

ORIGINAL RESEARCH

Airway

# The adjuncts for endotracheal tube passage in simulated pediatric airways (AET-SPA) study

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## Abstract

**Objectives:** To investigate whether the use of adjuncts such as stylet, railroaded bougie, and preloaded bougie increases first-pass success rate and decreases time to successful intubation when intubating simulated infant airways using direct laryngoscopy.

**Methods:** A crossover study using experienced practitioners (who were required to carry out emergency pediatric intubations as part of their usual practice) was completed. Participants completed a random sequence of 4 intubations in simulated "easy" airways and 4 intubations in simulated "difficult" airways, using naked endotracheal tube, stylet, railroaded bougie, and preloaded bougie on standardized infant airway manikins. First-pass success rates and times to successful intubations were measured.

**Results:** From June 1 to December 30, 2019, 109 participants performed a total of 872 intubation attempts. In the easy airway, both naked endotracheal tube (mean 96.3% [95% confidence interval 90.9%–99.0%]) and stylet (mean 98.2% [95% confidence interval 93.5%–99.8%]) had higher first-pass success rates than railroaded bougie and preloaded bougie. In the difficult airway, stylet (mean 76.1% [95% confidence interval 67.0%–83.8%]) had the highest first-pass success rate, followed by the naked endotracheal tube, and then both the railroaded bougie and preloaded bougie. Differences in first-pass success rates were independent of the participants' numbers of previous pediatric intubations.

**Conclusion:** Results of this simulation-based study suggest that stylet should be used as the first attempt technique for infant intubations regardless of the presence or absence of predicted airway difficulty. This finding needs further validation using alternative models and in non-simulation settings.

## KEYWORDS

bougie, infant, intubation, paediatric, preloaded bougie, railroaded bougie, stylet

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## 1 | INTRODUCTION

### 1.1 | Background

Definitive airway management is an integral part of the management of physiologically unstable patients in the emergency department (ED). Endotracheal intubation is commonly regarded as the “gold standard” for definitive airway control in these patients.<sup>1</sup> Endotracheal intubation involves the visualization of the glottis with a laryngoscope followed by the passage of an endotracheal tube.

Pediatric endotracheal intubations in the ED are relatively infrequent compared to adult intubations.<sup>2,3</sup> A recent study of 43 EDs in Australia and New Zealand showed that pediatric intubations accounted only for 4.94% (270/5463) of all total intubations.<sup>2</sup> This presents a problem to practitioners who manage pediatric patients, as they have fewer opportunities to “practice” real-life pediatric intubations. Additionally, endotracheal intubations in pediatric patients in the ED are frequently associated with adverse events. The NEAR4KIDS airway registry reported that 15.6% of courses of pediatric intubations in the ED were associated with tracheal intubation associated events (TIAEs), and 5.4% of all courses encountered severe TIAEs.<sup>4</sup> Examples of severe TIAEs are cardiac arrests with or without return of spontaneous circulation, esophageal intubation without immediate recognition, emesis with aspiration, and hypotension requiring interventions. Examples of non-severe TIAEs are mainstem bronchial intubation, esophageal intubation with immediate recognition, and emesis without aspiration.<sup>4</sup> According to Funakoshi et al, multiple intubation attempts in pediatric patients in the ED were associated with a significantly higher rate of adverse events (adjusted odds ratio 4.49, 95% confidence interval [CI] 2.36–8.53),<sup>5</sup> highlighting the need to optimize conditions during intubations to achieve first-pass success.

Pediatric intubations in the ED include patients of a variety of age ranges; however, a quarter of intubated children are infants, and 40% of intubations are in children younger than 2 years of age.<sup>2</sup> It is also in the under 1-year-old group where most difficult airways and TIAEs occur.<sup>4,6,7</sup>

Despite the increase in availability of video laryngoscopy, current airway publications have shown that most intubations are undertaken with direct laryngoscopy.<sup>7–9</sup> Even when video laryngoscopy is used, an airway adjunct like stylet or bougie may still be needed.

Adjuncts such as gum-elastic bougies (also called “bougies”), and stylets are readily available in most EDs and have traditionally been used as a “rescue” device for difficult intubations. A stylet consists of a malleable metal rod covered by a plastic sheath and is inserted into the endotracheal tube to give the endotracheal tube a certain shape. A bougie is a flexible endotracheal tube introducer with a coude tip that allows the passage of the endotracheal tube through the glottis with a Seldinger-like technique (“railroading”). Additionally, the bougie can also be used by “preloading” the bougie through the endotracheal tube and then sliding the endotracheal tube down the bougie and into the trachea.<sup>10</sup>

#### The Bottom Line

Pediatric intubations are high acuity events where first-pass success is important to prevent adverse outcomes. This crossover trial found that stylet use has higher first-pass success for simulated infant airways when compared to naked endotracheal tube, railroaded bougie, and preloaded bougie.

