SYSTEMATIC REVIEW/META-ANALYSIS

Airway

Video screen visualization patterns when using a video laryngoscope for tracheal intubation: A systematic review

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Funding and support: By JACEP Open policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Abstract

Objective: Published studies of video laryngoscopes are often limited by the lack of a clear definition of video laryngoscopy (VL). We performed a systematic review to determine how often published studies of VL report on video screen visualization.

Methods: We searched PubMed, EMBASE and Scopus for interventional and observational studies in which a video laryngoscope equipped with a standard geometry blade was used for tracheal intubation. We excluded simulation based studies. Our primary outcome was data on video laryngoscope screen visualization. Secondary outcomes were explicit methodology for screen visualization.

Results: We screened 4838 unique studies and included 207 (120 interventional and 87 observational). Only 21 studies (10% of 207) included any data on video screen visualization by the proceduralist, 19 in a yes/no fashion only (ie, screened viewed or not) and 2 with detail beyond whether the screen was viewed or not. In 11 more studies, visualization patterns could be inferred based on screen availability and in 16 more studies, the methods section stated how screen visualization was expected to be performed without reporting data collection on how the proceduralist interacted with the video screen. Risk of bias was high in the majority of included studies.

Conclusions: Published studies of VL, including many clinical trials, rarely include data on video screen visualization. Given the nuances of using a video laryngoscope, this is a critical deficiency, which largely prevents us from knowing the treatment effect of using a video laryngoscope in clinical practice. Future studies of VL must address this deficiency.

KEYWORDS
tracheal intubation, video laryngoscopy
INTRODUCTION

1.1 Background

Video laryngoscopes are increasingly the most common devices used for tracheal intubation in US emergency departments (EDs). Video laryngoscopy (VL) has consistently been reported to improve glottic visualization compared with direct laryngoscopy (DL). When incorporated into high-volume training programs, there is some evidence that emergency medicine residents acquire airway skills better with a video laryngoscope.

1.2 Importance

Despite hundreds of published studies, however, including 79 total clinical trials across 3 Cochrane reviews, we still do not know whether a video laryngoscope improves procedural success. A primary reason for this knowledge deficit is the lack of a consistent, explicit definition for VL. Especially with a standard geometry blade, using a video laryngoscope and VL are not equivalent. With a standard geometry video laryngoscope, proceduralists have the option to directly view the glottis by looking into the patient’s oropharynx, or indirectly view the glottis by looking at the video screen. In addition to having the option to view the screen or not view the screen in a yes/no fashion, proceduralists can show significant variations in their patterns of screen visualization including variations in the percentage of time during an intubation attempt spent viewing the video screen, the number of times they look back and forth between the patient and screen during an attempt, when during an attempt they first view the screen, and whether or not they view the screen during key moments during an attempt. With such a range of possibilities, the lack of a standard definition of VL, especially based on accurate methods of data collection, is a critical and persistent deficiency in airway literature.

1.3 Goals of this investigation

We performed a systematic review of studies of tracheal intubation with a video laryngoscope and a standard geometry blade. We specifically sought to determine how often video screen visualization patterns were defined or measured, including the approach to data collection.

METHODS

2.1 Data sources and searches

We registered our systematic review methodology with PROSPERO before study commencement, including the search strategy, outcomes, and inclusion and exclusion criteria. We designed this systematic review to be consistent with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology.

We conducted a search of PubMed, EMBASE, and Scopus, from database inception through May 2021. We used each of the following search terms in each database: "VL," "videolaryngoscopy," "video laryngoscope," and "videolaryngoscope."

2.2 Study selection

From the initial database search, one author (PD) conducted a manual review of identified studies, starting with the title, then the abstract, and finally review of the full text. From this manual review, we included only original research studies available in English that involved tracheal intubation on a live person in the systematic review. Additionally, the study needed to include at least one group intubated using a video laryngoscope equipped with a standard geometry blade. We included observational and interventional studies, including clinical trials. We excluded studies of video laryngoscopes with only a non-standard geometry or hyperangulated blade, as the proceduralist does not have the option for DL with these devices. We also excluded studies of nasotracheal intubation and of face-to-face intubation, given their fundamental procedural differences from traditional intubation techniques. We also excluded cadaveric studies, simulation-based studies, case reports, and conference abstracts. We defined standard and non-standard (hyperangulated) geometry blades as shown in Table 1.

