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# Direct Versus Video Laryngoscopy for Prehospital Intubation: A Systematic Review and Meta-analysis

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## ABSTRACT

**Objectives:** The use of video laryngoscopy (VL) for intubation has gained recent popularity. In the prehospital setting, it is unclear if VL increases intubation success rates compared to direct laryngoscopy (DL). We sought to conduct a systematic review and meta-analysis of studies comparing VL to DL in the prehospital setting to determine whether the use of VL increases overall and first-pass endotracheal intubation success rates compared to DL.

**Methods:** A systematic search was performed of the PubMed, Embase, and SCOPUS databases through May 2016 to include studies comparing overall and first-pass success for VL versus DL in patients requiring intubation in the prehospital setting. Data were abstracted by two reviewers. A meta-analysis was performed using a random-effects model.

**Results:** Of a potential 472 articles, eight eligible studies were included. Considerable heterogeneity ( $I^2 > 90\%$ ) precluded reporting an overall pooled estimate across all studies. When stratified by provider type, the pooled estimates for overall intubation success using VL versus DL were a risk ratio (RR) of 0.05 (95% confidence interval [CI] = 0.01–0.18) in studies of physicians and RR = 2.28 (95% CI = 1.00–5.20) in nonphysicians. For first-pass intubation success the pooled RR estimates for using VL versus DL were 0.32 (95% CI = 0.23–0.44) and 1.83 (95% CI = 1.18–2.84) among studies using physicians and nonphysicians, respectively. There was moderate to significant heterogeneity between studies when stratified by provider.

**Conclusions:** Among physician intubators with significant DL experience, VL does not increase overall or first-pass success rates and may lead to worsening performance. However, among nonphysician intubators with less experience with DL, VL may provide benefit in the prehospital setting.

The ability to perform oral endotracheal intubation safely and effectively is of paramount importance to the health of the patient in the prehospital setting. While protocols allowing for prehospital intubation vary, the most common indications are respiratory and cardiac arrest.<sup>1,2</sup> Prior studies of endotracheal

intubation in the prehospital setting have used overall intubation success as the primary outcome. First-pass success—defined as successful intubation of the patient on the first attempt—is also recognized as an important outcome measure as studies have shown an increase in the adverse event rate with successive failed

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intubation attempts.<sup>3,4</sup> In a recent study of 75,000 pre-hospital intubations attempts across 40 states, the overall intubation success was estimated to be 85%.<sup>1</sup> Studies examining the association between type of provider performing the procedure and success rate have shown that paramedics tend to have lower success rates than physicians, with first-pass success for paramedics to be 46% to 77%, compared with 71% to 88% for physicians outside the hospital and 61% to 97% for physicians performing the procedure inside the hospital.<sup>3</sup>

Until recently, the standard approach for intubation in all settings has been the direct laryngoscopy (DL) method. This requires a direct line of site between the operator's eyes and the vocal cords to place the endotracheal tube. In contrast to the direct approach, the video approach uses a device that indirectly views the vocal cords by employing fiber optics, video cameras, mirrors, or other methods to project an image of the patient's airway onto a screen, which is viewed by the operator in real time as he or she places the endotracheal tube. The use of DL in the emergency department (ED) setting has decreased from 95% of procedures in 2002 to approximately 55% of procedures in 2012, with a concomitant increase in video laryngoscopy (VL), from less than 5% to 39% of procedures.<sup>5</sup>

Meta-analyses examining first-pass success rates and rates of difficult intubation with direct versus video devices in hospital settings (operating room and intensive care) suggest that use of VL is associated with a higher first-pass success rate and a decrease in the rate of difficult intubation, especially among novice operators.<sup>6,7</sup> In the ED setting, studies have been mixed, suggesting either improved first-pass and overall success with video devices or no difference between the direct and video approach.<sup>8-10</sup> We are not aware of a systematic review or meta-analysis of studies comparing the effect of DL and VL on intubation success rates in the prehospital setting. In this meta-analysis, we hypothesized that VL confers benefit over DL, as measured by the rate of overall and first-pass intubation success for patients requiring intubation in the prehospital setting.

