



# ETView VivaSight single lumen vs. conventional intubation in simulated studies: a systematic review and meta-analysis

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## Abstract

**Objective:** The ETView VivaSight single lumen airway tube (ETView) is a tracheal tube incorporating a video camera. We carried out a meta-analysis of previous simulation studies by inexperienced personnel to determine if the ETView could improve the success rate of first-attempt intubation.

**Methods:** We collected data from randomized controlled trials comparing the use of the ETView VivaSight single lumen versus a conventional endotracheal tube in a simulated manikin or cadaver study.

**Results:** Eleven studies (558 participants, 3,254 intubations, and 19 scenarios) were included. The ETView had a significantly higher success rate and shorter insertion time than conventional intubation in both normal airways (with or without chest compression) and in difficult airways. In addition, the ETView demonstrated better results in terms of a higher rate of Cormack–Lehane grade I and a lower incidence of dental trauma.

**Conclusions:** Inexperienced personnel can insert the ETView more rapidly and with a higher intubation success rate compared with a conventional tube.

## Keywords

Airway management, laryngoscope, tracheal intubation, manikin, simulation, meta-analysis

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## Introduction

Endotracheal intubation is the gold standard technique for providing and maintaining a secure airway. Immediate airway interventions for oxygenation are necessary in emergency situations such as severe trauma, cardiac arrest, apnea, and coma because they can guarantee minimal pause in chest compressions.<sup>1</sup> However, endotracheal intubation requires considerable skill and experience and may be more difficult in certain situations, including in patients with an immobilized cervical spine as a result of severe trauma, or in chest compressions for cardiopulmonary resuscitation.<sup>2,3</sup> Delayed or failed intubation has been identified as an important indicator of major airway complications,<sup>4</sup> and failure to perform successful endotracheal intubation may have devastating outcomes. In this regard, education and training for endotracheal intubation in a variety of situations can be helpful, and manikins have been widely used for simulations related to airway management.<sup>5,6</sup>

A new single-use, endotracheal tube (ETView VivaSight, ETView Ltd., Misgav, Israel) has recently become available. The device has an integrated, high-resolution camera with a display monitor and a light source embedded at the distal tip of the tracheal lumen, enabling continuous visualization of the camera view.<sup>7,8</sup> The improved visualization features may facilitate effective airway management by inexperienced medical personnel in various situations. However, the ability of the ETView VivaSight single lumen (ETView) to improve intubation conditions overall, thereby increasing the first-attempt success rate and decreasing intubation time compared with conventional laryngoscopy, remains unclear.

We aimed to analyze pooled data from randomized controlled trials (RCTs) comparing the ETView, with conventional

endotracheal tubes (cETT) and a Macintosh laryngoscope in simulation studies by inexperienced personnel. The primary objective was to compare the success rates of first-attempt intubation using the ETView or cETT in different simulation scenarios. We also assessed the intubation time, overall success rate, Cormack–Lehane grade, incidence of dental trauma, ease of use, and device preference.

## Materials and methods

This systematic review and meta-analysis were performed according to the Cochrane Review Methods<sup>9</sup> and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations<sup>10</sup> (Supplemental material 1) and the study protocol was registered with PROSPERO (registration number: CRD42019132051). The study was designed to use existing literature and did not involve new human data, and was therefore exempt from institutional review board assessment.

### *Inclusion and exclusion criteria*

We defined the inclusion and exclusion criteria a priori. The inclusion criteria (specified according to the PICO acronym) were as follows: Population: adult participants (aged >16 years) with no previous experience in clinical intubation with ETView in a simulated adult manikin or cadaver (aged  $\geq 18$  years), in studies including a crossover design; Intervention: intubation with video-mounted endotracheal tube (ETView); Comparator: intubation with a cETT with a Macintosh laryngoscope; Outcomes: first-attempt success rate, intubation time, tooth damage, Cormack–Lehane grade, overall success rate, ease of intubation score, and device preference. The exclusion criteria were participants aged  $\leq 16$  years, pediatric manikin or cadaver aged <18 years, and studies in a real clinical setting.

### *Database and literature sources*

We searched MEDLINE (28 January 2020), Embase (28 January 2020), the Cochrane Controlled Trials Register and Cochrane Database on Systematic Reviews (28 January 2020), Web of Science (28 January 2020), Scopus (28 January 2020), and databases of RCTs that compared ETViva single lumen versus conventional intubation with a Macintosh laryngoscope in a simulated manikin or cadaver study including a crossover design. The following search terms were used: “intubation”, “ETView”, “VivaSight”, “manikin”, “manikins”, “mannequin”, “cadaver”, and “simulation”. There were no language restrictions imposed on the searches (Appendix 1).

After the initial electronic search, we evaluated the bibliographies of all the identified studies and performed a manual search using Google Scholar. We also searched the World Health Organization International Clinical Trials Registry Platform and the ClinicalTrials.gov database to identify unpublished or ongoing studies. The identified articles were individually assessed for inclusion in the analysis.

### *Data selection*

Two independent investigators (SKO and YJW) performed the study selection by searching the titles and abstracts of the potentially eligible articles. Finally, the full text of the identified articles was retrieved and assessed for eligibility. Disagreements between the two investigators were resolved by discussion and consultation with a third author (BGL).

### *Data extraction*

Among the searched trials, two authors (SKO and YJW) independently extracted the data for inclusion into a Microsoft Excel spreadsheet (Office 2016 professional

edition, Microsoft Corp., Redmond, WA, USA). Any ongoing disagreement was reviewed and resolved by the third author (BGL). The following data were extracted: name of the first author, year of publication, journal name, study design, participant characteristics and number, presence of concurrent chest compression or difficult situations, and outcomes including time to intubation and insertion success rate.

The primary outcomes of this review were the first-attempt success rates in the ETViva and cETT groups. Secondary outcomes were intubation time, tooth damage, Cormack–Lehane grade, overall success rate, ease of intubation score, and device preference. The success rate was determined according to the definitions of insertion failure (e.g., time limitation >60 s or incorrectly placed tube, such as esophageal intubation) described in each study. The overall success rate was defined as the final result after three attempts. The definition of intubation time (time to successful ventilation) varied among the studies: some studies used the initial grasp of the airway device (first contact) as the start point and first successful ventilation as the end point,<sup>11–13</sup> while others used the insertion of the laryngoscope blade between the teeth as the start point,<sup>14,15</sup> and others did not include any definition of the intubation time.