2.3 Data extraction and quality assessment

After applying inclusion and exclusion criteria, one reviewer (PD) assessed included studies for any data reporting on the video screen visualization pattern by the proceduralist. We included both actual data collection of screen visualization (outcome data) as well as a description of approach to video screen visualization in the study protocol (ie, methodologic data). We also collected information on the approach to data collection for screen visualization, including self-report, electronic record review, independent observer, and video. Video data sources included overhead or external cameras and the video laryngoscope itself.

For any study that reported either outcome or methodological data for screen visualization, both authors reviewers (PD and BK) conducted an independent review. Both reviewers assessed the risk for bias using the Cochrane Collaboration Bias Appraisal Tool. We categorized the reporting of proceduralist visualization as high risk, low risk, or unclear risk of bias, based on the method of data collection (self-report, video review, etc.). High risk studies included observational studies with self-reported visualization patterns and interventional or observational studies in which the study protocol/manuscript methods section prescribe visualization patterns but both direct and indirect visualization were available to the proceduralist and visualization patterns were not objectively recorded. Low risk studies included
TABLE 1  Standard geometry and non-standard (hyperangulated) geometry blades

| Device | Manufacturer | Location          |
|--------|--------------|-------------------|
|        | Standard geometry blades |                         |
|        | Macintosh and Miller versions of C-MAC | Storz | Tuttlingen, Germany |
|        | Macintosh and Miller versions of Glidescope | Verathon | Bothell, WA |
|        | Macintosh and Miller versions of McGrath | Medtronic | Minneapolis, MN |
|        | Macintosh and Miller versions of Direct Coupled Interface | Storz | Tuttlingen, Germany |
|        | Macintosh and Miller versions of UE scope | UE Medical Devices | Newton, MA |
|        | Macintosh and Miller versions of Intubrite Video Laryngoscopes | Salter Labs | Vista, CA |
| CEL-100 | ConnellEnergyTechnologyCo. | Shanghai, China |
| Venner AP advance | Venner Medical | Singapore |
| VLP-100 | Daiken Medical | Osaka, Japan |
| Infantview | Vyaire Medical | Mettawa, IL |
|        | Non-standard (hyperangulated) geometry blades |                         |
|        | C-MAC D-Blade | Storz | Tuttlingen, Germany |
|        | Hyperangulated versions of Glidescope | Verathon | Bothell, WA |
|        | Hyperangulated versions of McGrath | Medtronic | Minneapolis, MN |
|        | Hyperangulated versions of UE scope | UE Medical Devices | Newton, MA |
|        | Airtraq | Prodol Mediteq | Getxo, Spain |
|        | King VL | Ambu | Ballerup, Denmark |
|        | Airway scope | Nihon Kohden | Tokyo, Japan |
|        | Truvew | Truphatek | Natanya, Israel |
|        | Totaltrack | Medcom Flow | Barcelona, Spain |
|        | VL3 | HugeMed | Shenzhen, China |

those utilizing overhead video review and included a reliability assessment, studies in which the video screen was unavailable to proceduralists throughout the entire procedure and studies utilizing eye tracking devices. Unclear risk studies included those utilizing overhead video review but did not include a reliability assessment. Any disagreements between the two reviewers were resolved by a third party with content expertise. Because the goal of this review was to understand the video screen visualization patterns and not the outcome of an intervention, we did not perform measures of effect analyses or a meta-analysis.

2.4  Outcomes

Our primary outcome was a study including outcome or methodologic data for video screen visualization patterns. To maximize sensitivity, we recorded any description of screen visualization, including the dichotomous “yes/no.” We also recorded more granular data, including duration of video screen viewing, the number of times a proceduralist switched their gaze between the patient and the video screen, which portion of intubation attempts (laryngoscopy vs tube delivery) the proceduralist viewed the video screen, and the total proportion of video screen viewing during intubation attempts. Secondary outcomes included the method of video screen data collection.

3  RESULTS

3.1  Enrollment

In our primary database search, we identified 4838 unique studies (Figure 1). We excluded 3615 studies after title review, 948 after abstract review, and 68 after full text review. We included 207 unique studies after all exclusions—120 were interventional (84 randomized controlled trials) and 87 were observational (Table 2). The included studies were published from 2001 to 2021.

3.2  Main outcomes

Among the 207 studies included, only 21 studies (10%) reported outcome data for video screen visualization. Nineteen of these studies (9%) included only basic outcome data—that a screen visualization occurred or not (dichotomous), without further detail.