### 1.2 | Importance

Despite the prevalence of these adjuncts in clinical practice, there is limited research looking specifically at the first-pass success rates of bougie or stylet in pediatric or infant intubations. Research investigating the efficacy of bougies in first-pass success in the ED has mainly involved adult patients.<sup>11,12</sup> Research investigating the efficacy of stylets in first-pass success in pediatric patients has been limited to 2 neonatal studies.<sup>13,14</sup> Likewise, studies using airway manikins,<sup>1,15–20</sup> cadavers,<sup>21,22</sup> and elective surgical patients<sup>23</sup> to compare the efficacy of bougie and stylet have used only adult subjects.

### 1.3 | Goals of this investigation

Given the high risk and probability of adverse events surrounding pediatric ED intubations and adjunct variation, it is important to develop much greater evidence base around this practice. This study was designed to use simulation as an innovative research tool to compare the first-pass success rates and times to successful intubations of the stylet, railroaded bougie, preloaded bougie, and naked endotracheal tube in the intubation of a simulated infant manikin with direct laryngoscopy.

## 2 | METHODS

### 2.1 | Study design and setting

A crossover trial was carried out in 4 large metropolitan EDs in Auckland, New Zealand (Starship Children’s Hospital, Middlemore Hospital, Waitakere Hospital, and North Shore Hospital). The study was conducted over a 7-month period from June 1, 2019 to December 30, 2019. Low risk study ethics approval was provided by the local institution (Auckland District Health Board Research Approval Number A+8428).

### 2.2 | Selection of participants

Participants were required to fulfil criteria 1 and 2 to be eligible for this study:

1. Participant works in a clinical job that treats pediatric patients and is expected to attempt an endotracheal intubation if clinical indications arise and
2. Participant's current level of training is:
  - Specialist in a specialty, or
  - Specialty trainee in the final 2 years of their specialist training, or
  - Medical officer who has worked for more than 5 years in their current specialty.

These criteria were used in order to define a real-world group of clinicians who, in Auckland, would be expected to perform an emergency endotracheal intubation outside of the operating room. As such, we have not required participants to have had a certain number of previous pediatric intubations to be eligible for this study.

"Medical officer" in criterion 2 in our study included doctors, nurse practitioners, and nurse specialists. Only nurse practitioners and nurse specialists in the specialty of neonatology were enrolled for this study as they would be expected to attempt an emergency endotracheal intubation if required in the practice of neonatology in Auckland. Clinicians from the anesthesiology and otolaryngology specialties were not enrolled for this study as it is uncommon for them to be involved in emergency intubations of children outside of the operating room in Auckland.

## 2.3 | Interventions

All participants completed a pretest survey to document their specialty, number of previous pediatric intubations, and their preferred adjuncts to facilitate endotracheal tube passage (see supplementary data: Pre-test Survey). Participants then watched a short instructional video demonstrating intubation techniques with naked endotracheal tube, stylet, railroaded bougie, and preloaded bougie. The participants were then given 15 minutes to practice the intubation techniques on a standardized non-study manikin. The participants were allowed to practice whichever techniques they wanted to during these 15 minutes.

For the study, each participant performed 8 intubations in a single session. The intubations were combinations of airway difficulty and techniques: naked endotracheal tube on an easy airway, naked endotracheal tube on a difficult airway, stylet on an easy airway, stylet on a difficult airway, railroaded bougie on an easy airway, railroaded bougie on a difficult airway, preloaded bougie (Kiwi Grip) on an easy airway, and preloaded bougie (Kiwi Grip) on a difficult airway (see Figure 1). The railroaded bougie technique is done by first inserting the distal end of the bougie (without first preloading the endotracheal tube) past the vocal cords, followed by the passage of the endotracheal tube over the bougie and through the glottis with a Seldinger-like technique ("railroading"). The preloaded bougie technique is done by first preloading the bougie with an endotracheal tube in a Kiwi Grip fashion (see Figure 1), followed by insertion of the bougie past the vocal cords, and finally the passage of the endotracheal tube over the bougie and through the glottis. The sequence of the 8 intubations for each individual participant was randomized with

Microsoft Excel. All other study equipment was standardized for all participants:

- Direct laryngoscope (size 1 straight blade laryngoscope)
- Endotracheal tube (Mallinckrodt size 4 uncuffed endotracheal tube)
- Stylet (Mallinckrodt Satin Slip Intubating Stylet)
- Bougie (Frova Intubating Introducer, 8.0Fr/35cm)
- Bag mask (Laerdal Silicone Resuscitator, child sized)

After the completion of the 8 intubations, each participant then completed a posttest survey to document whether there has been a change in their preferred intubation adjunct (see supplementary data: Post-test Survey).