Crossover studies were treated as parallel studies, with each interventional phase treated as an independent arm of a parallel study.<sup>16</sup>

### *Assessment of methodological quality*

Two reviewers (SKO and YJW) independently assessed the risks of bias in the included articles according to the Cochrane Collaboration’s tool, consisting of selection, performance, detection, attrition, reporting, and other sources of bias.<sup>17</sup> Bias was graded as “low-risk,”

“high-risk,” or “unclear.” Any ongoing disagreements between the two reviewers were resolved through discussion, or by review by the third author (BGL). Publication bias was assessed by funnel plot tests for asymmetry and Egger’s linear regression test.

### Statistical analysis

This meta-analysis was carried out using RevMan version 5.3 software (The Cochrane Collaboration, Oxford, UK). Continuous variables, including intubation time, were analyzed using the inverse-variance method with the mean difference (MD) with 95% confidence intervals (CIs). An MD < 0 indicated that the intubation time was lower in the ETView group than in the cETT group. Dichotomous variables, including first-attempt success rate, overall insertion success rate, tooth damage, Cormack–Lehane grade, ease of intubation score, and device preference, were analyzed by pooled odds ratios (ORs), and 95% CI using the Mantel–Haenszel method. Random-effects models were conducted primarily to incorporate within and between study components of variance, and fixed-effect models were used secondarily to confirm and compare the results.

Each analysis was assessed for statistical heterogeneity using Cochran’s Q test and I<sup>2</sup> statistics. The proportion of between-study inconsistency due to true differences between the studies (rather than differences due to random error or chance) was determined for the I<sup>2</sup> statistics. Values >50% were considered to indicate significant heterogeneity. A *P*-value < 0.1 for Cochran’s Q test was considered statistically significant.<sup>9</sup>

Subgroup analyses were pre-planned to compare the following: 1) different scenarios (e.g. with or without chest compression, with or without cervical immobilization, in a car, or at rest); 2) different types of participants (e.g. novice, medical student,

physician, or paramedic); and 3) different subject types (e.g. manikin or cadaver).

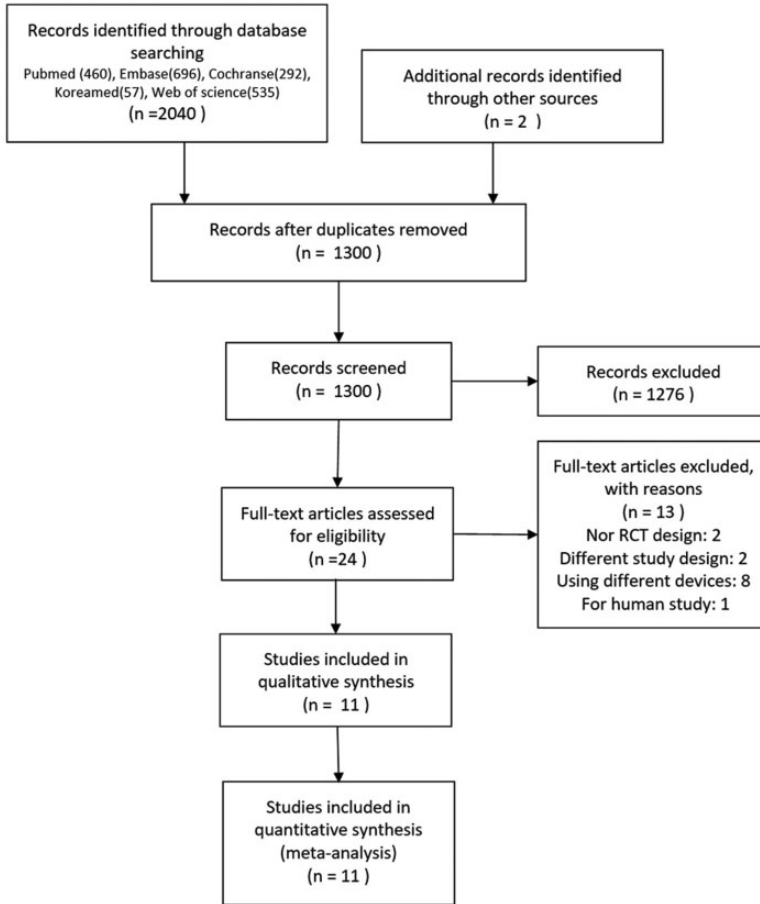
## Results

### Identification of studies

The initial literature search revealed 2,042 articles. After duplicate removal, 1,276 publications were excluded because it was clear from the title and abstract that they did not fulfill the selection criteria. We scrutinized the complete texts of the remaining 24 articles and identified 11 potentially relevant articles. The remaining 13 articles were excluded for the following reasons: two were not RCT designs, two were a different study design, eight used different devices, and one was a human study. Eleven studies were therefore finally included in the systematic review<sup>11–15,18–23</sup> (Figure 1).

### Study characteristics

The characteristics of the included articles are summarized in Table 1. All studies were randomized crossover trials using manikins,<sup>12–15,18–23</sup> except for one cadaver study.<sup>11</sup> Four studies were original research articles,<sup>11,12,14,15</sup> five were correspondence to the editor,<sup>13,18–21</sup> and two were poster presentations.<sup>22,23</sup> The 11 studies included 558 participants and 3,254 total intubations in 19 situation scenarios. Two trials<sup>18,20</sup> in car scenarios were continuation studies undertaken by the same participants, and 513 participants were therefore included in the analyses. However, considering each scenario in a crossover study as an individual parallel study increased the number of participants to 1116. The participants in four studies were physicians,<sup>14,15,22,23</sup> six were paramedics,<sup>11–13,18–20</sup> and one study involved medical students.<sup>21</sup> No participants had any previous experience with the ETView, and limited experience with



**Figure 1.** PRISMA flow-chart for retrieval of the 11 randomized controlled trials included in the systematic review. RCT, randomized controlled trial.

cETT intubation in clinical settings (<5 to 19), except in two studies with the same participant in a car scenario<sup>18,20</sup> where the participant had a mean of 9.4 career years as a healthcare provider, including experience with approximately 50 tracheal intubations in patients.