## METHODS

### Search Strategy

To be included in the systematic review, studies had to have been performed in and obtained data

exclusively from the prehospital setting, used living human subjects, and be published in English. Studies also had to include data permitting calculation of either an overall success rate of intubation, first-pass success rate or both. There was no time period limit for the search. Overall intubation success is defined as the ability to achieve successful intubation on a single patient, regardless of the number of attempts, while first-pass success is defined as the ability to achieve successful intubation on the first attempt. The search was performed in the PubMed, Embase, and SCOPUS databases, using search terms related to both the setting (prehospital) and the procedure (VL). The search terms for setting included EMS, emergency medical services, prehospital, paramedic, air medical, helicopter and out-of-hospital. To improve the capture of the procedure, we also searched for technical terms, as well as commonly used specific devices. The procedure search terms for were VL, video intubation, indirect laryngoscopy, indirect intubation, GlideScope (Verathon, Inc.), Airtraq (Prodol Meditec SA), Vividtrac (Vivid Medical Inc.), C-MAC (Karl Storz), and King Vision (Ambu). In addition to the search of the formal database, the references of relevant articles were reviewed to identify additional studies meeting inclusion criteria.

Studies were initially reviewed by title, abstract, and full text to determine whether they met inclusion criteria. Publications were excluded from the review if they were case reports, case series, reviews, studies restricted to children, studies comparing multiple video devices to each other without DL comparison, nonhuman studies, manikin/simulation studies or cadaver studies. After article selection, the papers were further organized into those that contained data for overall intubation success, first-pass success, or both. Studies were excluded from the meta-analysis if the article or correspondence with the author failed to provide data that would be amenable to pooling.

### Data Extraction and Statistical Methods

For each of the studies that met inclusion criteria, the following data were extracted: the number of patients in which intubation was attempted, the number of patients successfully intubated, the number of patients with failed intubation, the number of patients successfully intubated on the first attempt, and the number of patients with failed intubation on the first attempt. A comparison between direct and VL was performed by

calculating the relative risk (RR) for successful overall and first-pass intubation for the direct versus the video device. For selected papers that lacked data needed to calculate the RR for first-pass or overall intubation success, or those in which there was ambiguity of the results, the study authors were contacted to clarify or request missing data, if available. Results for first-pass success from Wayne and McDonnell<sup>19</sup> and Trimmel et al. (2011<sup>16</sup> and 2016<sup>17</sup> studies) were obtained by contacting study authors (Table 1). Clarification of first-pass success results by Selde et al.<sup>13</sup> were also obtained by contacting authors.

Data abstraction was performed by two separate reviewers and inter-rater reliability calculated. Final abstracted data was agreed upon between the two authors (PS and SR). Study quality was assessed using the Cochrane Handbook risk-of-bias tool. Studies were judged by two independent raters and differences were then resolved by consensus. Based on the abstracted data, pooled estimates for the RR of successful overall and first-pass intubation with a direct versus a video device were calculated with a 95% confidence interval (CI) using a random-effects model. The I<sup>2</sup> test for heterogeneity was performed for each pooled estimate.<sup>11</sup> Egger's test was performed and funnel plots constructed to evaluate for the presence of publication bias in the selected studies.<sup>12</sup> Calculations were performed and graphs created using Stata Version 14 (StataCorp).