Only 2 studies (1%) included more detailed outcome data on video screen visualization. In the first, Guyette et al.\textsuperscript{10} used proceduralist self-reporting to characterize screen visualization as only screen, mostly screen, mostly direct, or only direct. In the second study, Driver et al.\textsuperscript{11} used proceduralist self-report to characterize screen
3.3 Methods of data collection

The method of data collection in the 207 included studies varied widely (Table 2). Of the 21 studies that reported outcome data for screen visualization, 19 were based on some version of self-report, including the studies by Guyette et al. and Driver et al. Only 2 studies were based on video review, both overhead/external. Law et al. used eye-tracking technology during intubation attempts. In this study, only 2 intubations were performed with a video laryngoscope, and although visualization between patient and equipment was reported, direct visualization versus indirect visualization was not characterized.

4 LIMITATIONS

Our study has several limitations. First, our original objective was describing the various approaches to video screen visualization in the published literature on VL, but the rarity of detailed information on the use of the video laryngoscope prevented us from accomplishing this objective. Second, although we attempted to maximize sensitivity in
### TABLE 2  Included studies

| Study                  | Study design | Setting | Age (in years unless specified otherwise) | Device(s) | Visualization | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|------------------------|--------------|---------|------------------------------------------|-----------|---------------|-------------------------------------------------------------------------|----------------------------------------------------------|
| Studies in which video screen visualization was reported |
| Boedeker et al., 2008  | Interventionsal | OR      | Does not specify                         | C-Mac     | Protocol prescribed direct and indirect glottic visualization with video laryngoscope. Video screen unavailable to proceduralist during direct laryngoscopy. | Self-report                                              | High risk                                               |
| Brown et al., 2010     | Observational | ED      | ≥15                                      | C-Mac     | Protocol prescribed direct and indirect glottic visualization with video laryngoscope. Video screen unavailable to proceduralist during direct laryngoscopy. | Self-report                                              | High risk                                               |
| Byhahn et al., 2010    | Interventional | OR      | Adults                                   | C-Mac     | Protocol prescribed direct glottic visualization by proceduralist and indirect glottic visualization by independent observer, then protocol prescribed tube delivery under indirect visualization. Unclear if screen turned away from proceduralist. | Direct view based on self-report, indirect view based on independent observer | High risk                                               |
| Cavus et al., 2011     | Interventional | Pre-hospital | All                                      | C-Mac     | Screen visualization reported in yes/no fashion. | Self-report                                              | High risk                                               |
| Cavus et al., 2018     | Randomized trial | Pre-hospital | > 18                                     | C-Mac, AP Advance | Screen visualization reported in yes/no fashion. | Self-report                                              | High risk                                               |
| Cengiz and Yilmaz, 2019 | Randomized trial | OR      | 18-75                                    | C-Mac     | Protocol prescribed indirect laryngoscopy. | Independent observer recorded intubation success, not visualization patterns | High risk                                               |
| De Jong et al., 2013   | Interventional | ICU     | ≥18                                      | McGrath Mac | Screen visualization reported in yes/no fashion. | Self-report                                              | High risk                                               |
| De Jong et al., 2021   | QI            | OR      | ≥18                                      | C-Mac, McGrath Mac, AP Venner | Protocol prescribed direct and indirect glottic visualization with video laryngoscope. Based on the protocol, it is assumed that most proceduralists likely intubated via indirect visualization, however the true visualization patterns of proceduralist were not specifically reported. | Self-report                                              | High risk                                               |
| Dodd et al., 2019      | Observational | ED      | ≥18                                      | C-Mac     | Screen visualization reported in yes/no fashion. | Overhead video review                                      | Low risk                                                 |

(Continues)
TABLE 2 (Continued)

