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REPORTS OF ORIGINAL INVESTIGATIONS

# Glidescope® video-laryngoscopy versus direct laryngoscopy for endotracheal intubation: a systematic review and meta-analysis

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**Abstract**

**Introduction** *The Glidescope® video-laryngoscopy appears to provide better glottic visualization than direct laryngoscopy. However, it remains unclear if it translates into increased success with intubation.*

**Methods** *We systematically searched electronic databases, conference abstracts, and article references. We included trials in humans comparing Glidescope® video-laryngoscopy to direct laryngoscopy regarding the glottic view, successful first-attempt intubation, and time to intubation. We generated pooled risk ratios or weighted mean differences across studies. Meta-regression was used to explore heterogeneity based on operator expertise and intubation difficulty.*

**Results** *We included 17 trials with a total of 1,998 patients. The pooled relative risk (RR) of grade 1 laryngoscopy (vs $\geq$ grade 2) for the Glidescope® was 2.0 [95% confidence interval (CI) 1.5 to 2.5]. Significant heterogeneity was partially explained by intubation difficulty using meta-regression analysis ($P = 0.003$). The pooled RR for nondifficult intubations of grade 1 laryngoscopy (vs $\geq$ grade 2) was 1.5 (95% CI 1.2 to 1.9), and for difficult intubations it was 3.5 (95% CI 2.3 to 5.5). There was no difference between the Glidescope® and the direct laryngoscope regarding successful first-attempt intubation or time to intubation, although there was significant heterogeneity in both of these outcomes. In the two studies examining nonexperts, successful first-attempt intubation (RR 1.8, 95% CI 1.4 to 2.4) and time to intubation (weighted mean difference −43 sec, 95% CI −72 to −14 sec) were improved using the Glidescope®. These benefits were not seen with experts.*

**Conclusion** *Compared to direct laryngoscopy, Glidescope® video-laryngoscopy is associated with improved*

**Author contributions** *Donald E.G. Griesdale* was the principle investigator and responsible for the concept and design of the study. He had access to all of the data and takes full responsibility for the integrity of the data and the accuracy of the data analysis. He was also involved in interpretation of the data and drafting of the manuscript. He has no conflicts of interest and approves of the final submitted version of the manuscript. *David Liu* was involved in the design of the study. He was also involved in acquisition, abstraction, and interpretation of the data. He also helped draft and critically revised the manuscript. He has no conflicts of interest and approves of the final submitted version of the manuscript. *James McKinney* was involved in the design of the study. He was also involved in acquisition, abstraction, and interpretation of the data. He helped critically revise the manuscript. He has no conflicts of interest and approves of the final submitted version of the manuscript. *Peter Choi* was involved in the design of the study. He was involved in interpretation of the data and helped draft the manuscript. He also revised the manuscript prior to submission. He has no conflicts of interest and approves of the final submitted version of the manuscript.

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*glottic visualization, particularly in patients with potential or simulated difficult airways.*

**Résumé**

**Introduction** *Le vidéolaryngoscope Glidescope® semble procurer une meilleure visualisation de la glotte que la laryngoscopie directe. Il n'est toutefois pas certain que cela se traduise par une meilleure réussite des intubations.*

**Méthodes** *Nous avons fait une recherche systématique dans les bases de données électroniques, parmi les résumés de congrès et les références d'articles. Nous avons inclus les études chez l'homme comparant le vidéolaryngoscope Glidescope® à la laryngoscopie directe pour ce qui concerne la visualisation de la glotte, la réussite de l'intubation au premier essai et le délai d'intubation. Nous avons généré un risque relatif global ou des différences moyennes pondérées entre les études. Une métarégression a permis d'explorer l'hétérogénéité en fonction de l'expertise de l'opérateur et de la difficulté d'intubation.*

**Résultats** *Nous avons inclus 17 études incluant un total de 1998 patients. Le risque relatif (RR) global d'une laryngoscopie de grade 1 (contre une laryngoscopie de grade $\geq 2$) avec le Glidescope® a été de 2,0 (intervalle de confiance [IC] à 95 % : 1,5 à 2,5). L'hétérogénéité significative a été expliquée en partie par la difficulté d'intubation en utilisant l'analyse par métarégression ($P = 0{,}003$). Le RR global pour les intubations non difficiles de grade 1 à la laryngoscopie (contre les grades $\geq 2$) a été de 1,5 (IC à 95 % : 1,2 à 1,9) et le RR pour les intubations difficiles a été de 3,5 (IC à 95 % : 2,3 à 5,5). Il n'y a pas eu de différence entre le Glidescope® et la laryngoscopie directe pour ce qui concerne l'intubation réussie au premier essai ou pour le délai d'intubation, bien qu'une hétérogénéité significative ait été observée pour ces deux critères d'évaluation. Dans les deux études impliquant des non-experts, la première tentative réussie d'intubation (RR: 1,8; IC à 95 % : 1,4 à 2,4) et le délai d'intubation (différence de moyenne pondérée −43 sec; IC à 95 % : −72 à −14 sec) ont été améliorés par l'utilisation du Glidescope®. Ces avantages n'ont pas été retrouvés chez les experts.*

**Conclusion** *Comparée à la laryngoscopie directe, la vidéolaryngoscopie avec le Glidescope® est associée à une amélioration de la visualisation de la glotte, en particulier chez les patients avec des voies aériennes difficiles potentielles ou simulées.*

Anesthesiologists perform endotracheal intubation (ETI) in the operating room under controlled circumstances, and the procedure carries a low risk of complications.[1] Although laryngoscopy is difficult in 6-10% of intubations,[2-4] difficult or failed intubations are much less frequent, occurring in 1.8-5.8% and 0.13-0.30%, respectively.[2,5-8] Unfortunately, physical findings on examination of the airway discriminate poorly between potentially easy and difficult intubations.[9] Thus, anesthesiologists need to be prepared for the unanticipated difficult airway, as many of these patients have had a "reassuring" airway physical examination. In addition to the unanticipated difficult airway, there are circumstances that lend themselves to a high risk of difficult laryngoscopy and tracheal intubation. In particular, emergent ETI outside of the operating theatre is associated with a much higher risk of difficult laryngoscopy and intubation.[10-13] As such, techniques that may improve successful intubation may be especially beneficial in these emergent environments. Laryngoscopy with the Glidescope® video-laryngoscope (Verathon Medical, Bothell, WA, USA) appears to be associated with improved glottic visualization.[14,15] Whether the improved visualization translates into increased success at ETI, when compared to direct laryngoscopy, remains unclear.[14,16] Given this uncertainty, our goal was to perform a systematic review and meta-analysis of randomized and quasi-randomized trials comparing Glidescope® video-laryngoscopy to direct laryngoscopy regarding glottic visualization, successful first-attempt intubation, and time to intubation. In addition, we explored the heterogeneity in these outcomes based on operator expertise and according to the difficulty of the intubation.