**RESULTS**

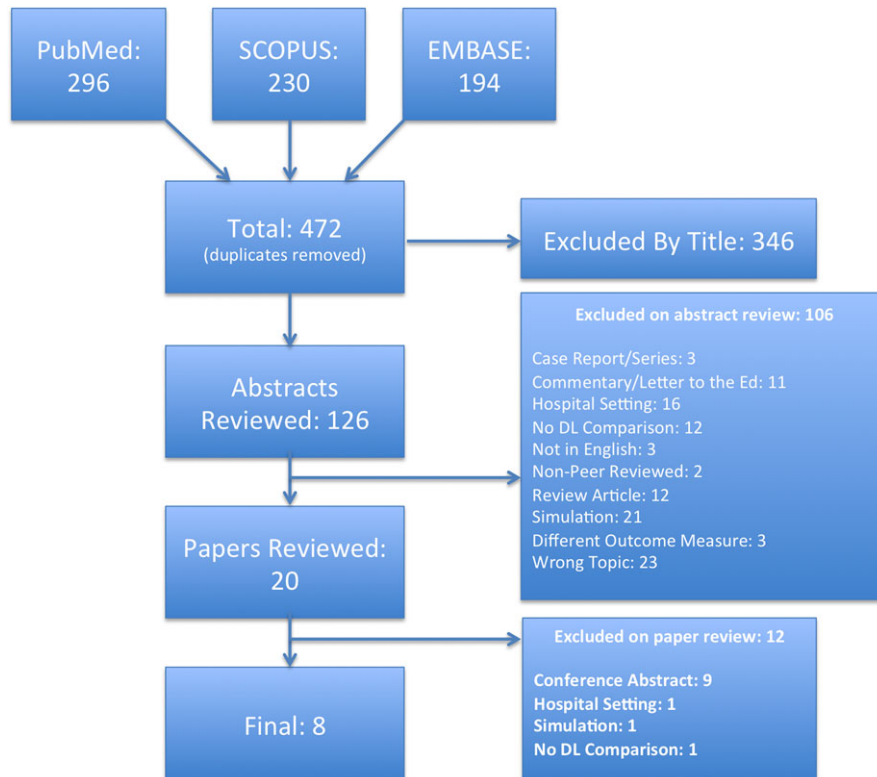
**Search Results, Data Extraction, and Publication Bias**

Searches of PubMed, Embase, and SCOPUS were performed on May 10, 2016, the results of which are shown in Figure 1. A total of eight studies met inclusion criteria. Study characteristics are shown in Table 1. Review of the reference lists of these publications did not reveal any additional studies meeting inclusion criteria. Data were abstracted from the studies, with seven studies containing outcome data for overall success and five studies containing outcome data for first-pass success. First-pass success data from three additional papers were obtained by contacting study authors. These data were readily available and collected during the initial study time frames, but not reported. One paper (Selde et al.<sup>13</sup>) did not use the same definition for overall intubation success as the definition being used in this review, so the data were

Table 1  
Study Characteristics

Reference	Study Type	Device	Country	Operators	Setting	N	Baseline Intubations per Year	Outcomes	Age (y)
Arima 2013 <sup>15</sup>	Randomized controlled trial	Airway Scope	Japan	Physicians	Ground	109	≥100	Overall and first-pass success	≥18
Boehringer 2015 <sup>20</sup>	Retrospective cohort	C-MAC	United States	Nurses and paramedics	Air	788	Not reported	Overall and first-pass success	All
Guyette 2013 <sup>18</sup>	Nonrandomized trial	C-MAC	United States	Nurses and paramedics	Air	858	12	Overall and first-pass success	≥18
Jarvis 2015 <sup>21</sup>	Before-after	King Vision	United States	Paramedics	Ground	514	2.9	Overall and first-pass Success	All
Selde 2014 <sup>13</sup>	Retrospective cohort	Airtraq	United States	Nurses and paramedics	Air	130	Not reported	First-pass success	≥18
Trimmel 2011 <sup>16</sup>	Randomized controlled trial	Airtraq	Austria	Physicians	Air	212	≥80	Overall and first-pass success*	≥18
Trimmel 2016 <sup>17</sup>	Randomized controlled trial	GlideScope Ranger	Austria/Norway	Physicians	Air and ground	326	≥80	Overall and first-pass success*	≥18
Wayne 2010 <sup>19</sup>	Before-after	GlideScope Ranger	United States	Paramedics	Ground	615	6-10	Overall and first-pass success*	≥6

\*Authors contacted for first-pass success data.



**Figure 1.** Results of systematic review.

not included in the meta-analysis for overall intubation success. Inter-rater reliability between the two data abstractors was assessed using percent agreement and was 94%. Both abstractors agreed upon final included data.

Two study authors (PS and MM) independently reviewed each study for risk of bias using The Cochrane Collaboration's tool for assessing risk of bias. A third author (RW) with experience in utilizing the Cochrane Collaboration risk of bias tool in previous published studies mediated any incongruence.<sup>14</sup> Initial percent agreement between the two independent raters for all risk of bias elements was 88%. Final scores were agreed upon by all three study authors. Eleven separate domains were judged as low, high, or unclear. Based on the judgment of the individual domains, a final score for individual study quality was given as weak, moderate, or strong. We judged three of the studies to be strong, four of the studies as moderate, and one study to be weak (Table 2).

