a 46% FPS.⁹ The stylet ETT and railroaded bougie are the only methods compared. Gataure *et al.*, in a human study conducted on 100 elective patients with Cormack–Lehane grade 3 airways, found that the stylet and railroaded bougie had a 48% and 82% FPS rate, respectively.¹³ Phelan *et al.* conducted a manikin study with 96 participants, identifying an FPS rate of 67% and 72% for the stylet and railroaded bougie, respectively.¹⁴ The remaining studies have low numbers and focus on time-to-intubation as a measure of performance. However, thus far, only one study has shown correlation between adverse events and FPS.¹⁹ As a result, FPS is seen to have more clinical importance as a measured outcome.

The present study demonstrates that the naked ETT is inferior. It had the worst FPS, longest median time-to-intubation the highest variation in time-to-intubation, and most frequent simulated dental trauma, which are far more relevant than the perceived safety or cost issues associated with other methods. Based on these data, it is reasonable to continue advocating against the routine use of naked ETTs on potentially difficult airways.

The stylet ETT had the best FPS, fastest time-to-intubation and the lowest rate of teeth clicks. Although 85% of participants reported having a stylet immediately available, only a few participants regarded it as their preferred technique (17%). However, the stylet ETT had, on average, a 20.5% better

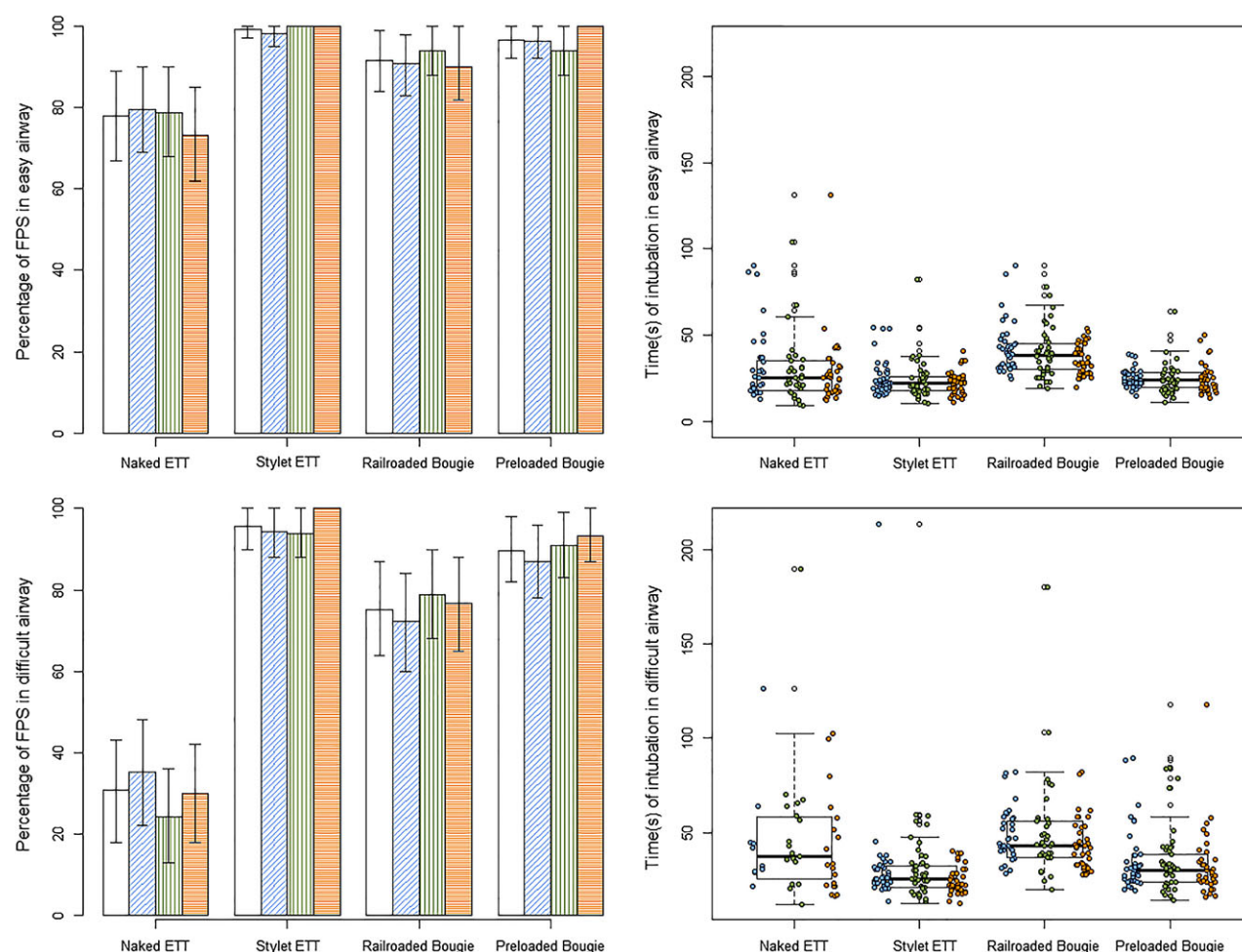


Figure 2. A comparison of first pass success rate and time-to-intubation for different tube passage methods by specialty on 'easy' and 'difficult' airway models. Top – Specialty: (●), Anaes (n = 54); (●), EM (n = 33); (●), OOH (n = 30). Bottom – Specialty: (□), all (n = 117); (□), Anaes (n = 54); (□), EM (n = 33); (□), OOH (n = 30). EM, emergency medicine; Anaes, anaesthesia; OOH, out-of-hospital.