Four studies established a scenario with a normal airway at rest (in a neutral position) with no chest compression,<sup>11,12,14,15</sup> and four others used a normal airway at rest including chest compression.<sup>11,14,21,23</sup> Difficult airway situations requiring

manual in-line stabilization were used in three studies,<sup>11,12,15,22</sup> cervical immobilization using a cervical extraction collar was used in three studies,<sup>12,15,18</sup> and cervical immobilization using a vacuum mattress was used in one study.<sup>15</sup> Another four difficult intubation situation settings were used,<sup>13,18–20</sup> including one scenario of face-to-face intubation with a tongue-swelling situation,<sup>18</sup> and two studies with a normal airway car scenario without chest compression.<sup>11,12,14,15</sup> In one case, access was through the open driver's door (reclining

**Table 1.** Characteristics of the included trials.

Study ID	Participants	Manikin or cadaver	Study design/type of publication	Scenario	Outcomes
Kurowski et al. <sup>14</sup> (2015)	107 physicians	SimMan 3G training manikin (Laerdal, Stavanger, Norway)	Randomized, crossover trial/original research	A. Normal airway at rest without CC B. Normal airway at rest with CC	Intubation time, first-attempt success rate, overall success rate, Cormack–Lehane grade, dental trauma, ease of use (difficulty of use) <sup>b</sup> , device preference
Truszewski et al. <sup>11</sup> (2016)	52 paramedics	Cadaver (18–65 years at time of death)	Randomized, crossover trial/original research	A. Normal airway at rest without CC B. Normal airway at rest with CC C. Cervical stabilization at rest without CC (manual in-line stabilization)	Intubation time, first-attempt success rate, Cormack–Lehane grade, ease of use, device preference <sup>b</sup>
Gawlowski et al. <sup>12</sup> (2017)	67 paramedics	MegaCode Kelly advanced life support manikin (Laerdal)	Randomized, crossover trial/original research	A. Normal airway at rest without CC C. Cervical stabilization at rest without CC (manual in-line stabilization) C. Cervical stabilization at rest without CC (cervical collar)	Intubation time, overall success rate, first-attempt success rate, Cormack–Lehane grade, dental trauma, ease of use, device preference
Karczewska et al. <sup>15</sup> (2107)	50 physicians	Airway Assessment Training Model BT-CSIE BT Inc, A-313 (Samsung Techno-Valley, Gyeonggi-do, Korea)	Randomized, crossover trial/original research	A. Normal airway at rest without CC C. Cervical stabilization at rest without CC (cervical collar) C. Cervical stabilization at rest without CC (cervical immobilization using vacuum mattress)	Overall success rate, first-attempt success rate, intubation time, Cormack–Lehane grade, device preference
Szarpak et al. <sup>13</sup> (2016)	56 paramedics	SimMan manikin (Laerdal)	Randomized, crossover trial/correspondence	C. Cervical stabilization at rest without CC (cervical collar) D. Difficult situation at rest without CC (cervical collar and tongue inflation)	Intubation time, first-attempt success rate
Madziala et al. <sup>19</sup> (2016)	62 paramedics	SimMan manikin (Laerdal)	Randomized, crossover trial/correspondence	D. Difficult situation without CC (face-to-face tracheal intubation)	First-attempt success rate, intubation time
Truszewski et al. <sup>20</sup> (2016) <sup>a</sup>	45 paramedics	SimMan manikin (Laerdal)	Randomized, crossover trial/correspondence	D. Difficult situation without CC (car scenario: access through open driver's door)	Intubation time, first-attempt success rate, overall success rate, dental trauma

(continued)

**Table 1.** Continued

Study ID	Participants	Manikin or cadaver	Study design/type of publication	Scenario	Outcomes
Szarpak et al. <sup>18</sup> (2016) <sup>a</sup>	45 paramedics	SimMan manikin (Laerdal)	Randomized, crossover trial/correspondence	D. Difficult situation without CC (back seat of the car scenario: manikin entrapped in a car's left front seat, with access to the patient from the back seat)	First-attempt success rate, overall success rate, intubation time, dental trauma, ease of use
Madziana et al. <sup>21</sup> (2018)	45 medical students	MegaCode Kelly advanced life support manikin (Laerdal)	Randomized, crossover trial/correspondence	B. Normal airway at rest with CC	First-attempt success rate, intubation time, Cormack-Lehane grade <sup>b</sup>
Szarpak et al. abstract <sup>22</sup> (2016)	29 physicians	Adult Airway Management Trainer (Stimulaid, Inc., Saugerties, NY, USA)	Randomized, crossover trial/abstract	C. Cervical stabilization at rest without CC (manual in-line stabilization)	First-attempt success rate, overall success rate, intubation time
Dabrowski et al. abstract <sup>23</sup> (2017)	57 physicians	SimMan manikin (Laerdal)	Randomized, crossover trial/abstract	B. Normal airway at rest with CC	Intubation time, first-attempt success rate

Letters in the scenario represent the same categorized simulation scenarios. <sup>a</sup>Of these two trials, the trial by Szarpak et al.<sup>18</sup> was a continuation of the study by Truszewski et al.<sup>20</sup> <sup>b</sup>These outcomes were described in the trials but the complete data were not provided. CC, chest compression

seat was not allowed),<sup>20</sup> and the other was a car back-seat scenario with the manikin trapped in the left front seat with the only access to the patient from the back seat.<sup>13</sup>

The scenarios were categorized into four types of scenarios: A, normal airway at rest without chest compression; B, normal airway at rest with chest compression; C, cervical stabilization at rest without chest compression; and D, difficult situation without chest compression. Considering that each study had two or three scenarios and was also performed as a crossover design, each participant experienced multiple intubation events, and the intubation event was therefore considered as the unit of analysis.

The devices used in the included studies were the ETView and a cETT with Macintosh laryngoscope. All intubations were performed with a size 7.0-mm tracheal tube.

**Quality of included studies**

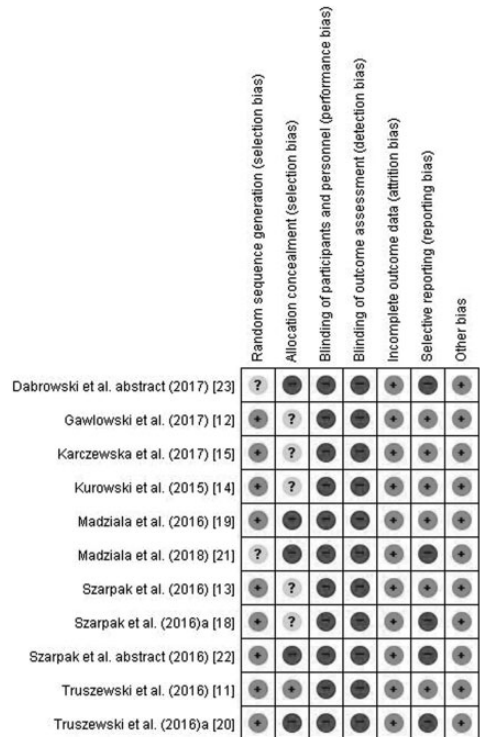
The methodology for the quality assessment of each trial is described in Figure 2.