Egger's test for publication bias was performed both for the question of overall success and for first-pass success. For overall success, the p-value was 0.186, suggesting against publication bias; however, the funnel plot may represent some bias (Figure 2). For first-pass success, the p-value was 0.357, again suggesting

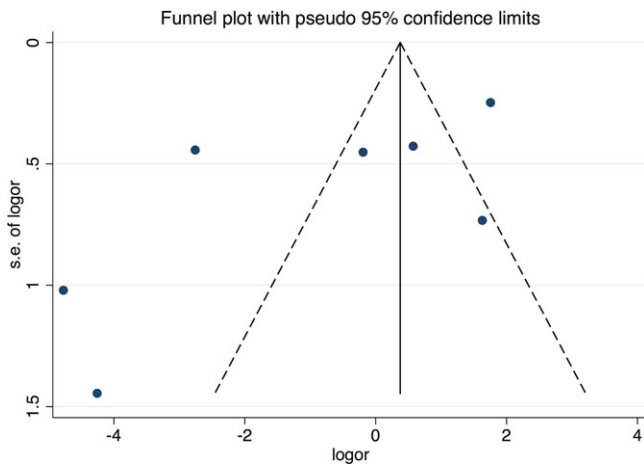
against publication bias, with the funnel plot supporting this finding (Figure 3).

### Overall Intubation Success

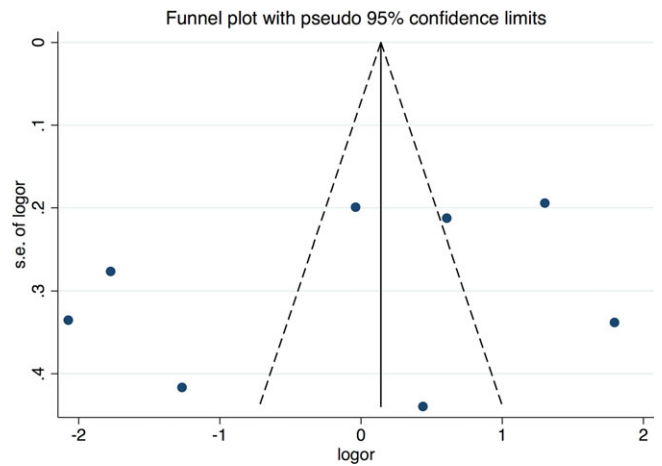
Seven of the eight studies were included in the meta-analysis for overall intubation success, using a random-effects model. Figure 4 represents the relative rate of intubation success using VL. Studies favoring VL have a relative risk > 1. Studies favoring DL have a relative risk < 1. The results are stratified by type of provider performing the intubation in the study (i.e., physician vs. nonphysician). This stratification scheme also incidentally resulted in stratification by study type (RCT vs. observational). The pooled estimate for the relative risk of VL compared to DL for overall success is not reported due to very high heterogeneity with an  $I^2 > 90\%$ . Studies using physician intubators had a much lower rate of success with VL compared to DL (RR = 0.05, 95% CI = 0.01–0.18), while studies using nonphysicians had higher rate of success with VL compared to DL (RR = 2.28; 95% CI = 1.00–5.20). When stratified by provider type, there is moderate heterogeneity between physician studies ( $I^2 = 46.1\%$ ) and substantial heterogeneity between nonphysician studies ( $I^2 = 76.6\%$ ).