## Methods

This article reports our meta-analysis of controlled trials of Glidescope® video-laryngoscopy compared to direct laryngoscopy in accordance with the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) statement.[17] A review protocol was not published for this study.

### Search strategy

We systematically searched MEDLINE (1966 to June 13, 2011), EMBASE (1977 to June 13, 2011), and The Cochrane Central Register of Controlled Trials (CENTRAL) (1948 to June13, 2011) for randomized and quasi-randomized trials comparing Glidescope® video-laryngoscopy to direct laryngoscopy regarding the glottic view, successful first-attempt intubation, and time to intubation. We included non-English publications. We hand-searched abstracts of selected conferences from 2000 to 2010, including those of the American Society of Anesthesiologists, the Canadian Anesthesiologists' Society, and the International Anesthesia Research Society. We also hand-searched bibliographies of all relevant trials and review articles.

For the bibliographic review, we constructed search filters for the concepts "Glidescope video-laryngoscope" and "clinical trials" using a combination of exploded Medical Subject Heading (MeSH) terms and text words all combined with the Boolean operator "OR." The Glidescope® video-laryngoscope filter contained the text words *glidescope* and *video-laryngoscope*. The clinical trials filter included the MeSH terms *clinical trials [publication type], clinical trials as topic, placebos* with text words *trial*, random** or *placebo*. A similar search strategy was used for both EMBASE and CENTRAL.

### Selection criteria, data abstraction, and methodological quality

In duplicate and independently, two authors (D.G., D.L.) screened all articles and abstracts, which were included if they 1) were randomized or quasi-randomized controlled trials, 2) compared direct laryngoscopy to Glidescope® video-laryngoscopy, 3) addressed adult patients, and 4) contained any outcome of interest (Cormack-Lehane view,[18] successful first-attempt intubation, time to intubation).

The same two authors abstracted the data and assessed the study quality in duplicate and independently. Disagreement was resolved by discussion and arbitrated if necessary by a third author (P.C.). We abstracted the year of publication, sample size, country of origin, operator training and experience, physical examination of the airway, anticipated or history of difficult intubation, application of manual in-line stabilization, Cormack-Lehane grade, successful first attempt at intubation, and time required to intubate. We contacted investigators for missing data as necessary.

### Statistical analysis

We used relative risk (RR) as the summary measure for dichotomous outcomes (glottic view and successful first intubation attempt) and the weighted mean difference (WMD), in seconds, as the summary measure for time to intubate. We applied a half-integer continuity correction to all four cells if the event rates were zero. The random effects method of DerSimonian and Laird was used to generate a pooled RR or WMD across studies.[19] Random effects analysis yields a more conservative estimate than the fixed-effects model in the presence of between-study heterogeneity. We assessed statistical heterogeneity using Cochran's $Q$ statistic[20] (with $P < 0.10$ considered significant) and expressed the quantity using the $I^2$ statistic and 95% confidence interval (CI). The $I^2$ statistic indicates the percentage of variation in study results that is due to between-study heterogeneity rather than sampling variability.[21] We assessed for the following outcomes: Cormack-Lehane view grade 1 *vs* grade $\geq 2$, successful first-attempt intubation, and time to intubate (in seconds).

Sources of potential heterogeneity identified *a priori* were the experience level of the operator (anesthesia or casualty consultants or house staff *vs* "other") and potential difficulty. Intubations were considered difficult in studies that included patients with a known prior difficult intubation, physical examination features suggesting a difficult intubation, or in whom difficult intubation was simulated by providing manual-in-line stabilization. Random-effects meta-regression was used to evaluate the relation between these subgroups on the final pooled estimates.[22] We evaluated the presence of publication bias by visual inspection of the funnel plot and by using Egger's and Begg's tests, with $P < 0.05$ considered statistically significant. All analyses were done using Stata 10.0 (2007) (StataCorp LP, College Station, TX, USA).