## 2.4 | Measurements

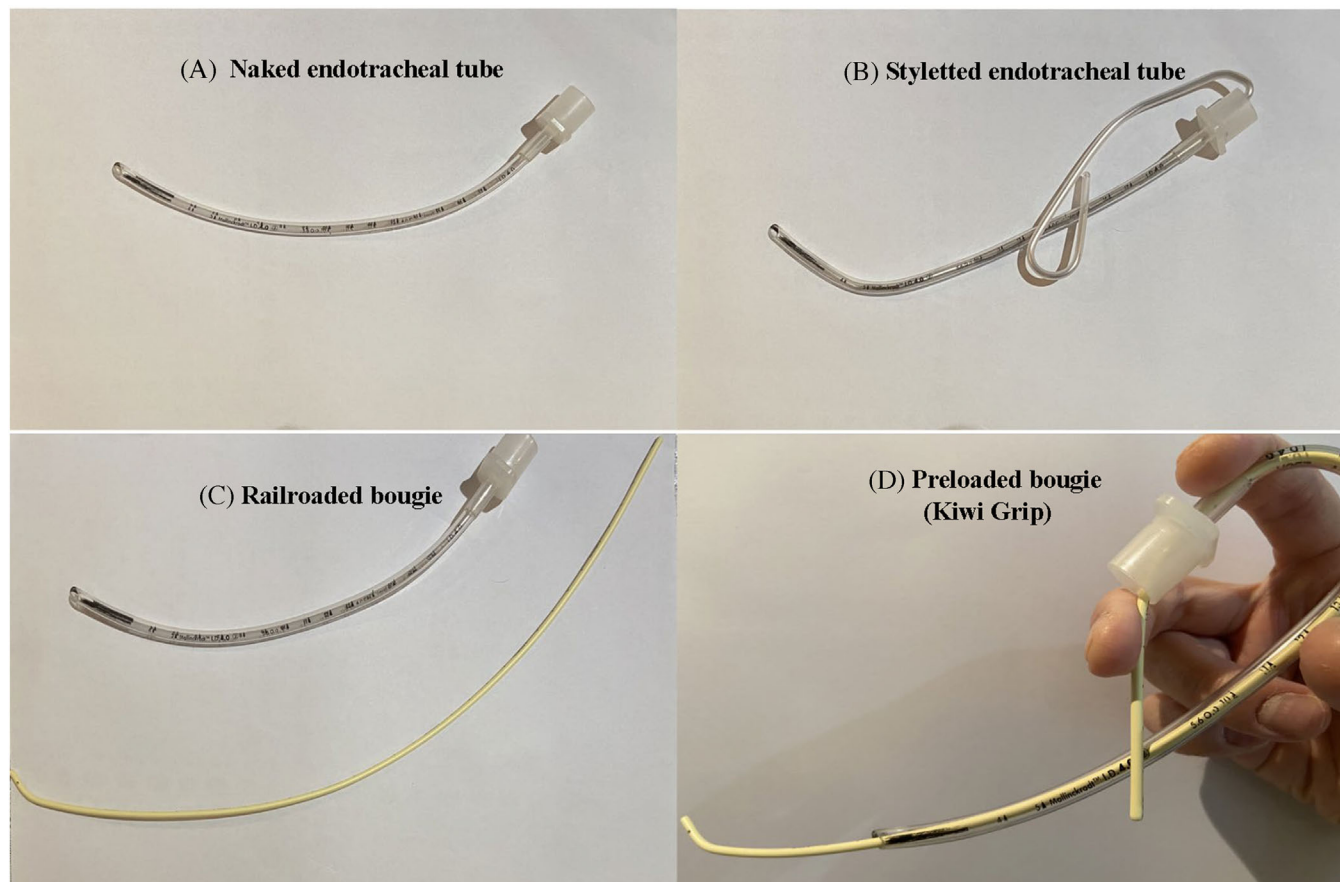
The easy airway was simulated with the Trucorp AirSim Baby X, which is an anatomically accurate airway trainer with an equivalent age of 6 months. The difficult airway was simulated with addition of a fiberglass cast around the Trucorp AirSim Baby X to limit neck movement (see Figure 2). In order to validate the difficult airway model, 8 specialist pediatric anesthesiologists from Starship Children's Hospital were invited to grade both the easy and the difficult airways based on the Cormack-Lehane classification. The median view for the easy airway was Cormack-Lehane Grade I. The views for the difficult airway were more variable, with a median view of Cormack-Lehane Grade III.