**Allocation**

Eleven of the included studies reported randomization,<sup>11–15,18–23</sup> but only nine studies<sup>11–15,18–20,22</sup> included information on the random sequence generation method applied. Allocation concealment was adequately reported in only one study.<sup>12</sup>

**Blinding**

Performance and detection bias regarding the blinding of participants and assessors was assessed as having a high risk of bias in all studies.<sup>11–15,18–23</sup> It was not possible to blind the participant performing the intubation nor to blind the investigators to the process measures because the device type could not be concealed during the performance.



**Figure 2.** Risks of bias in seven methodological domains. Risk of bias was categorized as low (green), unclear (yellow), or high (red).

**Incomplete outcome data**

All studies reporting the completeness of outcome data for each main outcome were assessed as having a low risk of bias.<sup>11–15,18–23</sup>

**Selective reporting**

Six studies were assessed as having a low risk of bias.<sup>11,12,14,15,18,19</sup> Five studies<sup>13,20–23</sup> where one or more reported primary outcomes were not pre-specified, or not all of the study’s pre-specified primary outcomes had been reported, were assessed as having a high risk of bias.

**Other potential sources of bias**

All studies had a low risk of other potential sources of bias.<sup>11–15,18–23</sup>



### Meta-analysis of primary outcome measures

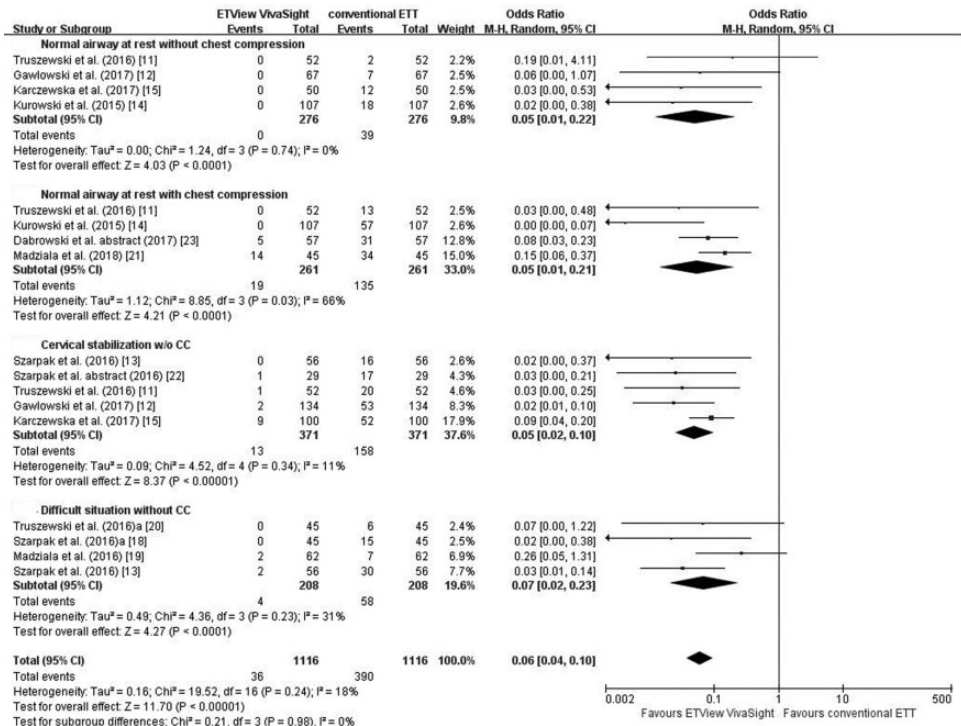
Information on the first-attempt success rate was available in all the included studies.<sup>11–15,18–23</sup> The analysis demonstrated fewer failed intubations using the ETView in all scenarios (OR: 0.06, 95% CI: 0.04 to 0.10;  $P < 0.001$ ,  $I^2 = 18\%$ ). The pooled OR for the first-attempt success rate (decreased failure rate) in a normal airway at rest without chest compression was 0.05 (95% CI: 0.01 to 0.22,  $P < 0.001$ ). This result showed no heterogeneity ( $I^2 = 0\%$ ), (Figure 3).

### Meta-analysis of secondary outcome measures

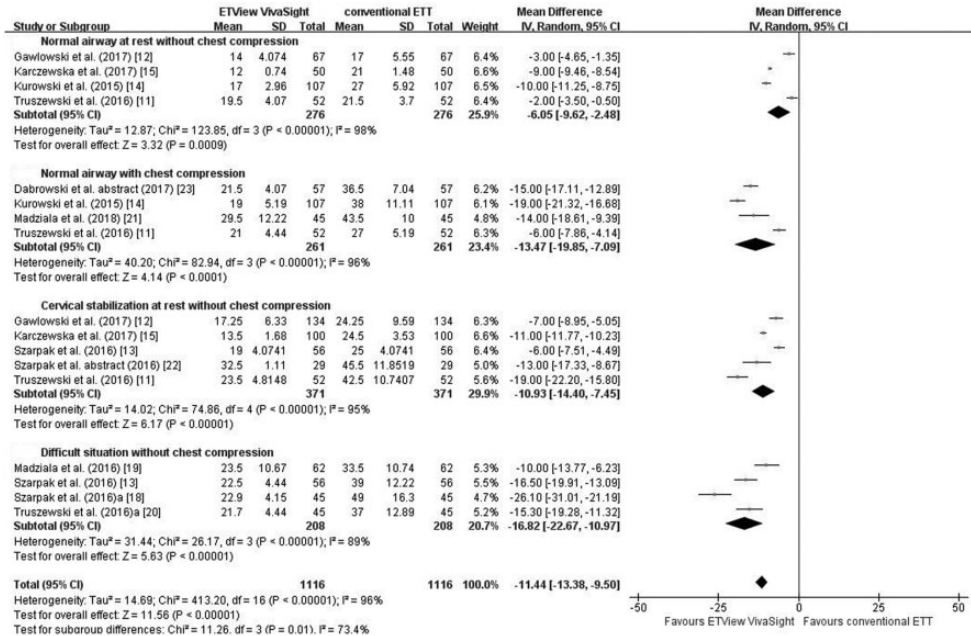
Intubation time was assessed in all the included studies.<sup>11–15,18–23</sup> Assessment using a normal airway with or without chest

compression and also with an airway situated in a difficult position revealed a significantly shorter insertion time in the ETView compared with the cETT group. The pooled MD for all 17 scenarios was  $-11.44$  s (95% CI:  $-13.38$  to  $-9.50$ ,  $P < 0.001$ ), although the heterogeneity was high ( $I^2 = 96\%$ ). The pooled MD in four studies using a normal airway at rest without chest compression was  $-6.05$  s (95% CI:  $-9.62$  to  $-2.48$ ,  $P < 0.001$ ,  $I^2 = 98\%$ ),<sup>12–15</sup> and the MD in four studies with difficult situations was  $-16.82$  s (95% CI:  $-22.67$  to  $-9.50$ ,  $P < 0.0001$ ,  $I^2 = 98\%$ )<sup>11,18–20</sup> (Figure 4).