FPS and was 18.2 s faster than the railroaded bougie. The disparity between preference and performance in the data could be due to unfamiliarity with the technique, concerns about airway trauma and/or other factors not elicited in this research. Despite these concerns, data confirm that the stylet ETT is a useful aid and performed better than either of the two bougie techniques.

However, most participants preferred using one of the bougie techniques. The bougie has a long history of being a recommended device for difficult airways.²⁰ Traditionally intended to be used on Cormack–Lehane grade 4 airways, they provide additional sources of placement confirmation through use of the tactile vibration on the *coude*

tip from the tracheal rings, as well as the cessation of bougie advancement when reaching the bronchi, known as 'hold-up'.²¹ However, we have observed that even on grades 1–3 views, the bougie can ease ETT passage.

Pretest, the railroaded bougie was the most commonly used and most preferred technique. However, after performing the study, only 12% of participants continued to consider the railroaded bougie as their preferred method. The railroaded bougie had a mean of 44.4% better FPS than the naked ETT, although it was, on average, 6% (5.7 s) slower on the difficult airway model. A disadvantage of the railroaded bougie is

that it often requires an assistant to railroad the ETT.

The preloaded bougie has most of the railroaded bougie's advantages over the naked ETT. It performed much better on difficult airways than the naked ETT, with a 59% better FPS and a 7.4 s better time-to-intubation. It also had a 15% better FPS and was 13.1 s faster than the railroaded bougie. After being able to practice and use the preloaded bougie, participants recorded an increase in preference over the railroaded bougie. This increased preference is likely related to the ability to intubate without an assistant, the perception that there was decreased time-to-intubation and/or the novelty of the preloaded technique.