**Table 2**  
Risk of Bias Assessment

	Trimmel 2011 <sup>16</sup>	Trimmel 2016 <sup>17</sup>	Arima 2013 <sup>15</sup>	Boehringer 2015 <sup>20</sup>	Guyette 2013 <sup>18</sup>	Jarvis 2015 <sup>21</sup>	Selde 2014 <sup>13</sup>	Wayne 2010 <sup>19</sup>
Randomized design	Yes	Yes	Yes	No	No	No	No	No
Random sequence generation (selection bias)	Low	Low	Unclear	N/A	N/A	N/A	N/A	N/A
Allocation concealment (selection bias)	Low	Low	Low	High	High	High	N/A	High
Blinding of participants and personnel (performance bias)	High	High	High	High	High	High	High	High
Similar baseline cohort characteristics	Low	Low	Low	Unclear	Low	Low	Unclear	Low
Intervention independent of other changes	Low	Low	Low	Unclear	Low	Unclear	Unclear	Unclear
Blinding of outcome	High	High	High	High	High	High	High	High
Intervention unlikely to affect data collection	Low	Low	Low	Low	Low	Low	Low	Low
Incomplete outcome data (attrition bias)	Low	Low	High	Low	Low	Low	High	Low
Study adequately protected against contamination	Low	Low	High	High	Unclear	Low	High	Low
Selective outcome reporting (reporting bias)	Low	Low	Low	Low	Low	Low	Low	Low
Other confounding	Low	Low	Unclear	High	High	High	High	High
Summary assessment of study quality	Strong	Strong	Moderate	Weak	Strong	Moderate	Moderate	Moderate



**Figure 2.** Funnel plot for overall intubation success of VL versus DL. DL = direct laryngoscopy; VL = video laryngoscopy.



**Figure 3.** Funnel plot for first-pass intubation success of VL vs. DL. DL = direct laryngoscopy; VL = video laryngoscopy.