## Results

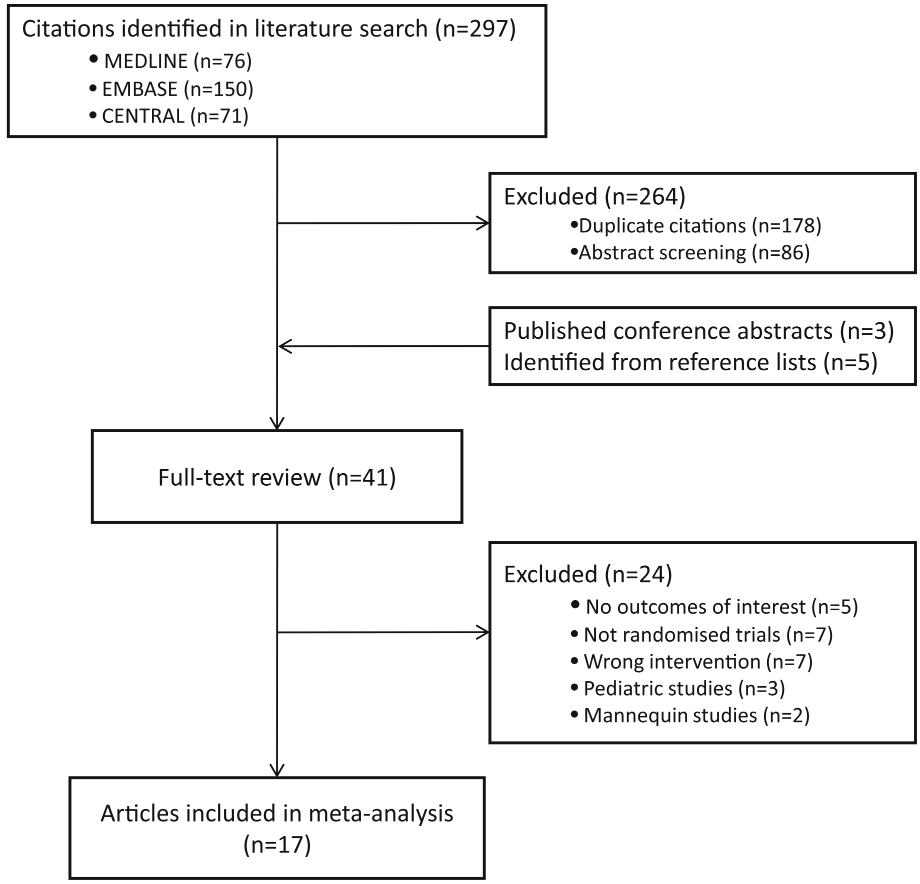
### Literature search

A total of 297 citations were identified during the bibliographic search: 76 from MEDLINE, 150 from EMBASE, and 71 from CENTRAL. We excluded 264 citations on the initial abstract screen (178 duplicate citations, 86 from screening). We identified three published abstracts from conference screening and five citations from reference lists. This resulted in 41 citations for full text review. The exclusion of 24 citations (for reasons listed in Fig. 1) resulted in 17 trials being included in the current analysis.[14-16,23-36] We contacted one author, who provided the raw data for the number of attempts required for intubation, which was not included in the published article.[25]

### Study characteristics

Table 1 lists the trial characteristics. Of the 17 included trials with a total of 1,998 subjects, three were published abstracts.[33-35] One trial was published in Japanese.[36] Although most of the studies randomized subjects to Glidescope® video-laryngoscopy *vs* direct laryngoscopy, in four studies subjects underwent both techniques sequentially, with the order of the techniques allocated randomly.[24,29,31,33] The operators in most of the studies were anesthesiologists experienced with both techniques. There were two studies in which the primary operators were inexperienced personnel consisting of nonanesthesia house staff[36] or trainees consisting of paramedics, nurses,

**Fig. 1** Study selection flow chart




and medical students.[14] Although the trial by Jones and colleagues included anesthesia consultants and residents, only 39% were experienced with the Glidescope® (≥ 10 intubations).[16] In contrast to all the other studies of elective patients in the operating theatre, the trial by Yeatts *et al.* examined patients presenting to the casualty department.[35]

Most of the studies specifically excluded patients with a known or anticipated difficult airway.[14,16,23,25,27,28,30-34] In contrast, two studies selected patients with clinical examination features suggesting a difficult intubation.[24,26] Five studies attempted to increase the difficulty of laryngoscopy by applying manual in-line stabilization.[23,28,29,31,34] Finally, three studies did not specify any exclusion or inclusion criteria based on prior or anticipated difficulty of laryngoscopy.[15,35,36]

Grade 1 glottic view

Twelve studies presented outcomes corresponding to our primary outcome, glottis visualization (Table 2).[14-16,23,24,26-29,32-34] A forest plot is presented in Fig. 2. The pooled RR across all studies was 2.0 (95% CI 1.5 to 2.5, $P < 0.001$), indicating improved glottic visualization using the Glidescope® when compared to the direct laryngoscope. There was significant between-study heterogeneity in our primary analysis ($Q = 74.8$, $df = 11$, $P < 0.001$), with a corresponding $I^2$ statistic of 85% (95% CI 76 to 91). Only one study used inexperienced operators[14]; thus, we were unable to explore heterogeneity by expertise. We examined for effect modification by anticipated or simulated difficult laryngoscopy (manual in-line stabilization). Meta-regression demonstrated that the benefit to glottic visualization afforded by Glidescope® was even more pronounced in studies that considered patients with anticipated or simulated difficult airways ($P = 0.003$). The resultant pooled estimates were as follows: for non-difficult intubations (RR 1.5, 95% CI 1.2 to 1.9) and for difficult intubations (RR 3.5, 95% CI 2.3 to 5.5). Visual inspection of the funnel plot revealed an absence of small studies favouring direct laryngoscopy (not shown). This publication bias was confirmed on Begg's ($P = 0.04$) and Egger's ($P = 0.07$) regression testing.

Successful first-attempt intubation

Fourteen studies presented data on intubation success (Table 2).[14-16,23-28,30,32,33,35,36] A forest plot is presented in Fig. 3. The pooled RR across studies was 1.1 (95% CI 0.99 to 1.2, $P = 0.09$). There was significant between-study heterogeneity ($Q = 117.12$, $df = 13$, $P < 0.001$), with a

**Table 1** Characteristics of randomized and quasi-randomized trials comparing Glidescope® video-laryngoscopy to direct laryngoscopy