Data collection was performed by research team members. A first-pass success was defined as the successful passage of endotracheal tube within 30 seconds of the start of the first laryngoscopy attempt, confirmed by successful inflation of the airway manikin's lungs. The cutoff time of 30 seconds was chosen in keeping with recommendation from the Advanced Paediatric Life Support (Australia and New Zealand) that an intubation attempt should be limited to 30 seconds.<sup>24</sup> A laryngoscopy attempt is defined as insertion of the laryngoscope blade into the oropharynx, regardless of whether an attempt was made to pass the endotracheal tube. A laryngoscopy attempt ends when the laryngoscope is removed from the mouth. Time recording starts when the first laryngoscopy attempt starts. Time recording ends when a participant successfully intubates the manikin. A first-pass intubation attempt is deemed unsuccessful if a participant takes longer than 30 seconds to intubate using his/her first laryngoscopy attempt or if he/she is unable to intubate the manikin successfully with his/her first laryngoscopy attempt. Unsuccessful intubation attempts are not included for times to successful intubations analysis. Every participant had a trained airway assistant who assisted the participants in connecting the bag mask to the inserted endotracheal tube and then inflating the airway manikin's lungs.

## 2.5 | Outcomes

The outcomes of interest were as follows:

Primary outcome: first-pass success rates for naked endotracheal tube, stylet endotracheal tube, railroaded bougie, preloaded bougie.



**FIGURE 1** The different intubation techniques: (A) naked endotracheal tube, (B) styletied endotracheal tube, (C) railroaded bougie, and (D) preloaded bougie with the Kiwi Grip



**FIGURE 2** The difficult airway, simulated with the addition of a fiberglass cast around the neck of the AirSim Baby X

Secondary outcomes:

- The times to successful intubations of naked endotracheal tube, styletied endotracheal tube, railroaded bougie, preloaded bougie. An intubation qualifies for time to successful intubation analysis only if it attains first-pass success within 30 seconds.

- Subanalysis of first-pass success rates and times to successful intubations based on participants' numbers of previous pediatric intubations.
- Subanalysis of first-pass success rates and times to successful intubations based on participants' specialties.
- Change in preferred adjunct post study.
- First-pass success rates of participants when intubating the difficult airway with their preferred adjunct.

## 2.6 | Analysis

Based on a similar study of adult airway,<sup>10</sup> the primary outcome – first-pass success rates for difficult airways – was predicted to be 30.8%, 95.7%, 75.2%, and 89.8% respectively for naked endotracheal tube, stylet, railroaded bougie, and preloaded bougie. To detect the smallest difference in first-pass success rates (44.4%, between naked endotracheal tube and railroaded bougie), 30 participants were required to obtain 90% statistical power (type II error of 0.10) and type I error of 0.05 based on the simulations. Statistical analyses were carried out using SAS 9.4 (SAS Institute Inc., Cary, NC, USA) and R [R Core Team (2019)]. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria,

**TABLE 1** Participants' characteristics

Variable	Numbers	Total
<b>Specialty</b>		
<b>Emergency medicine (ED)</b>		<b>36</b>
Specialist	26	
Senior trainee in final 2 years of training	10	
Medical officer >5 years in current specialty	0	
<b>General pediatrics</b>		<b>34</b>
Specialist	16	
Senior trainee in final 2 years of training	16	
Medical officer >5 years in current specialty	2	
<b>Pediatric emergency medicine</b>		<b>30</b>
Specialist	17	
Senior trainee in final 2 years of training	12	
Medical officer >5 years in current specialty	1	
<b>Intensive care</b>		<b>4</b>
Specialist	3	
Senior trainee in final 2 years of training	1	
Medical officer >5 years in current specialty	0	
<b>Neonatology</b>		<b>5</b>
Specialist	2	
Senior trainee in final 2 years of training	0	
Medical officer >5 years in current specialty	3	
<b>Number of previous pediatric intubations</b>		
Less than 5	23	
6–10	21	
11–20	25	
21–50	17	
More than 50	23	

<https://www.R-project.org/>). Pairwise comparisons of the first-pass success rates of the different techniques were undertaken using chi-square analyses. Scheffe's test was used to determine the presence or absence of statistically significant differences in the time to successful intubation for each technique. An intubation was included for time to successful intubation analysis only if first-pass success was attained.