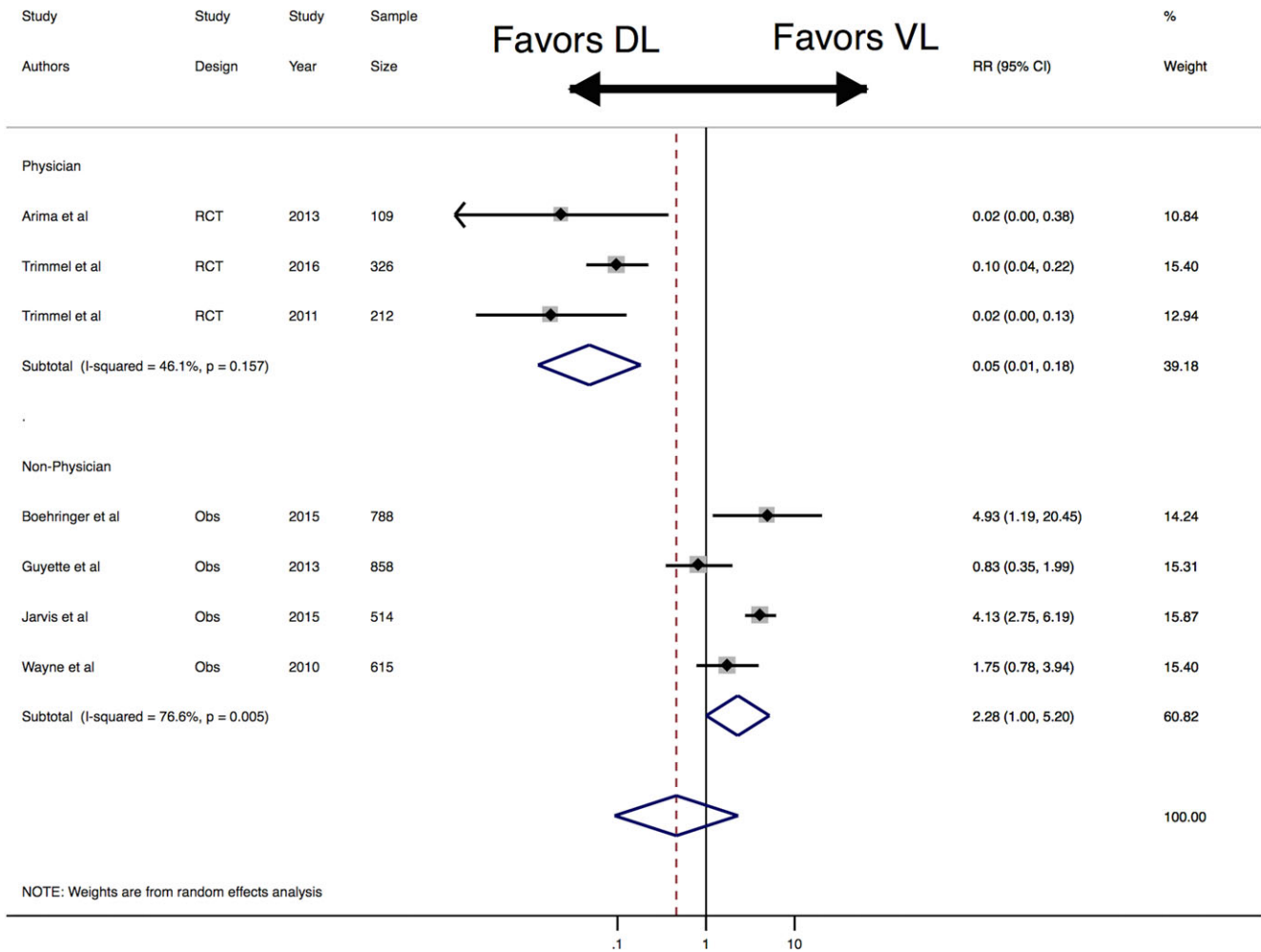
**First-pass Intubation Success**

All eight studies were included in the meta-analysis for first-pass intubation success, again using a random-effects model. The pooled estimate for first-pass successful intubation using VL compared to DL is not reported due to extreme heterogeneity ( $I^2 > 90\%$ ). When stratified by provider, studies with physician intubators had a lower rate of first-pass success with VL compared to DL (RR = 0.32, 95% CI = 0.23–0.44) while nonphysicians had a higher rate of success with video compared to direct devices (RR = 1.83, 95% CI = 1.18–2.84). When stratified by provider type, there is minimal heterogeneity between physician studies ( $I^2 = 28.9\%$ ) and substantial heterogeneity ( $I^2 = 84.9\%$ ) between nonphysician studies (Figure 5).

**DISCUSSION**

This meta-analysis is the first to address the question of intubation success in the prehospital setting when comparing the direct and video approach. We searched for studies comparing VL versus DL in the prehospital setting and identified eight studies for inclusion in this meta-analysis. There was significant variation among the studies with respect to study design, providers performing the intubations, and study outcomes. Our overall meta-analysis suffered from substantial heterogeneity, leading us to not report point estimates for overall and first-pass success. The cause for the heterogeneity is likely multifaceted, although we suspect that a large contributing





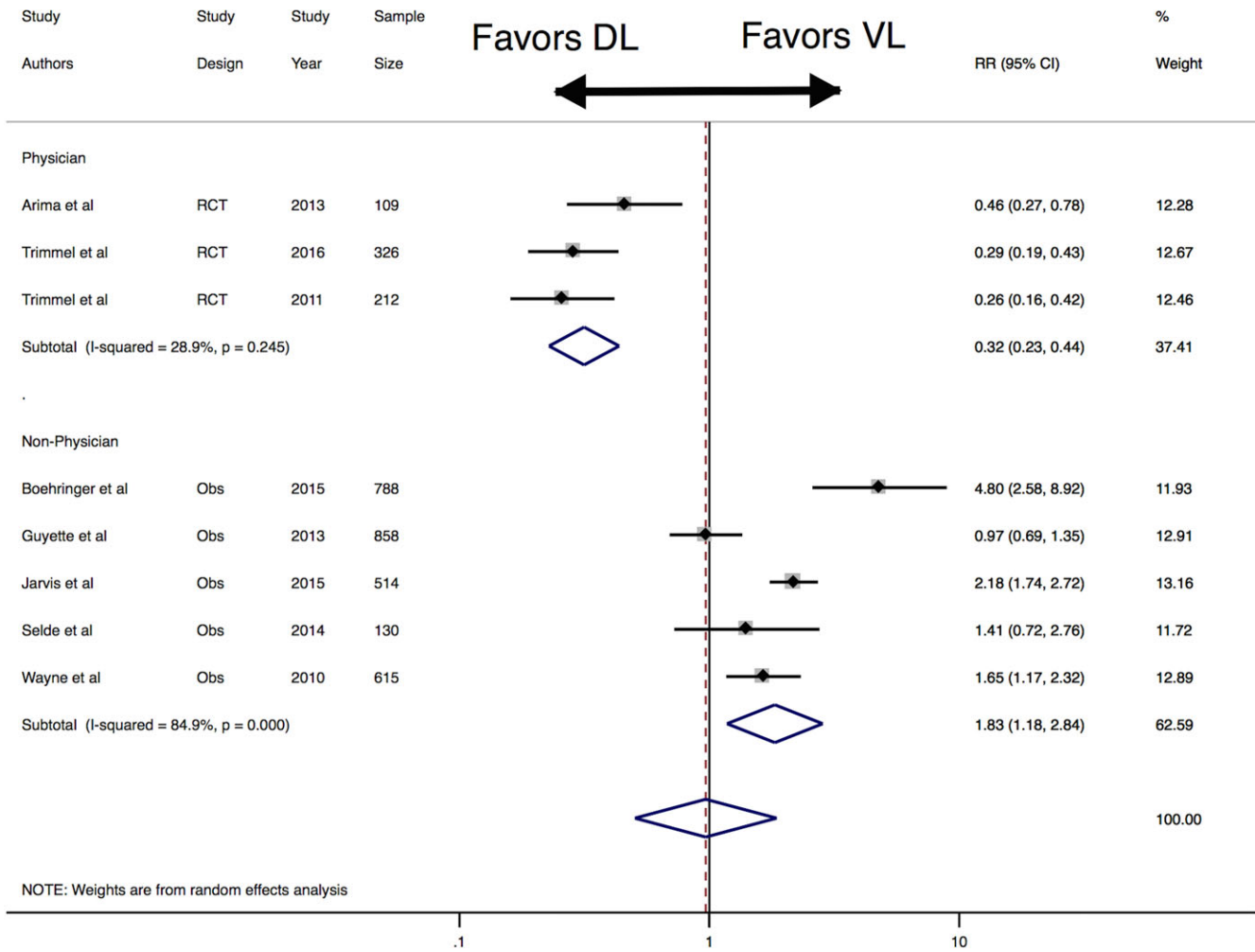
**Figure 4.** Forest plot for overall intubation success, relative risk. DL = direct laryngoscopy; RCT = randomized-controlled trial; Obs = observational study; RR = relative risk; VL = video laryngoscopy.