The Cormack–Lehane grade was assessed in five studies,<sup>11,12,14,15,21</sup> but detailed data were not reported in one of these.<sup>21</sup> The incidence of Cormack–Lehane grade 1 was significantly higher in the ETView compared with the cETT group



**Figure 3.** Forest plots for first-attempt success rate (displayed as odds ratio for decreased failure rate; events were failure of intubation). M-H, Mantel–Haenszel; df, degrees of freedom.



**Figure 4.** Forest plots for intubation time (displayed as mean difference in seconds). SD, standard deviation; IV, inverse variation; CI, confidence interval; df, degrees of freedom.

in a normal airway at rest without chest compression (OR: 65.20, 95% CI: 12.58 to 338.03,  $P < 0.001$ ,  $I^2 = 0\%$ ), in cervical stabilization (OR: 687.11, 95% CI: 103.85 to 4546.16,  $P < 0.001$ ,  $I^2 = 38\%$ ), and in all nine included scenarios from four studies (OR: 207.99, 95% CI: 68.91 to 627.76,  $P < 0.001$ ,  $I^2 = 24\%$ )<sup>11,12,14,15</sup> (Table 2).

Data on the overall success rate were available in six studies,<sup>11-15,22</sup> and showed significantly fewer overall failed intubations in the ETView group in a normal airway situation with or without chest compression, and also with an airway situated in a difficult position (OR: 0.04, 95% CI: 0.01 to 0.15,  $P < 0.001$ ,  $I^2 = 0\%$ ) (Table 2).

The incidence of dental trauma was evaluated in four trials,<sup>12-14,20</sup> and was significantly lower in the ETView compared with the cETT group (OR: 0.02, 95% CI: 0.01 to 0.08,  $P < 0.001$ ,  $I^2 = 0\%$ ) (Table 2).

Ease/difficulty of device use was assessed in three studies.<sup>12,15,18</sup> The ETView was

significantly easier to use than conventional intubation in cervical stabilization and difficult situations (standardized MD, inverse-variance, random-effects:  $-2.15$ , 95% CI:  $-2.47$  to  $-1.83$ ,  $P < 0.001$ ,  $I^2 = 0\%$  and  $-3.03$ , 95% CI:  $-3.64$  to  $-2.42$ ;  $P < 0.001$ ,  $I^2$  not applicable, respectively), but not in normal airway at rest without chest compression scenarios ( $-0.02$ , 95% CI:  $-0.74$  to  $0.70$ ,  $I^2 = 87\%$ ) (Table 2).

Participants were asked about their device preference in four studies.<sup>11,12,14,15</sup> The ETView was the preferred device in normal airway at rest without chest compression scenarios (OR: 163.40, 95% CI: 6.82 to 3913.17,  $P = 0.002$ ,  $I^2 = 95\%$ ) and in normal airway at rest with chest compression, with 100% selection (Table 2).

**Subgroup analysis**

Subgroup analysis was conducted in different types of participants (physicians versus

**Table 2.** Secondary outcomes in four categorized scenarios.

Outcome (number of trials) [number of scenarios]	No. of intubations (event/total)		Odds ratio or MD (95% CI)	I <sup>2</sup> (%)	P value	Model	References
	ETView	cETT					
Cormack-Lehane grade I (n = 4)	716/721	345/721	207.99 (68.91 to 627.76)	24	<0.001	M-H, random	11,12,14,15
Scenario A [n = 4]	276/276	213/276	65.20 (12.58 to 338.03)	0	<0.001		11,12,14,15
Scenario B [n = 2]	159/159	89/159	155.67 (21.08 to 1149.40)	0	<0.001		11,14
Scenario C [n = 3]	281/286	43/286	687.11 (103.85 to 4546.16)	38	<0.001		11,12,15
Overall success rate (event: failure) (n = 6)	0/755	54/755	0.04 (0.01 to 0.15)	0	<0.001	M-H, random	11–15,22
Scenario A [n = 5]	0/298	6/298	0.06 (0.00 to 1.14)	N/A	N/A		11–15
Scenario B [n = 2]	0/173	34/174	0.01 (0.00 to 0.16)	N/A	0.001		11,14
Scenario C [n = 4]	0/258	14/258	0.05 (0.01 to 0.43)	0	0.006		11–13,22
Scenario D [n = 1]	0/45	0/45	Not estimable	N/A	<0.001		13
Incidence of dental trauma (n = 4)	2/371	78/371	0.02 (0.01 to 0.06)	0	<0.00001	M-H, random	12–14,20
Scenario A [n = 2]	0/174	14/174	0.06 (0.01 to 0.47)	0	0.007		12,14
Scenario B [n = 1]	0/107	12/107	0.04 (0.00 to 0.61)	N/A	0.02		11
Scenario D [n = 2]	2/90	52/90	0.01 (0.00 to 0.04)	4	<0.001		13,20
Ease of use <sup>a</sup> (n = 4)	279	279	-1.39 (-2.36 to -0.42)	97	<0.001	IV, random	12,15,18
Scenario A [n = 2]	117	117	-0.02 (-0.74 to 0.70)	87	0.96		12,15
Scenario C [n = 2]	117	117	-2.15 (-2.47 to -1.83)	0	<0.001		12,15
Scenario D [n = 1]	45	45	-3.03 (-3.64 to -2.42)	N/A	<0.001		18
Device preference (n = 4)	624/721	97/721	163.96 (33.62 to 799.02)	93	<0.001	M-H, random	11,12,14,15
Scenario A [n = 4]	238/276	38/276	163.40 (6.82 to 3913.17)	95	0.002		11,12,14,15
Scenario B [n = 2]	159/159	0/159	22.614.17 (1,400.70 to 36,513.77)	0	<0.001		11,14
Scenario C [n = 3]	227/286	59/286	22.40 (4.51 to 111.22)	0	<0.001		11,12,15