### 3 | RESULTS

#### 3.1 | Characteristics of study subjects

The study population comprised 109 participants who performed a total of 872 intubation attempts. See Table 1 for detailed description of participants' characteristics, including the breakdown of specialties, seniority, and numbers of previous pediatric intubations.

#### 3.2 | Main results

In the easy airway, there were statistically significant differences in the first-pass success rates of the different techniques ( $P$  value <0.0001). Pairwise comparisons showed that both the naked endotracheal tube (mean 96.3% [95% CI 90.9%–99.0%]; Table 2) and the stylet (mean 98.2% [95% CI 93.5%–99.8%]; Table 2) had the highest first-pass success rates, followed by both the railroaded bougie (mean 78.9% [95% CI 70.0%–86.1%]; Table 2) and the preloaded bougie (mean 76.1% [95% CI 67.0%–83.8%]; Table 2). There was no statistically significant difference between the first-pass success rates of the naked endotracheal tube and the stylet. There was also no statistically significant difference between the first-pass success rates of the railroaded bougie and the preloaded bougie. See Table 2 for detailed description of first-pass success rates of different intubation techniques in the easy airway.

In the difficult airway, there were statistically significant differences in the first-pass success rates of the different techniques ( $P$  value <0.0001). Pairwise comparisons showed that the stylet (mean 76.1% [95% CI 67.0%–83.8%]; Table 2) had the highest first-pass success rate, followed by the naked endotracheal tube (mean 56.0% [95% CI 46.1%–65.5%]; Table 2), and lastly, both the preloaded bougie (mean 30.3% [95% CI 21.8%–39.8%]; Table 2) and the railroaded bougie (mean 26.6% [95% CI 18.6%–35.9%]; Table 2). There was no statistically significant difference between the first-pass success rates of the railroaded bougie and the preloaded bougie. See Table 2 for detailed description of first-pass success rates of different intubation techniques in the difficult airway.

In the easy airway, there were statistically significant differences in the times to successful intubations of the different techniques ( $P$  value <0.0001). Pairwise comparisons showed that the naked endotracheal tube (mean 12.8 seconds [95% CI 11.9–13.7 seconds]; Table 3) had the fastest time to successful intubation, followed by the stylet (mean 14.6 seconds [95% CI 13.7–15.5 seconds]; Table 3), then preloaded bougie (mean 18.8 seconds [95% CI 17.7–19.8 seconds]; Table 3), and lastly, the railroaded bougie (mean 21.5 seconds [95% CI 20.6–22.4 seconds]; Table 3). See Table 3 for detailed description of times to successful intubations of different intubation techniques in the easy airway, including the number of intubations eligible for times to successful intubations analysis. Only intubations with successful first-pass success within 30 seconds are eligible for times to successful intubations analysis.

In the difficult airway, statistically significant differences were present in the times to successful intubations of the different techniques ( $P$  value <0.0001). The naked endotracheal tube (mean 19.0 seconds [95% CI 17.7–20.4 seconds]; Table 3) and the stylet (mean 19.6 seconds [95% CI 18.6–20.6 seconds]; Table 3) both had statistically significant faster times to successful intubations than the railroaded bougie (mean 24.5 seconds [95% CI 23.1–26.0 seconds]; Table 3), but there was no statistically significant difference between the times to successful intubations of the naked endotracheal tube and the stylet. There were also no statistically significant differences between the

**TABLE 2** First-pass success rates of naked endotracheal tube, styletied endotracheal tube, railroaded bougie, and preloaded bougie in both the easy and the difficult airways

Intubation techniques	"Easy" airway			"Difficult" airway		
	Total n	FPS rate (mean)	FPS rate (95% CI)	Total n	FPS rate (mean)	FPS rate (95% CI)
Naked ETT	109	105(96.3%)	90.9%–99.0%	109	61(56.0%)	46.1%–65.5%
Styletied ETT	109	107(98.2%)	93.5%–99.8%	109	83(76.1%)	67.0%–83.8%
Railroaded bougie	109	86(78.9%)	70.0%–86.1%	109	29(26.6%)	18.6%–35.9%
Preloaded bougie	109	83(76.1%)	67.0%–83.8%	109	33(30.3%)	21.8%–39.8%

Note: Mean first-pass success rates are presented as successful n (%).

Abbreviations: CI, confidence interval; ETT, endotracheal tube; FPS, first-pass success.