component is the vastly different results between studies using physician and nonphysician providers as well as the varying study designs. When stratified by provider type, the amount of heterogeneity improves significantly. In studies with physician intubators, VL resulted in lower rates of success when compared to direct. In studies with nonphysician intubators, VL resulted in higher rates of success when compared to DL.

The results of this meta-analysis are similar to in-hospital studies, which suggested that inexperienced intubators may have increased success rates with VL. Griesdale et al.<sup>7</sup> found a statistically significant increase in first-pass success among novice intubators using VL; however, this benefit disappeared for expert intubators (RR = 1.0, 95% CI = 0.94–1.20). Our meta-analysis suggests a similar pattern of results with expert intubators, showing decreased success associated with VL compared to DL use by experienced physicians in the field (RR = 0.34, 95% CI = 0.22–0.52).

Another meta-analysis by De Jong et al. in the hospital setting suggested improved first-pass success for all intubators when using VL; however, De Jong et al.<sup>6</sup> did not stratify results by experience and noted this as a potential limitation in their study.

Our study suggests that physician intubators do not experience the same benefit from VL as nonphysician intubators in the prehospital setting. We suspect that this difference lies largely with the amount of previous experience physician providers reportedly had with DL rather than their credentials. The physician studies reported a baseline intubation rate of at least 80 intubations per year per individual provider, while nonphysicians ranged from 2.9 to 12 intubations per year per individual provider. This may suggest that extensive training and experience with DL could yield results that outperform VL in some EMS systems. It could also suggest that VL may lead to increased overall and first-pass success rates in those systems in which providers have less experience with intubation.



**Figure 5.** Forest plot for first-pass intubation success, relative risk. DL = direct laryngoscopy; RCT = randomized-controlled trial; Obs = observational study; RR = relative risk; VL = video laryngoscopy.

It should be noted, however, that these nonphysician studies were nonrandomized and retrospective placing them at high risk for bias. The studies by Trimmel et al.<sup>16,17</sup> also noted environmental factors such as ambient light/glare on the VL screens may have impacted their success with the device.