<sup>a</sup>Ease of use analyzed as standardized mean difference; other outcomes analyzed by odds ratio. ETView, ETView VivaSight single lumen; cETT, conventional endotracheal tube; Scenario A, normal airway at rest without chest compression; Scenario B, normal airway at rest with chest compression; Scenario C, cervical stabilization at rest without chest compression; Scenario D, difficult situation without chest compression; MD, mean difference; CI, confidence interval; N/A, not applicable; M-H: Mantel-Haenszel; IV, inverse variation.

non-physicians, such as medical students and paramedics). The results are summarized in Appendix 2. The ETView group consistently showed a significantly higher first-attempt success rate for intubation and shorter intubation time than the cETT group, regardless of the type of participant (physician or not).

### *Sensitivity analysis and publication bias*

We conducted a sensitivity analysis by systematically removing unpublished articles (abstracts) and high-risk of randomization studies and recalculating the significance of the results to determine if each study influenced the overall results. No study significantly affected the heterogeneity and ORs. Additionally, a cadaver study<sup>12</sup> sensitivity analysis showed that heterogeneity and ORs were not significantly impacted.

Funnel plots were used to evaluate publication bias for the primary outcome. All the funnel plots appeared symmetrical, suggesting a low risk of publication bias. We used the trim and fill method to address publication bias, with a 12% reduction in effect size (2.413, 95% CI, 1.879 to 2.947, to 2.152, 95% CI, 1.658 to 2.646). Egger's test gave a *P*-value of 0.06, confirming no significant evidence of a small-study effect (Appendix 3).

### **Discussion**

The results of this meta-analysis showed that implementation of the ETView increased the success rate and shortened the intubation time in simulated studies, compared with conventional intubation using a Macintosh laryngoscope.

The success rate of the first intubation attempt is important because the risks of hypoxemia, aspiration, and even cardiac arrest have been shown to increase significantly after more than two intubation attempts.<sup>24</sup> Furthermore, improving the

first-attempt success rate is considered the main goal of emergency intubation.<sup>25</sup> A shorter intubation time is also important in terms of securing airway patency during cardiopulmonary resuscitation, given that recent resuscitation guidelines emphasize that chest compressions should be interrupted only briefly when placing airway devices.<sup>26,27</sup> The mean intubation time was 13.47 s faster with the ETView compared with the cETT. This difference may reduce the duration of interruptions to chest compression, thereby contributing to better perfusion of the major organs during resuscitation. Minimizing the hands-off time and maximizing organ perfusion are major factors affecting resuscitation outcome.<sup>28,29</sup> In this regard, the ETView may be a critical device for improving patient outcomes during resuscitation. The difference in intubation time between the ETView and conventional intubation was further increased in difficult situations, with a pooled MD for normal at rest airways without chest compression of  $-6.05$  s and a pooled MD in difficult situations of  $-16.82$  s. The benefit of the ETView may thus be highlighted in difficult situations.

The superior success rate and faster insertion time of the ETView versus cETT, which was consistent across all types of scenarios in the current meta-analysis, suggest that the results may be clinically applicable in various conditions, such as during cardiopulmonary resuscitation, neck stabilization, and other difficult situations.

The participants included in this review had no previous experience with the ETView and limited experience with a conventional laryngoscope. However, despite this difference in device familiarity, the results demonstrated a clear advantage of the ETView vs. cETT in inexperienced operators.

In addition, the ETView had better intubation results in terms of a higher rate of

Cormack–Lehane grade 1 and a lower incidence of dental trauma compared with the Macintosh laryngoscope.

Cervical immobilization limits the optimal head and neck position, termed the sniffing position. However, the ETView improves intubation conditions in this situation by visualizing the glottis without alignment of the oral-pharyngeal-tracheal axes. The difference in the incidence of Cormack–Lehane grade 1 was substantially increased in stabilization status scenario C, indicating that the ETView may enable faster and easier intubation than the cETT during cervical immobilization.

The ease of use of the two methods was similar in scenario A (normal airway without chest compression), unlike the other scenarios, suggesting that ETView had no advantages in controlled situations, such as typical elective surgery in the operating room. However, intubation outside the operation room is generally much more difficult, and the perceived ease of use of the ETView may thus make it convenient in these situations.

Numerous studies and several meta-analyses have compared video and direct laryngoscopy for endotracheal intubation.<sup>30–35</sup> Although the results of these meta-analyses regarding first-attempt success were inconsistent, use of a video laryngoscope decreased failed intubation of difficult airways in some studies.<sup>30–32</sup> However, a video laryngoscope did not increase the first-attempt success rates of inexperienced or experienced operators in emergency situations, such as during cardiopulmonary resuscitation or trauma.<sup>33–35</sup> The current review, which provides the first meta-analysis comparing a video-mounted endotracheal tube (ETView VivaSight single lumen) with a cETT, clearly showed superior intubation success rates with the video-mounted endotracheal tube in emergency situations. The video-mounted ETView endotracheal tube, instead of

a video laryngoscope, may thus offer a better alternative than cETTs in emergency intubation situations.

There was substantial heterogeneity in the pooled data for intubation time in the present meta-analysis because the definition of intubation time differed between the studies: each study specified a different starting time point (e.g. touching the device, or inserting the device into the manikin), resulting in an extremely high level of heterogeneity. This heterogeneity prevented a higher quality meta-analysis of intubation time, and the first-attempt success rate was therefore defined as the primary outcome in our review.

The current review included correspondence and short reports, in addition to original research. The funnel plot displayed a visually symmetrical distribution, qualitatively indicating a low risk of publication bias, and all types of publications were therefore included in our review. The ETView produced consistently superior results, regardless of publication type, in all the included studies.

This study had several limitations. An important intrinsic deficiency in the studies was the difficulty in blinding, which was impossible because of the nature of the airway devices. Second, only simulated studies using manikins or cadavers were included instead of those conducted in clinical settings, and the implications of the results may thus be limited because the outcomes may differ in actual clinical patients. Further investigations in certified clinical settings are therefore necessary to verify the current findings. However, it would be difficult to perform RCTs in simulated emergency situations, such as during chest compression, neck stabilization, and difficult situations, especially with inexperienced personnel because of ethical issues. Simulated studies are therefore important to try and overcome these situational limitations and ethical challenges.