| First author, year | Country of origin | No. of patients | Total no. patients randomized | Operators | Patients | Mallampati I/II/III/IV (%) | Setting |
|---|---|---|---|---|---|---|---|
| Bilehjani 2009[32] | Iran | 80 | DL 40<br>GS 40 | Anesthesiologists | Excluded MP III-IV or history of DI | 59/36/5/0 | ASA I-III<br>Elective CABG surgery |
| Jones 2008[16] | Canada | 70 | DL 35<br>GS 34 | Anesthesiologist consultants 39%<br>House staff 61%<br>Experienced ($\geq$ 10 GS intubations) 39% | Excluded if history of DI | 63/30/8/0 | Elective dental or maxillofacial surgery |
| Lim 2005[23] | Singapore | 60 | DL 30<br>GS 30 | Anesthesiologists with varying experience with the GS | ASA I + II patients<br>Excluded patients with a potentially difficult airway or MP III/IV<br>Patients maintained in manual in-line stabilization | 85/15/0/0 | ASA I and II patients admitted for elective gynecological procedures |
| Malik 2008[28] | Ireland | 60 | DL 30<br>Truview EVO2 30<br>GS 30<br>AWS 30 | Anesthesiologists experienced with each device ($\geq$ 20 clinical intubations) | Excluded if (1) history of DI or (2) features suggestive of DI (MP III/IV, TMD < 6.0 cm, IID < 3.5 cm)<br>Manual in-line stabilization applied | 38/62/0/0 | ASA I-III. Any surgical procedure requiring intubation |
| Malik 2009[26] | Ireland | 50 | DL 25<br>GS 25<br>AWS 25 | Anesthesiologists experienced with each device ($\geq$ 50 clinical intubations) | At least two features of DI (TMD < 6 cm, MP III/ IV, IID < 4 cm) | 0/0/80/20 | ASA I-III. Any surgical procedure requiring intubation |
| Morello[a] 2009[33] | Italy | 300 | DL 150<br>GS 150<br>All patients had examinations with both | Skilled anesthesiologist | No signs of predicted DI | | ASA I-III patients |
| Nouruzi-Sedeh 2009[14] | Germany | 200 | DL 100<br>GS 100<br>Each operator performed 5 intubations with each technique | Inexperienced trainees: 8 paramedics, 4 first-year house staff, 4 nurses, 4 medical students | No history of signs of DI<br>MP I or II, mouth opening > 4 cm | 120/80/0/0 | ASA I or II undergoing elective surgery requiring ETI |
| Robitaille 2008[29] | Canada | 20 | All 20 patients had laryngoscopy with DL and GS (in randomized order) | Two senior anesthesiology house staff ($\geq$ 30 GS intubations) | Patients maintained in manual in-line stabilization | 7/12/1/0 | Elective neuroradiological procedure |
| Serocki 2010[24] | Germany | 120 | All 120 patients had laryngoscopy with each device (in randomized order) | Two anesthesiology consultants with $\geq$ 50 intubations with each device | At least one predictor of difficult airway (MP $\geq$ II, decreased atlantooccipital joint movement $\leq$ 15°, mouth opening $\leq$ 38 mm, TMD $\leq$ 65 mm) | 0/68/49/3 | ASA I-III elective patients |

**Table 1** continued

| First author, year | Country of origin | No. of patients | Total no. patients randomized | Operators | Patients | Mallampati I/II/III/IV (%) | Setting |
|---|---|---|---|---|---|---|---|
| Shimada 2010[36] | Japan | 40 | GS 20<br>DL 20 | Nonanesthesia house staff | Nasotracheal intubation | NR | Elective dental surgery |
| Siddiqui 2009[25] | Canada | 40 | DL 20<br>GS 20<br>TL 20 | Single anesthesiologist with $\geq$ 50 intubations with each device | Excluded patients with a history of anticipated/difficult airway, or MP III/IV | NR | ASA I and II patients scheduled for elective surgery |
| Sun 2005[15] | Canada | 200 | GS 100<br>DL 100 | 5 Experienced anesthesiologists (> 10 years practice) and > 20 GS intubations) | No exclusions based on known or anticipated difficulty | 51/39/10/1 | ASA I-IV. Elective operating room patients |
| Teoh 2009[27] | Singapore | 200 | Pentax AWS 100<br>C-MAC 100<br>GS 100<br>DL 100 | Experienced anesthesiologists with > 30 intubations with each device | Excluded patients with BMI > 40 and those with limited mouth opening | 37/39/23/3 | ASA I-III. Elective gynecological, orthopedic, breast, or esthetic surgery |
| Turkstra 2005[31] | Canada | 18 | All 18 patients had both GS and DL (in random order) | One anesthesiologist who performed > 50 intubations with each device | Excluded: BMI > 35, prior neck surgery, or difficult airway<br>In-line stabilization maintained | 44/44/6/6 | ASA I-III elective noncardiac surgery |
| Vernick[a] 2006[34] | USA | 78 | GS 39<br>DL 39 | Not reported | Excluded: BMI > 35, prior difficult intubation<br>In-line stabilization maintained | Not reported | |
| Xue 2007[30] | China | 57 | GS 30<br>DL 27 | One anesthesiologist experienced in GS and DL | Excluded patients with predicted difficult airways | | ASA I patients for elective plastic surgery |
| Yeatts[a] 2010[35] | USA | 405 | GS 200<br>DL 205 | Anesthesiology and emergency medicine house staff | | | Patients requiring emergent airway management at a level 1 trauma center |

ASA = American Society of Anesthesiologists; BMI = body mass index; CABG = coronary artery bypass graft; DI = difficult intubation; DL = direct laryngoscopy; ETI = endotracheal intubation; GS = Glidescope®; IID = interincisor distance; MP = Mallampati; TMD = thyromental distance

[a] Published as an abstract

**Table 2** Outcomes of randomized and quasi-randomized trials comparing Glidescope® video-laryngoscopy to direct laryngoscopy