Appropriate airway management in the prehospital setting is critical to patient survival and neurologic outcomes. Failed or delayed intubation can lead to increased episodes of harm, including significant morbidity and mortality.<sup>3,4</sup> Introduction of VL into the prehospital setting has offered the potential to increase first-pass success, decrease time to intubation, and thereby reduce morbidity to patients. However, to date, studies exploring the efficacy of VL compared to the direct approach have been limited by study population size and setting, as well as retrospective design and convenience sampling. Additionally, with a range of video laryngoscopic products on the market, it is

difficult to differentiate success or failures of individual devices versus the video-guided approach. EMS medical directors would benefit from stronger evidence to support the large operational and training investments necessary to support widespread implementation of VL.

### LIMITATIONS

The extensive heterogeneity across all studies was a limitation for our meta-analysis. A likely reason for the heterogeneity we observed is the varied study designs. Both Trimmel et al.<sup>16,17</sup> and Arima et al.<sup>15</sup> used randomized controlled trials for their design. Patients were randomly assigned to receive either VL or DL at the time of initial contact with the prehospital provider. Guyette et al.<sup>18</sup> used a nonrandomized process, choosing specific helicopters to employ the video devices based on the frequency of intubations



performed at each site. Wayne and McDonnell,<sup>19</sup> Selde et al.,<sup>13</sup> Boehringer et al.,<sup>20</sup> and Jarvis et al.<sup>21</sup> all used an observational, retrospective design.

An additional potential source of heterogeneity may be the varying types of video devices employed between studies. While all of the devices compared against DL were video devices, there is evidence based on airway simulation studies that different types of video devices do not necessarily perform equally. A 2009 study comparing overall success rates for the GlideScope and C-MAC video devices (both devices represented in this meta-analysis) on simulated manikin airways found that the C-MAC device was superior.<sup>22</sup> In addition, a study by Burnett et al.<sup>23</sup> showed that the C-MAC device outperformed the King Vision device in both first-pass success and overall success rates in a nonrandomized, controlled trial. This difference in device performance based on their innate product design may also have increased the amount of heterogeneity seen in our meta-analysis. It is also important to note that intubation success relies highly on the provider performing the procedure. This “operator-dependent” nature of intubation could also affect the heterogeneity of the results.

The included studies also reported outcome variables on which a meta-analysis was not performed. Of these variables, the most commonly reported was the mean number of intubation attempts per patient. Evidence suggests that fewer attempts prior to successful intubation are associated with fewer adverse patient events.<sup>3,4</sup> Three of the studies included mean number of intubation attempts per patient. The results were conflicting. Wayne and McDonnell<sup>19</sup> and Boehringer et al.<sup>20</sup> both reported statistically significant reductions in the mean number of intubation attempts using VL when compared to DL (1.2 vs. 2.3,  $p < 0.05$ ; and 1.08 vs. 1.33,  $p < 0.0001$ , respectively). Guyette et al.<sup>18</sup> found no difference in the mean number of intubation attempts between VL and DL (1.17 vs. 1.16 attempts per patient). Meta-analysis was not performed on this outcome as there were too few studies reporting the data. Other outcome variables reported included median time to intubation (one study), mean time to successful intubation (one study), laryngoscopic view (one study), and success per attempt (one study).<sup>15,18,19,21</sup>

Another potential limitation to the study involves the definition of first-pass intubation success. The National Association of EMS physicians defines an intubation attempt as “insertion of the blade” of the

laryngoscope into the mouth.<sup>24</sup> Many of the reviewed papers did not specify the definition of an intubation attempt, so it is possible varied definitions could have been used across studies.

Finally, it is unclear if the results of this meta-analysis are generalizable to United States EMS systems. The United States relies largely on non-physician prehospital providers and the studies we identified including these providers are observational and at high risk of bias. The studies of physician providers were performed outside of the United States and, while high quality, may not be generalizable to the U.S. setting.

## CONCLUSION

The emergence of video laryngoscopy in the prehospital setting introduces a method of intubation that has not, up until this point, been shown to improve outcomes with regard to overall or first-pass intubation success. There may be some benefit to video laryngoscopy specifically in those settings in which prehospital providers have less experience and opportunity to perform intubation, while those systems in which providers are highly versed in direct laryngoscopy may not experience improvement. Prospective, randomized trials, comparing direct laryngoscopy and video laryngoscopy in settings in which prehospital providers are nonphysicians are needed.

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