Further systematic evaluation of the ETView in patients is also needed to assess its performance in emergency intubation situations, with a potentially high degree of airway soiling and consequent camera blurring.

## Conclusions

Our evidence suggests that the ETView can minimize intubation failure and allow faster and easier intubation in simulated studies, compared with cETTs. This advantage is particularly evident in difficult situations, such as during chest compression, cervical stabilization, and outside-hospital settings. The use of the ETView is also likely to improve glottis visualization and reduce the possibility of dental trauma during intubation. These advantages may influence the ease of use and operator preference for the ETView compared with cETT in difficult situations. The ETView, as a video-mounted endotracheal tube, may be useful for emergency intubation performed by inexperienced personnel. However, the current results were based on simulated situations, and the demonstrated advantages of the ETView should be confirmed in further studies in clinical settings.

## Declaration of conflicting interest

The authors declare that there is no conflict of interest.


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**Supplemental material 1. PRISMA checklist**

**Appendix 1. Search terms used for database searches.**

PubMed	Embase	Cochrane	WoS	KoreaMed
#1 Intubation, Intratracheal[mh]	('endobronchial intubation'/exp OR 'endotracheal intubation'/exp)	[mh "Intubation, Intratracheal"]		
#2 (Trachea[mh] OR trachea [tiab] OR tracheas[tiab] OR tracheal[tiab] OR endotracheal[tiab] OR intratracheal[tiab] OR orotracheal[tiab] OR nasotracheal[tiab] OR endobronchial[tiab]) AND (intubat*[tiab] OR tube [tiab] OR tubes[tiab] OR cannula[tiab] OR cannulae[tiab] OR Cannula[mh])	((tracheal/exp OR trachea OR tracheas OR tracheal OR endotracheal OR intratracheal OR orotracheal OR nasotracheal OR endobronchial): ti,ab) AND (cannula/de OR 'nasal cannula'/exp OR (intubat* OR tube OR tubes OR cannula OR cannulas OR cannulae): ti,ab) OR 'endotracheal tube'/de	[[mh Trachea] OR (trachea OR tracheas OR tracheal OR endotracheal OR orotracheal OR nasotracheal OR endobronchial): ti,ab) AND ((intubat* OR tube OR tubes OR cannula OR cannulas OR cannulae): ti,ab OR [mh Cannula])	TS=((trachea OR tracheas OR tracheal OR endotracheal OR intratracheal OR orotracheal OR nasotracheal OR endobronchial) AND (intubat* OR tube OR tubes OR cannula OR cannulas OR cannulae))	(trachea OR tracheas OR tracheal OR endotracheal OR intratracheal OR orotracheal OR nasotracheal OR endobronchial) AND (intubat* OR tube OR tubes OR cannula OR cannulas OR cannulae)
#3 #1 OR #2	#1 OR #2	#1 OR #2		
#4 Videotape Recording[mh] OR Video Recording[mh] OR video [tiab] OR videotape*[tiab] OR videodisc [tiab] OR videodisk [tiab] OR videorecord*[tiab] OR camcorder*[tiab] OR camera [tiab] OR audio-visual record*[tiab]	videorecording/exp OR videorecorder/exp OR videotape/exp OR 'video disk'/exp OR 'audiovisual recording'/exp OR (video OR videodisc OR videodisk OR videorecord* OR camcorder* OR camera OR audio-visual record*): ti,ab	[mh "Video Recording"] OR [mh "Videotape Recording"] OR (video OR videotape* OR videodisc OR videodisk OR videorecord* OR camcorder* OR camera OR audio-visual recording*): ti,ab	TS=(video OR videotape* OR videodisc OR videorecord* OR camcorder* OR camera OR cameras OR "audio-visual record*")	(video OR videotape* OR videodisc OR videorecord* OR camcorder* OR camera OR cameras OR "audio-visual record*")

(continued)

## Continued

	PubMed	Embase	Cochrane	WoS	KoreaMed
#5	ETView[ <i>tw</i> ] OR ET:View[ <i>tw</i> ] OR VivaSight[ <i>tw</i> ] OR Blue Line[ <i>tw</i> ] OR Endoflex[ <i>tw</i> ] OR Fastrach[ <i>tw</i> ] OR Flex-Tip[ <i>tw</i> ] OR Guedel[ <i>tw</i> ] OR Super Safety[ <i>tw</i> ] OR Teleflex Isis HVT[ <i>tw</i> ] OR Parker Flex-Tip[ <i>tw</i> ]	ETView OR ET:View OR VivaSight OR 'Blue Line' OR Endoflex OR Fastrach OR Flex-Tip OR Guedel OR 'Super Safety' OR 'Teleflex Isis HVT' OR 'Parker Flex-Tip'	ETView OR ET:View OR VivaSight OR "Blue Line" OR Endoflex OR Fastrach OR Flex-Tip OR Guedel OR "Super Safety" OR "Teleflex Isis HVT" OR "Parker Flex-Tip"	TS=(ETView OR ET-View OR VivaSight OR "Blue Line" OR Endoflex OR Fastrach OR Flex-Tip OR Guedel OR "Super Safety" OR "Teleflex Isis HVT" OR "Parker Flex-Tip")	(ETView OR ET:View OR VivaSight OR "Blue Line" OR Endoflex OR Fastrach OR Flex-Tip OR Guedel OR "Super Safety" OR "Teleflex Isis HVT" OR "Parker Flex-Tip")
#6	videolaryngoscop*[ <i>tiab</i> ] OR videolaryngoscop*[ <i>tiab</i> ] OR VL[ <i>tiab</i> ] OR VLS[ <i>tiab</i> ] OR VDLT[ <i>tiab</i> ] #4 OR #5 OR #6	videolaryngoscope/exp OR (videolaryngoscop* OR videolaryngoscop* OR VL OR VLS OR VDLT): <i>ti,ab</i> #4 OR #5 OR #6	(videolaryngoscop* OR videolaryngoscop* OR VL OR VLS OR VDLT): <i>ti,ab</i> #4 OR #5 OR #6	TS=(videolaryngoscop* OR videolaryngoscop* OR VL OR VLS OR VDLT) #4 OR #5 OR #6	(videolaryngoscop* OR videolaryngoscop* OR VL OR VLS OR VDLT)
#7	Manikins[ <i>mh</i> ] OR Cadaver [mh] OR manikin*[ <i>tiab</i> ] OR mannequin*[ <i>tiab</i> ] OR cadaver*[ <i>tiab</i> ] OR corpse*[ <i>tiab</i> ] OR dummy[ <i>tiab</i> ] OR dummies[ <i>tiab</i> ] OR Simulation Training[ <i>mh</i> ] OR simulac*[ <i>tiab</i> ]	manikin/exp OR cadaver/exp OR simulation/exp OR (manikin* OR mannequin* OR cadaver* OR corpse* OR dummy OR dummies OR simulac*): <i>ti,ab</i>	[mh Manikins] OR [mh Cadaver] OR [mh "Simulation Training"] OR (manikin* OR mannequin* OR cadaver* OR corpse* OR dummy OR dummies OR simulac*): <i>ti,ab</i>	#4 OR #5 OR #6 TS=(manikin* OR mannequin* OR cadaver* OR corpse* OR dummy OR dummies OR simulac*)	(manikin* OR mannequin* OR cadaver* OR corpse* OR dummy OR dummies OR simulac*)
#9	#3 AND #7 AND #8	#3 AND #7 AND #8	#3 AND #7 AND #8	#2 AND #7 AND #8	(#2 AND #4) OR (#2 AND #5) OR (#2 AND #6) OR (#2 AND #8)
#10	Animals[ <i>mh</i> ] NOT (Humans [mh] AND Animals[ <i>mh</i> ])	Animal/exp NOT (Human/exp AND Animal/exp)			
#11	#9 NOT #10	#9 NOT #10			