**TABLE 3** Times to successful intubations of naked endotracheal tube, styletied endotracheal tube, railroaded bougie, and preloaded bougie in both the easy and the difficult airways

Intubation techniques	"Easy" airway			"Difficult" airway		
	n included in TTSI analysis	TTSI (mean)	TTSI (95% CI)	n included in TTSI analysis	TTSI (mean)	TTSI (95% CI)
Naked ETT	105	12.8 s	11.9–13.7 s	61	19.0 s	17.7–20.4 s
Styletied ETT	107	14.6 s	13.7–15.5 s	83	19.6 s	18.6–20.6 s
Railroaded bougie	86	21.5 s	20.6–22.4 s	29	24.5 s	23.1–26.0 s
Preloaded bougie	83	18.8 s	17.7–19.8 s	33	21.4 s	19.9–22.9 s

Note: "n" for each intubation technique denotes the number of intubations eligible for times to successful intubations analysis (ie, only intubations with successful first-pass success within 30 seconds are eligible for times to successful intubations analysis). Times to successful intubations are presented in seconds. Abbreviations: CI, confidence interval; ETT, endotracheal tube; s, seconds; TTSI, time to successful intubation.

**TABLE 4** First-pass success rates in both the easy and the difficult airways based on subanalysis of participants' number of previous pediatric intubations

Number of previous pediatric intubations	"Easy" airway			"Difficult" airway		
	n	FPS rate (mean)	FPS rate (95% CI)	n	FPS rate (mean)	FPS rate (95% CI)
1–5	92 (23 participants)	76 (82.6%)	73.3%–89.7%	92 (23 participants)	40 (43.5%)	33.2%–54.2%
6–10	84 (21 participants)	76 (90.5%)	82.1%–95.8%	84 (21 participants)	39 (46.4%)	35.5%–57.6%
11–20	100 (25 participants)	86 (86.0%)	77.6%–92.1%	100 (25 participants)	54 (54.0%)	43.7%–64.0%
21–50	68 (17 participants)	60 (88.2%)	78.1%–94.8%	68 (17 participants)	30 (44.1%)	32.1%–56.7%
More than 50	92 (23 participants)	83 (90.2%)	82.2%–95.4%	92 (23 participants)	43 (46.7%)	36.3%–57.4%

Note: "n" for each group with different number of previous pediatric intubations denote the total number of study intubations performed by all participants in the group (eg, group 1–5 previous pediatric intubations had 23 participants who each performed 4 intubations in the easy airway with naked endotracheal tube, styletied endotracheal tube, railroaded bougie and preloaded bougie, leading to an "n" of 92). Mean first-pass success rates are presented as successful n (%).

Abbreviations: CI, confidence interval; FPS, first-pass success.

times to successful intubation of the preloaded bougie (mean 21.4 seconds [95% CI 19.9–22.9 seconds]; Table 3) when compared to either the naked endotracheal tube, stylet, or railroaded bougie. See Table 3 for detailed description of times to successful intubations of different intubation techniques in the difficult airway, including the number of intubations eligible for times to successful intubations analysis.

Subanalysis based on study participants' numbers of previous pediatric intubations showed that there were no statistically significant differences in the first-pass success rates (Table 4) and times to successful intubations (Table 5) in both the easy and difficult airways. See Tables 4 and 5 for detailed description of first-pass success rates and times to successful intubations in both the easy and the difficult airways based on participants' number of previous pediatric intubations. Table 5 also

**TABLE 5** Times to successful intubations in both the easy and the difficult airways based on subanalysis of participants' number of previous pediatric intubations

Number of previous pediatric intubations	"Easy" airway			"Difficult" airway		
	n included in TTSI analysis	TTSI (mean)	TTSI (95% CI)	n included in TTSI analysis	TTSI (mean)	TTSI (95% CI)
1-5	76	16.4 s	15.1-17.7 s	40	21.4 s	19.7-23.1 s
6-10	76	17.2 s	15.9-18.5 s	39	21.8 s	20.2-23.4 s
11-20	86	16.4 s	15.1-17.7 s	54	19.9 s	18.5-21.3 s
21-50	60	16.8 s	15.4-18.2 s	30	20.4 s	18.8-22.0 s
More than 50	83	16.1 s	14.9 - 17.3 s	43	19.0 s	17.7 - 20.3 s

Note: "n" for each intubation technique denotes the number of intubations eligible for times to successful intubations analysis (ie, only intubations with successful first-pass success within 30 seconds are eligible for times to successful intubations analysis). Times to successful intubations are presented in seconds. Abbreviations: CI, confidence interval; s, seconds; TTSI, time to successful intubation.

includes the number of intubations eligible for times to successful intubations analysis.