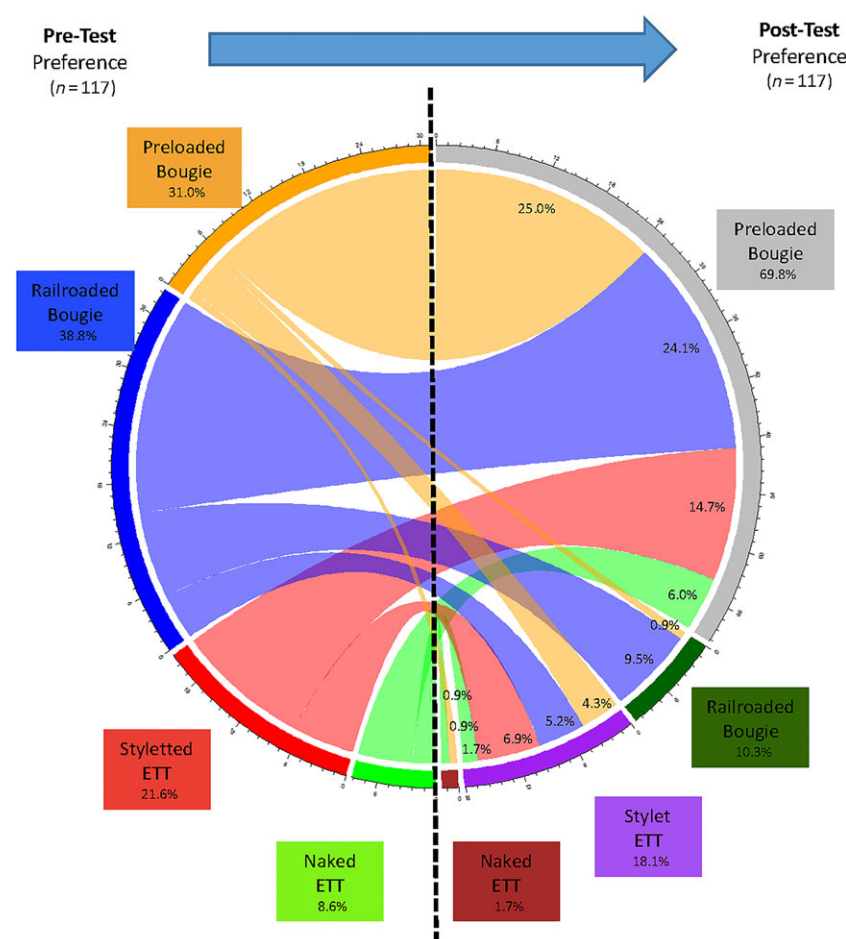


Figure 3. Change in participant preference of each of the four methods of tube passage before and after the intervention.

Although the preloaded bougie technique was more effective, faster and caused less simulated dental trauma than the railroaded bougie, there are possible disadvantages in its use. It might be more difficult to feel the tracheal rings and more difficult to assess 'hold-up' in the lung. However, the ability to reliably feel the tracheal rings with any bougie technique has been disputed, and both feeling the tracheal rings and hold-up can be used with the preloaded technique if sufficient length of the bougie protrudes distal to the ETT.^{22,23}

There were no significant differences in performance between the different providers; this might indicate that the differences in performance are due to the tube passage technique rather than participant background.

Finally, even though these participants were experienced providers

with an average 7 years of experience, 70% of participants stated that they would change their practice based on the experience gained in the study.

Limitations

As a manikin-based investigation, the present study is limited by not measuring patient-orientated outcomes such as failed intubation, airway trauma, vital sign abnormalities, cardiac arrest or mortality. However, with manikins, airway techniques can be standardised, measured and replicated.^{24,25} Much previous research of airway techniques is based on manikin studies, and data collected on actual patients are scant. By using manikin methodology, we were able to limit extraneous variables while collecting a large amount of data.²⁶ It would have been

challenging to collect homogenous data on 936 intubations by the same 117 airway operators using anything other than a manikin model.

The commonly taught philosophy of 'making the first look the best look' is aimed at increasing FPS. It has been shown that increased FPS is associated with fewer adverse events.^{19,27}

Our difficult airway model with a cervical collar allowed a limited view of the vocal cords, and other conditions (e.g. soft tissue swelling, emesis or masses) were not simulated.

Time-to-intubation and teeth clicks are some reasonable proxies for the proficiency of airway care. Faster time-to-intubation reduces apnoea time, which is vitally important in critically ill, paediatric or obese patients, and 60 s was a reasonable cut-off value for airway proficiency. Teeth clicks are a simple proxy for dental trauma and provide an additional indication of ease and 'gentleness' of each technique.

Despite these limitations, this is the largest study comparing different methods of tube passage and provides useful data on the relative values of each method. Replicating the present study using simulation, elective intubations, critically ill patients or patients with predicted difficult airways might yield more clinically relevant data. However, until such research is conducted, manikin-based studies remain the most appropriate research methodology to evaluate improvements in the methods of tube passage.

Conclusion

The present study shows that tube passage with a stylet ETT or a preloaded bougie is superior with a higher FPS, faster time-to-intubation and higher post-test preference. The naked tube is clearly inferior to other methods. This research supports the recommendation to use a stylet ETT or bougie for every predicted difficult intubation.

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Competing interests

None declared.

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Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Appendix S1. Four methods of tube passage – DuCanto Video.

Appendix S2. Pre- and post-test surveys.

Appendix S3. CONSORT flow chart for four methods.