| First author, year | Cormack-Lehane I/II/III/IV (no.) | | Successful 1st intubation attempt (event/total patients) | | Time to intubation (sec) (SD or IQR) | |
|---|---|---|---|---|---|---|
| | Glidescope® | Direct laryngoscope | Glidescope® | Direct laryngoscope | Glidescope® | Direct laryngoscope |
| Bilehjani 2009[32] | 36/4/0/0 | 30/7/1/0 | 29/40(73%) | 35/38 (92%) | 48.8 (47.8) | 14.5 (8.3) |
| Jones 2008[16] | 32/2/0/0 | 23/11/1/0 | 33/34(97%) | 32/35 (91%) | 43.5 (39.8-67.3) | 66.7 (53.8-89.9) |
| Lim 2005[23] | 20/10/0/0 | 4/18/8/0 | 28/30 (93%) | 26/30 (87%) | 41.8 (20.2) | 56.2 (26.6) |
| Malik 2008[28] | 21/9/0/0 | 6/19/5/0 | 28/30 (93.3%) | 26/30 (87.6%) | 18.9 (6.0) | 11.6 (6.0) |
| Malik 2009[26] | 22/3/0/0 | 2/15/6/2 | 22/25 (88%) | 17/25 (68%) | 17 (12-31) | 13 (8-23) |
| Morello[a] 2009[33] | 239/61/0/0 | 128/152/20/0 | 134/150 (89%) | 95/150 (63%) | NR | NR |
| Nouruzi-Sedeh 2009[14] | 66/26/5/3 | 32/18/37/13 | 93/100 (93%) | 51/100 (51%) | 63 (30) | 89 (35) |
| Robitaille 2008[29] | 10/10/0/0[c] | 0/19/1/0[c] | NR | NR | NR | NR |
| Serocki 2010[24] | 43/75/2/0 | 10/74/35/1 | 38/40 (95%) | 35/40 (88%) | 13 (11-15) | 13 (11-16) |
| Shimada 2010[36] | NR | NR | 20/20 (100%) | 11/20 (55%) | 57 (22) | 141 (79) |
| Siddiqui 2009[25] | NR | NR | 16/20 (80%) | 18/20 (90%) | 30.9 (9) | 13.9 (7.8) |
| Sun 2005[15] | 75/24/1/0[b] | 59/26/15/0[b] | 94/100 (94%) | 97/100 (97%) | 46 (43-49) | 30 (28-33) |
| Teoh 2009[27] | 78/21/1/0 | 58/37/5/0 | 91/100 (91%) | 98/100 (98%) | 31.2 (15) | 22.4 (13.6) |
| Turkstra 2005[31] | NR | NR | NR | NR | 27 (12) | 17 (8) |
| Vernick[a] 2006[34] | Gr 1 or 2: 37/39 | Gr 1 or 2: 17/39 | NR[d] | NR[d] | 56.9 (25.8) | 39.1 (10.5) |
| Xue 2007[30] | NR | NR | 28/30 | 27/27 | 37.4 (9.9) | 28.4 (11.7) |
| Yeatts[a] 2010[35] | NR | NR | 150/200 | 154/205 | 69 (61.6-76.4) | 57 (50.3-63.7) |

DL = direct laryngoscopy; GS = Glidescope®; IQR = interquartile range; NR = not reported; SD = standard deviation

[a] Published as an abstract

[b] These were all patients ($n$ = 100) randomized to the GS group who underwent both GS and DL. The assessors for DL and GS were not involved in the patients' care and were not present during each other's assessment

[c] Each patient served as their own controls, randomized to first look with either GS or DL

[d] Although they reported "success," this was based entirely on view rather than actual success. If they did not have an adequate view, they did not attempt laryngoscopy, and it was recorded as a failed procedure

corresponding $I^2$ statistic of 89% (95% CI 83 to 93). Two studies presented data on inexperienced operators,[14,36] and meta-regression demonstrated effect modification by operator expertise ($P = 0.001$). Compared to the direct laryngoscope, the Glidescope® increased the success of first intubation attempts in studies with nonexpert operators (RR 1.8, 95% CI 1.4 to 2.4) but not amongst airway experts (RR 1.0, 95% CI 0.94 to 1.20). There was no effect measure modification by potential or simulated difficult airways ($P = 0.89$). There was no evidence of publication bias on this outcome by Begg's ($P = 0.38$) or Egger's ($P = 0.86$) testing.

Time to intubation

The time required to intubate was available in 15 studies (Table 2).[14-16,23-28,30-32,34-36] A forest plot is presented in Fig. 4. The pooled WMD across studies did not differ between Glidescope® video-laryngoscopy and direct laryngoscopy (WMD 3.8 sec, 95% CI −1.7 to 9.3 sec, $P = 0.17$). However, there was significant between-study heterogeneity in these results ($Q = 675.7$, $df = 14$, $P < 0.001$) with an $I^2$ statistic of 98% (95% CI 97 to 98) that was not explained by the difficulty of the intubation on meta-regression ($P = 0.85$). Meta-regression did demonstrate that operator expertise explained some of the between-study heterogeneity observed ($P = 0.004$), with the Glidescope® being associated with a shorter time to intubation in the two studies with nonexperts as the primary operators (WMD −43 sec, 95% CI −72 to −14 sec). There was no difference in time to intubation amongst experts (WMD 8 sec, 95% CI −2 to 17 sec). There was no effect measure modification by airway difficulty on meta-regression ($P = 0.74$). There was no evidence of publication bias on this outcome by Begg's ($P = 0.18$) or Egger's ($P = 0.96$) testing.

## Discussion

In this meta-analysis of randomized trials comparing Glidescope® video-laryngoscopy to direct laryngoscopy, the former was associated with improved glottic visualization, particularly amongst studies that considered

CL Grade 1 (event / total patients)

| Author, Year | Glidescope® | Direct Laryngoscope | RR (95% CI) | Weight (%) Random-Effects |
|---|---|---|---|---|
| **Non-difficult intubations** | | | | |
| Sun 2005[15] | 75 / 100 | 59 / 100 | 1.27 (1.04, 1.55) | 17.28 |
| Jones 2008[16] | 32 / 34 | 23 / 35 | 1.43 (1.11, 1.85) | 15.54 |
| Bilehjani 2009[32] | 36 / 40 | 30 / 38 | 1.14 (0.94, 1.38) | 17.43 |
| Morello 2009[33] | 239 / 300 | 128 / 300 | 1.87 (1.62, 2.15) | 18.90 |
| Nouruzi-Sedeh 2009[14] | 66 / 100 | 32 / 100 | 2.06 (1.50, 2.84) | 13.51 |
| Teoh 2010[27] | 78 / 100 | 58 / 100 | 1.34 (1.10, 1.64) | 17.35 |
| ***All non-difficult intubations*** ($I^2$= 81.5%, p < 0.001) | 526 / 674 | 330 / 673 | 1.47 (1.15, 1.89) | 100.00 |
| **Difficult intubations** | | | | |
| Lim 2005[23] | 20 / 30 | 4 / 30 | 5.00 (1.94, 12.89) | 16.40 |
| Malik 2008[28] | 21 / 30 | 6 / 30 | 3.50 (1.65, 7.43) | 19.76 |
| Robitaille 2008[29] | 10 / 20 | 0 / 20 | 21.00 (1.31, 335.74) | 3.64 |
| Serocki 2010[24] | 43 / 120 | 10 / 120 | 4.30 (2.27, 8.15) | 21.90 |
| Malik 2009[26] | 22 / 25 | 2 / 25 | 11.00 (2.89, 41.89) | 11.23 |
| Vernick 2009[34] | 37 / 39 | 17 / 39 | 2.18 (1.51, 3.13) | 27.07 |
| ***All difficult intubations*** ($I^2$= 64.1%, p = 0.016) | 153/ 264 | 39 / 264 | 3.52 (2.26, 5.48) | 100.00 |
| **All patients** ($I^2$= 85.3%, p < 0.001) | 679 / 938 | 369 / 937 | 1.97 (1.54, 2.52) | |