Subanalysis based on participants' specialty showed that in the easy airway, the emergency medicine group and the pediatric emergency medicine (PEM) group each had statistically significant higher first-pass success rates compared to the general pediatrics group (Table S1). There were no statistically significant differences in other pairwise comparisons of practitioner specialty (Table S1). In the difficult airway, the ED group had statistically significant higher first-pass success compared to both the general pediatrics and the PEM group, but no other statistically significant differences in other pairwise comparisons were present (Table S1). Please refer to Tables S1 and S2 for detailed description of first-pass success rates and times to successful intubations in both the easy and the difficult airways based on participants' specialty. Table S2 also includes the number of intubations eligible for times to successful intubations analysis.

For the easy airway, the naked endotracheal tube was the preferred technique both in prestudy (46.8% of participants; Table S3) and poststudy (39.4% of participants; Table S3). For the difficult airway, the railroaded bougie was the preferred technique prestudy (44.0% of participants; Table S3) but poststudy the stylet became the preferred technique for the difficult airway (45.0% of participants; Table S3). Prestudy, the preloaded bougie was the least preferred technique for both the easy and difficult airways, but poststudy there was an increase in the number of participants preferring preloaded bougie (from 0 to 9 participants in the easy airway, and from 4 to 15 in the difficult airway; Table S3). Please refer to Table S3 for detailed description of the preferred intubation techniques pre- and poststudy when intubating both the easy airway and the difficult airway.

Participants who preferred the stylet in the difficult airway prestudy had a statistically significant higher first-pass success rate during intubation with the stylet (mean 77.3% [95% CI 62.2%-88.5%]; Table S4), compared to participants who preferred the railroaded bougie in the difficult airway during intubation with the railroaded bougie (mean 27.1% [95% CI 15.3%-41.8%]; Table S4). Please refer to Table S4 for detailed description of first-pass success rates of partici-

pants when using their preferred technique to intubate the difficult airway.

### 3.3 | Limitations

A limitation of this study is that it was manikin based. Tracheal intubation adverse events, such as hypoxic events, hypotension, cardiac arrest, and airway trauma, were unable to be measured. However, a manikin-based study allowed for a more controlled study with minimal variables and allowed us to solely focus on the investigation of the performance of the adjuncts.

Another limitation of this study is the inability to reliably assess dental, oral, or airway injury because of the very robust nature of the Trucorp AirSim Baby X airway model. For example, participants were able to intubate the manikin with the styletted endotracheal tube without causing airway trauma. Some participants may have subconsciously "rocked" the laryngoscope, leading to a "straighter" line of vision from the eyes of the participants to the laryngeal inlet. This may explain, to some extent, why the styletted endotracheal tube, which is more rigid, has a higher first-pass success rate in the difficult airway.

The 15-minute prestudy practice time may have given the participants a "just in time" training before the study and may have influenced the overall scores; although it is unlikely to have affected the comparisons of the first-pass success rates and times to successful intubations of the 4 different intubation techniques. We were also aware that our study may not be generalizable to all pediatric age groups. For this study, we opted to use an infant airway manikin because a quarter of intubated children are infants, and 40% of intubations are in children younger than 2 years of age.<sup>2</sup> It is also in the under 1-year-old group where most difficult airways and intubation-related adverse events occur.<sup>4,6,7</sup> Further studies should be undertaken in alternative airway models with an older chronological age to investigate the performance of the adjuncts in older pediatric age groups.

There are emerging data suggesting that video laryngoscopy results in a higher first-pass success rate than direct laryngoscopy in emergency pediatric intubations.<sup>25</sup> Our study did not include the use of video laryngoscopy, and this may have limited the exploration of the best combination of laryngoscopy mode (direct vs video laryngoscopy) and intubation adjunct that results in the highest first-pass success rate. However, we argue that including a video laryngoscopy arm is not feasible as this would have required at least doubling of the number of intubations per participant. Using only a single mode of laryngoscopy also allows for a more controlled study with minimal variables and allowed us to solely focus on the investigation of the performance of the adjuncts.

## 4 | DISCUSSION

There is little current evidence supporting the use of stylet or bougie in children to attain first-pass success. Current literature on the association between stylet use and first-pass success rates have been limited to 2 neonatal studies that showed no difference in the first-pass success rates with or without stylet use.<sup>13,14</sup> With regard to the bougie, publications involving adult patients requiring emergency intubations showed that bougie results in higher first-pass success rates than naked endotracheal tube or stylet. Driver et al.<sup>11</sup> reported that the use of bougie in ED intubations resulted in a higher first-pass success rate (95%) compared to intubations without bougie use (86%). Driver et al.,<sup>12</sup> in a randomized controlled trial comparing the first-pass success rates of bougie versus stylet in the ED, reported that the use of bougie resulted in a higher first-pass success rate (98%) compared to stylet (87%). However, neither study involved any pediatric patients. Similarly, studies using simulated airways,<sup>1,15–20</sup> cadavers,<sup>21,22</sup> and patients undergoing elective surgeries<sup>23</sup> to compare the first-pass success rates of bougie, stylet, and naked endotracheal tube have all used adult subjects.