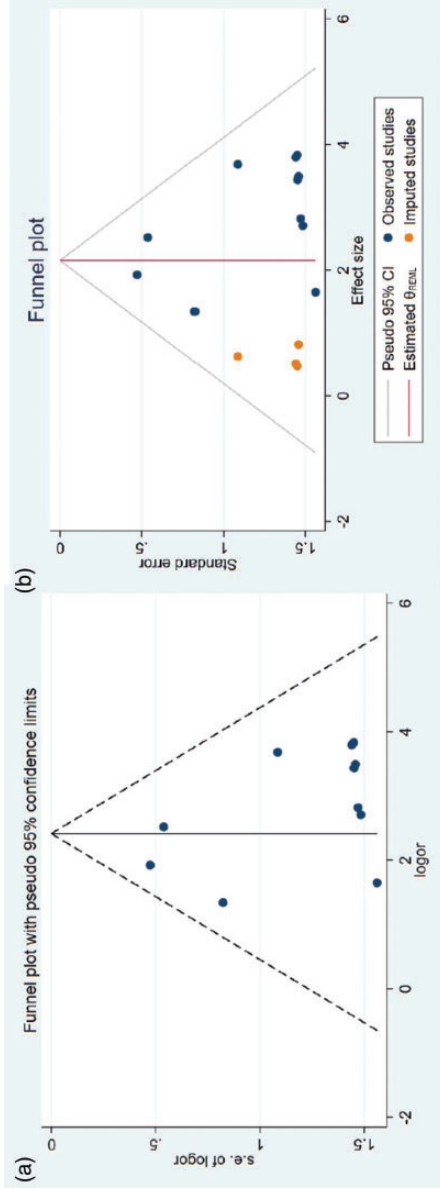
WoS, Web of Science

**Appendix 2. Subgroup analysis of first-attempt success rate in physicians and non-physicians.**

Subgroup	Outcome (number of trials) [number of scenarios]	No. of intubations (event: failure/total)		Odds ratio or MD (95% CI)	I <sup>2</sup> (%)	P value	Model	References
		ETView	cETT					
Physician	First-attempt success rate	6/350	135/350	0.03 (0.01 to 0.10)	30	<0.001	M-H, random	14,15,22,23
	Scenario A [n=2]	0/157	30/157	0.03 (0.00 to 0.19)	0	0.004		14,15,
	Scenario B [n=2]	5/164	88/164	0.02 (0.00 to 0.70)	82	<0.001		14,23
	Scenario C [n=1]	1/29	17/29	0.03 (0.00 to 0.21)	N/A	<0.001		22
	Intubation time	350	350	-13.08 (-16.37 to -9.78)	95	<0.001	IV, random	14,15,22,23
	Scenario A [n=2]	157	157	-9.32 (-10.24 to -8.41)	54	<0.001		14,15,
	Scenario B [n=2]	164	164	-16.97 (-20.89 to -13.05)	84	<0.001		14,23
	Scenario C [n=1]	29	29	-13.00 (-17.33 to -8.67)	N/A	<0.001		22
Non-physician	1st attempt success rate	21/666	203/666	0.06 (0.03 to 0.12)	16	<0.001	M-H, random	11-13,18-21
	Scenario A [n=2]	0/119	9/119	0.10 (0.01 to 0.84)	0	0.02		11,12
	Scenario B [n=2]	14/97	47/97	0.10 (0.03 to 0.42)	26	<0.001		11,21
	Scenario C [n=3]	3/242	89/242	0.02 (0.01 to 0.07)	0	<0.001		11-13
	Scenario D [n=4]	4/208	58/208	0.07 (0.02 to 0.23)	31	<0.001		13,18-20
	Intubation time	666	666	-11.01 (-14.45 to -7.57)	96	<0.001	IV, random	11-13,18-21
	Scenario A [n=2]	119	119	-2.45 (-3.56 to -1.34)	0	<0.001		11,12
	Scenario B [n=2]	97	97	-9.71 (-17.53 to -1.89)	90	0.01		11,21
Scenario C [n=3]	242	242	-10.50 (-16.72 to -4.27)	96	0.001		11-13	
Scenario D [n=4]	208	208	-16.82 (-22.67 to -10.97)	89	<0.001		13,18-20	

ETView, ETView VivaSight single lumen; cETT, conventional endotracheal tube; MD, mean difference; CI, confidence interval; Scenario A, normal airway at rest without chest compression; Scenario B, normal airway at rest with chest compression; Scenario C, cervical stabilization at rest without chest compression; Scenario D, difficult situation without chest compression; M-H, Mantel-Haenszel; IV, inverse variation; N/A, not applicable.

**Appendix 3. Funnel plots of first-attempt success rate, with precision rate (vertical axis) plotted against effect size (horizontal axis). OR, odds ratio; SE(log[OR]), standard error of the log odds ratio.**



(A) Funnel plot of observed data from studies.

(B) Funnel plot after application of trim and fill method; observed data from studies with imputed study data