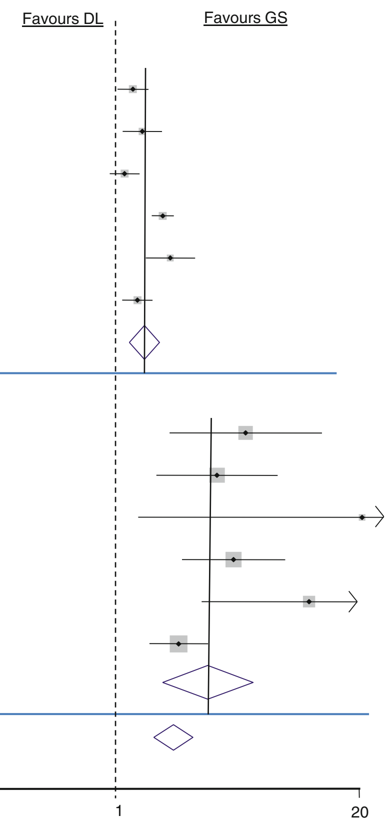



**Fig. 2** Risk ratios (RR) of Cormack-Lehane (CL) grade 1 (*vs* ≥ grade 2) in clinical trials comparing Glidescope® video-laryngoscopy to direct laryngoscopy stratified by the difficulty of the intubation. Subjects were considered to have difficult intubations in studies that included patients with known prior difficult intubation, physical examination features suggesting difficult intubation, or in which difficult intubation was simulated by providing manual-in-line stabilization. The pooled estimate was derived using the DerSimonian and Laird random effects method with grey squares depicting individual study point estimates of the RR. Larger squares indicate a larger weight of the study when calculating the pooled estimate. Solid horizontal lines display the 95% confidence interval (CI) of the point estimate. Dashed vertical line represents an RR of 1.00, indicating no difference between Glidescope® video-laryngoscopy and direct laryngoscopy. Solid vertical lines represent the pooled estimates. Test for heterogeneity was significant using meta-regression analysis ($P = 0.003$). DL = direct laryngoscopy; GS = Glidescope®

patients with potential or simulated difficult airways. Although there was an improved successful first intubation attempt and faster time to intubation with Glidescope® video-laryngoscopy, it was confined to studies of nonexpert operators. There was no benefit in either of these outcomes in studies with expert operators. Importantly, there was marked between-study heterogeneity in all three outcomes.

Improved glottic visualization (compared to that with direct laryngoscopy) is a consistent finding with nonstandard laryngoscopes, including video-laryngoscopes.[37] Building on this, we have demonstrated that improvement in glottic visualization afforded by the Glidescope® is even greater in studies using patients with either simulated (*via* manual in-line stabilization) or physical examination predictors of difficult laryngoscopy. This is not surprising as the Glidescope® appears to be used often by clinicians in these situations. A large observation cohort study by Aziz and colleagues of 2,004 Glidescope® intubations showed that most were performed in patients with clinical examination predictors of a difficult direct laryngoscopy.[38] Thus, clinicians are triaging patients to video-laryngoscopy when difficulty with endotracheal intubation is anticipated.

As in our current review, a prior systematic review demonstrated significant heterogeneity when comparing the Glidescope® results to those achieved with the direct laryngoscope.[37] In contrast, we attempted to quantify and evaluate sources of heterogeneity by both operator expertise and potential difficulty of the intubation. Given that most of the studies were performed by airway management experts on patients without predictors of difficult intubation, it is not surprising that the Glidescope® did not result in improved first-attempt success. Aside from one trial with a markedly low rate of 63%, documented by Morello *et al.*,[33] the rest of the studies with experts—and excluding difficult airways—

Success on 1st attempt (event / total patients)

| Author, Year | Glidescope | Direct Laryngoscope | RR (95% CI) | Weight (%) Random-Effects |
|---|---|---|---|---|
| **Expert intubators** | | | | |
| Lim 2005[23] | 28 / 30 | 26 / 30 | 1.08 (0.91, 1.28) | 7.72 |
| Sun 2005[15] | 94 / 100 | 97 / 100 | 0.97 (0.91, 1.03) | 11.11 |
| Xue 2007[30] | 28 / 30 | 27 / 27 | 0.94 (0.83, 1.05) | 9.50 |
| Jones 2008[16] | 33 / 34 | 32 / 35 | 1.06 (0.94, 1.19) | 9.45 |
| Malik 2008[28] | 28 / 30 | 26 / 30 | 1.08 (0.91, 1.28) | 7.72 |
| Serocki 2010[24] | 38 / 40 | 35 / 40 | 1.11 (0.98, 1.27) | 9.10 |
| Bilehjani 2009[32] | 29 / 40 | 35 / 38 | 0.79 (0.64, 0.97) | 6.45 |
| Malik 2009[26] | 22 / 25 | 17 / 25 | 1.29 (0.95, 1.76) | 4.33 |
| Morello 2009[33] | 134 / 150 | 95 / 150 | 1.41 (1.23, 1.61) | 8.90 |
| Siddiqui 2009[25] | 16 / 20 | 18 / 20 | 0.89 (0.68, 1.16) | 5.18 |
| Yeatts 2010[35] | 150 / 200 | 154 / 205 | 1.00 (0.89, 1.12) | 9.61 |
| Teoh 2010[27] | 91 / 100 | 98 / 100 | 0.93 (0.87, 0.99) | 10.93 |
| ***All expert intubators*** ($I^2$= 79.5%, p < 0.001) | 691 / 799 | 660 / 800 | 1.03 (0.95, 1.12) | 100.00 |
| **Non-expert intubators** | | | | |
| Nouruzi-Sedeh 2009[14] | 93 / 100 | 51 / 100 | 1.82 (1.49, 2.23) | 79.63 |
| Shimada 2010[36] | 20 / 20 | 11 / 20 | 1.78 (1.20, 2.64) | 20.37 |
| ***All non-expert intubators*** ($I^2$= 0.0%, p = 0.92) | 113 / 120 | 62 / 120 | 1.82 (1.52, 2.17) | 100.00 |
| **All patients** ($I^2$= 88.9%, p < 0.001) | 804 / 919 | 722 / 920 | 1.10 (0.99, 1.22) | |