The findings of this manikin-based, pediatric-focused simulated airway study suggest that in the easy infant airway, the use of either naked endotracheal tube or stylet results in the highest first-pass success rates. In the easy airway, the naked endotracheal tube had the fastest time to successful intubation, and the stylet had the second fastest time to successful intubation. These findings were expected, as an easy airway with a Cormack-Lehane Grade I view provides a straight “line of vision” between the eyes and the laryngeal inlet, which works to the naked endotracheal tube’s and stylet endotracheal tube’s advantage without the added complexity of having to maneuver another adjunct (the bougie).

In the difficult infant airway in our study, intubation with a stylet result in the highest first-pass success rate. There was no statistically significant difference in the times to successful intubations of the stylet and the naked endotracheal tube. Both the stylet and the naked endotracheal tube are faster than the railroaded bougie in the intubation of a difficult airway. There were fewer intubations that qualified for time to successful intubation analysis in the difficult airway compared to the easy airway for all 4 intubation techniques (Table 3). This may have con-

tributed, to some extent, the findings of no statistically significant difference between the times to successful intubations of the naked endotracheal tube and the stylet endotracheal tube in the difficult airway (by virtue of “inadvertent” sampling bias of naked endotracheal tube intubations with faster intubation times for time to successful intubation analysis).

The preloaded bougie did not perform well in our study when compared to Kingma et al.,<sup>10</sup> who found that the preloaded bougie had a high first-pass success rate of 89.8% in the simulated adult difficult airway. In fact, in our study, the preloaded bougie had the lowest first-pass success rate, in conjunction with the railroaded bougie. A possible reason that the bougie did not perform well in our simulated difficult infant airway is that the bougie for an infant is softer and less rigid than its adult counterpart. As the infant airway is higher and more anterior, it is expected to be more difficult to maneuver the softer bougie anteriorly and upwards in the difficult airway. The poor performance of the bougie in the simulated difficult airway in our study, however, does not by any means negate the role of the bougie in the difficult airway. It is not uncommon for a difficult airway to require multiple attempts. Future simulated airway studies should consider including the analysis of second- or even the third-pass success rates and the times to achieve these. This would validate the performances of the adjuncts in a difficult airway.

In both the easy and the difficult airways, there were increases in the number of participants preferring the preloaded bougie after the study. We suspect this is because a large proportion of the study participants were unaware of the preloaded bougie technique or had no prior experience intubating with preloaded bougie before the study. We suspect that the preloaded bougie would have performed better in our study if the study participants had more prior practice or real-life experience with preloaded bougie.

Despite the study limitations, this study represents the biggest study involving the largest number of intubation attempts to directly compare the first-pass success rates and times to successful intubations of the naked endotracheal tube, stylet, and bougie in the intubation of an infant-sized simulated airway. Conversely, conducting comparative airway adjunct studies in real human patients in both easy and difficult airways are unrealistic due to the number of sample size required. Our study also demonstrated an absence of statistically significant differences in the first-pass success rates and times to successful intubations when subanalyzed based on the participants’ numbers of previous pediatric intubations, suggesting that the differences seen in the first-pass success rates and times to successful intubations of the different techniques are down to the adjuncts, rather than the participants’ previous intubation experience.

This study raises future research opportunities. It is hoped that further research on the comparative efficacy of the different airway adjuncts in different-sized airway manikins will lead to knowledge about the most effective airway adjunct in older pediatric age groups. Future studies may also use a different “difficult airway” (eg, using macroglossia to simulate a difficult airway), a video laryngoscope research arm, a different bougie, or allowing more practice time for preloaded bougie before the study.



In summary, results of this simulation-based study suggest that stylet should be used as the first attempt technique for intubations in infants regardless of the presence or absence of predicted airway difficulty. This finding needs further validation using alternative models and in non-simulation settings.

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## CONFLICT OF INTEREST

The authors of this article do not have any conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript. There is no financial interest to report.

## AUTHOR CONTRIBUTIONS

Khang Hee Gan and Mike Shepherd conceived the study and designed the trial. Khang Hee Gan supervised the conduct of the trial and data collection, undertook recruitment of participating centers, and analyzed the data. Khang Hee Gan drafted the manuscript, and Mike Shepherd contributed substantially to its revision. Khang Hee Gan takes responsibility for the paper as a whole.

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## SUPPORTING INFORMATION

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