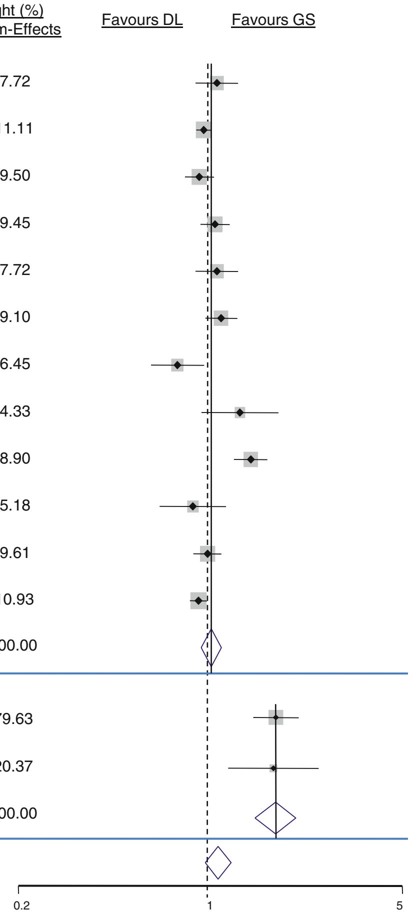



**Fig. 3** Risk ratios (RR) of successful first-attempt intubation in clinical trials comparing Glidescope® video-laryngoscopy to direct laryngoscopy stratified by operator expertise (anesthesia or casualty consultants or house staff *vs* "other"). The pooled estimate was derived using the DerSimonian and Laird random effects method with grey squares depicting individual study point estimates of the RR. Larger squares indicate a larger weight of the study when calculating the pooled estimate. Solid horizontal lines display the 95% CI of the point estimate. Dashed vertical line represents an RR of 1.00, indicating no difference between Glidescope® video-laryngoscopy and direct laryngoscopy. Solid vertical lines represent the pooled estimates. Test for heterogeneity by operator expertise was significant using meta-regression analysis ($P = 0.001$). DL = direct laryngoscopy; GS = Glidescope®

had a first-attempt success rate of $> 90\%$.[15,16,27,32] This high rate of success with direct laryngoscopy by anesthesiologists is reflected in other clinical studies.[6] Even in the unlikely scenario that Glidescope® video-laryngoscopy would improve the success rate in patients without difficult airways by experts, it would require a large sample of patients to prove it. Thus, potential benefits of Glidescope® video-laryngoscopy may lie with: 1) use in patients with clinical features indicating difficult laryngoscopy; 2) it being used as a rescue method following failed direct laryngoscopy; or 3) it being used by nonexpert providers. Indeed, the observational study by Aziz *et al.* demonstrated that the Glidescope® was successful in 96% of patients with predictors of difficult direct laryngoscopy and in 94% following failed direct laryngoscopy.[38]

Although our review did show increased first-attempt success and decreased time to intubation in studies of nonexperts with the Glidescope® compared to direct laryngoscopy, these results must be interpreted with caution given that there were only two studies in this subgroup.[14,36] Rather, the possible benefit of Glidescope® video-laryngoscopy amongst nonexperts should be viewed as an area that requires further research.

This systematic review and meta-analysis highlights several areas that need to be addressed. How is expertise developed and defined, particularly when a new technology is introduced? What role should nonexperts play in airway management? Studies examining new technology are prone to proficiency bias. Despite this fact, anesthesiologists have incorporated the Glidescope® into their armamentarium

Time required to intubate in seconds (SD or IQR)

| Author, Year | Glidescope® | Direct laryngoscope | WMD in seconds (95% CI) | Weight (%) Random-Effects |
|---|---|---|---|---|
| **Expert intubators** | | | | |
| Lim 2005[23] | 41.8 (20.2) | 56.2 (26.6) | -14.40 (-26.35, -2.45) | 6.24 |
| Sun 2005[15] | 46 (43 – 49) | 30 (28 – 33) | 16.00 (14.87, 17.13) | 8.85 |
| Turkstra 2005[31] | 27 (12) | 17 (8) | 10.00 (0.58, 19.42) | 7.03 |
| Xue 2007[30] | 37.4 (9.9) | 28.4 (11.7) | 9.00 (3.34, 14.66) | 8.11 |
| Jones 2008[16] | 43.5 (39.8 – 67.3) | 66.7 (53.8 – 89.9) | -23.20 (-34.39, -12.01) | 6.47 |
| Malik 2008[28] | 18.9 (6) | 11.6 (6.0) | 7.30 (4.26, 10.34) | 8.65 |
| Serocki 2010[24] | 13 (11 – 15) | 13 (11 – 16) | 0.00 (-0.85, 0.85) | 8.87 |
| Bilehjani 2009[32] | 48.8 (47.8) | 14.5 (8.3) | 34.30 (19.25, 49.35) | 5.31 |
| Malik 2009[26] | 17 (12 – 31) | 13 (8 – 23) | 4.00 (-3.03, 11.03) | 7.75 |
| Siddiqui 2009[25] | 30.9 (9) | 13.9 (7.8) | 17.00 (11.78, 22.22) | 8.22 |
| Vernick 2006[34] | 56.9 (25.8) | 39.1 (10.5) | 17.80 (9.06, 26.54) | 7.24 |
| Yeatts 2009[35] | 69 (61.6 – 76.4) | 57 (50.3 – 63.7) | 12.00 (9.96, 14.04) | 8.78 |
| Teoh 2010[27] | 31.2 (15) | 22.4 (13.6) | 8.80 (4.83, 12.77) | 8.49 |
| ***All expert intubators*** ($I^2$= 98.0%, p < 0.001) | | | 7.61 (-1.80, 17.02) | 100.00 |
| **Non-expert intubators** | | | | |
| Nouruzi-Sedeh 2009[14] | 63 (30) | 89 (35) | -26.00 (-35.03, -16.97) | 54.68 |
| Shimada 2010[36] | 57 (22) | 141 (79) | -84.00 (-119.94, -48.06) | 45.32 |
| ***All expert intubators*** ($I^2$= 89.4%, p = 0.002) | | | -42.67 (-71.76, -13.56) | 100.00 |
| **All patients** (I-squared = 97.9%, p < 0.0001 | | | 3.80 (-1.68, 9.29) | |

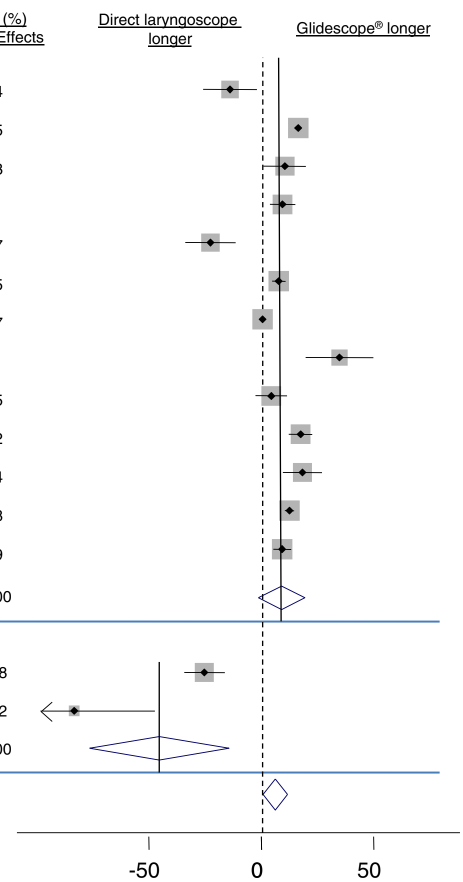



**Fig. 4** Weighted mean difference (WMD), in seconds, in clinical trials comparing Glidescope® video-laryngoscopy to direct laryngoscopy stratified by operator expertise (anesthesia or casualty consultants or housestaff *vs* "other"). The pooled estimate was derived using the DerSimonian and Laird random effects method with grey squares depicting an individual study point estimate of the mean difference. Larger squares indicate a larger weight of the study when calculating the pooled estimate. Solid horizontal lines display the 95% CI of the point estimate. Dashed vertical line represents a WMD of 0, indicating no difference between Glidescope® video-laryngoscopy and direct laryngoscopy. Solid vertical lines represent the pooled estimate. Test for heterogeneity by operator expertise was significant using meta-regression analysis ($P = 0.004$)

with a high rate of success.[39] Although it seems reasonable to assume that anesthesia consultants are experts, it remains less clear how, and at what point, this competence develops. When examining trainees, we have previously shown that anesthesia house staff were successful in 85% of their first attempts at intubating critically ill patients.[40] This success rate is very respectable given that this is a population with a 6.6-22.0% risk of a difficult intubation.[11,13,41] Furthermore, anesthesia house staff require fewer attempts to perform tracheal intubation compared to their nonanesthesia counterparts. Having an airway management expert at the bedside for each intubation may be advantageous, but there are many situations when this is not feasible. In many environments, there may be limited, if any, access to anesthesiologists, and airway management must be delivered by physicians from different speciality backgrounds. Endotracheal intubation remains a competence objective of the Royal College of Physicians and Surgeons of Canada in training for internal medicine.[42] Also, use of an advanced airway (e.g., endotracheal tube) remains a fundamental skill in Advanced Cardiac Life Support according to the 2005 American Heart Association Guidelines.[43] Thus, technologies that can improve the success of airway management, particularly in the hands of nonexperts, are desirable and should be studied. An example is Glidescope® use by prehospital paramedics.[44]

There are several limitations to our review. As previously stated, there was marked heterogeneity in all of our endpoints that was only partially explained by subgroup analysis. We attempted to account for this heterogeneity by performing a random-effects meta-regression, which yields a more conservative pooled estimate when between-study heterogeneity exists.[45] In addition, we explored heterogeneity by *a priori* defined subgroups and presented these results when they were significant. As with all meta-analyses, our review is subject to information bias. We defined expertise and difficulty *a priori*, but there may be marked differences between studies with respect to subject or operator characteristics that we were unable to evaluate from the available information. Another limitation is the low number of studies that included nonexperts, which markedly limits the ability to evaluate the effect of video-laryngoscopy in this important subgroup. Finally, there was evidence of publication bias in our primary outcome of the glottic view, suggesting that small studies favouring direct laryngoscopy were not being published. However, tests of publication bias are subject to a high risk of a type I error in the presence of significant heterogeneity, limiting their interpretability.[46]

In conclusion, we have shown in our meta-analysis that, compared to direct laryngoscopy, Glidescope® video-laryngoscopy is associated with improved glottic visualization, particularly in studies that considered patients with potential or simulated difficult airways. In addition, there is marked heterogeneity in all of our outcomes that is partially explained by operator expertise or the difficulty of intubation. There is a need for further evaluation of potential improvements in successful first-attempt intubations or time to intubate among nonexperts.

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