| Study                          | Study design | Setting | Age (in years unless specified otherwise) | Device(s) | Visualization | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|--------------------------------|--------------|---------|-------------------------------------------|-----------|---------------|----------------------------------------------------------------------|----------------------------------------------------------|
| Driver et al., 2016<sup>63</sup> | Randomized trial | ED      | Adults                                    | C-Mac     | Proceduralists randomized to either direct or indirect visualization. When randomized to direct visualization, the video screen was made unavailable to proceduralist. Video screen visualization and protocol deviations in both directions (ie, were randomized to direct visualization and viewed video screen or were randomized to indirect visualization and did not view video screen or did not use video laryngoscope) were reported. | Self-report | High risk |
| Driver et al., 2017<sup>64</sup> | Observational | ED      | ≥18                                       | C-Mac     | Screen visualization reported in yes/no fashion. | Overhead video review | Low risk |
| Driver et al., 2018<sup>11</sup> | Randomized trial | ED      | ≥18                                       | C-Mac, Glidescope Mac | Screen visualization reported as “screen never used,” “screen viewed for entire attempt,” or “screen viewed during passage of tube or bougie into glottis.” | Self-report | High risk |
| Elattar et al., 2020<sup>69</sup> | Randomized trial | OR      | ≤2                                        | C-Mac     | When the C-Mac was used, a screenshot was taken using the C-Mac device and additionally, a photograph was taken through the oropharynx simulating a direct view. Despite this, how the proceduralist actually visualized the glottis (direct vs indirect) was not reported. | Still-image photographs | High risk |
| García-Pintos et al., 2021<sup>75</sup> | Observational | Pre-hospital | ≥18                                      | C-Mac     | Protocol prescribed direct and indirect glottic visualization with video laryngoscope. Video screen “obscured or turned away from proceduralist’s field of view” during direct laryngoscopy. Did not report screen visualization patterns during tube delivery. | Self-report | High risk |
| Glasheen et al., 2020<sup>79</sup> | Observational | Pre-hospital | All                                      | McGrath Mac | Screen visualization reported in yes/no fashion. | Self-report | High risk |

(Continues)
| Study                           | Study design | Setting     | Age (in years unless specified otherwise) | Device(s) | Visualization                                                                 | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|--------------------------------|--------------|-------------|-----------------------------------------|-----------|-------------------------------------------------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------|
| Guyette et al., 2013<sup>10</sup> | Interventional | Pre-hospital | ≥18                                      | C-Mac     | Screen visualization reported as only screen, mostly screen, mostly direct or only direct | Self-report                                                                 | High risk                                             |
| Hackel et al., 2009<sup>8</sup>   | Observational | OR          | Infants                                 | Storz DCI | Case series of seven difficult infant intubations. Screen visualization patterns (direct vs indirect) described in six of the seven cases. | Self-report                                                                 | High risk                                             |
| Hofstetter et al., 2006<sup>91</sup> | Interventional | OR          | ≥18                                      | Storz DCI | Protocol prescribed direct and indirect glottic visualization with video laryngoscope. | Self-report                                                                 | High risk                                             |
| Hossfeld et al., 2015<sup>92</sup> | Observational | Pre-hospital | All                                      | C-Mac     | Protocol prescribed direct and indirect glottic visualization with video laryngoscope. | Self-report                                                                 | High risk                                             |
| Hossfeld et al., 2016<sup>93</sup> | Observational | Pre-hospital | All                                      | C-Mac     | Protocol prescribed direct and indirect glottic visualization with video laryngoscope. | Self-report                                                                 | High risk                                             |
| Hossfeld et al., 2020<sup>94</sup> | Observational | Pre-hospital | All                                      | C-Mac     | Direct and indirect laryngoscopic views reported in the majority of cases. Otherwise, did not report visualization patterns of proceduralist. | Self-report                                                                 | High risk                                             |
| Howard- Quijano et al., 2008<sup>95</sup> | Interventional | OR          | ≥12                                      | C-Mac     | Video screen unavailable to proceduralist                                     | Intraoral video recordings                                           | Low risk                                              |
| Hwang et al., 2018<sup>96</sup>   | Observational | ED          | ≥18                                      | C-Mac     | Screen unavailable to proceduralist on first attempt. If subsequent attempt(s) needed, screen visualization was permitted but not reported on. | Self-report                                                                 | High risk                                             |
| Jungbauer et al., 2009<sup>106</sup> | Randomized trial | OR          | >18                                      | Storz Berci-Kaplan | Protocol prescribed direct or indirect glottic visualization with video laryngoscope. | Self-report                                                                 | High risk                                             |
| Kaplan et al., 2006<sup>107</sup> | Interventional | OR          | ≥18                                      | C-Mac     | Protocol prescribed direct glottic visualization with video laryngoscope followed by indirect glottic visualization with video laryngoscope. | Self-report                                                                 | High risk                                             |
| Knapp et al., 2021<sup>116</sup>  | Observational | Pre-hospital | All                                      | C-Mac     | Screen visualization reported in yes/no fashion.                                | Intraoral video and self-report                                     | High risk                                             |

(Continues)
| Study                        | Study design | Setting | Age (in years unless specified otherwise) | Device(s) | Visualization                                                                 | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|------------------------------|-------------|---------|------------------------------------------|-----------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------|
| Lascarrou et al., 2017       | Randomized trial | ICU     | ≥18                                      | McGrath Mac | Protocol prescribed indirect glottic visualization and tube delivery using video laryngoscope on initial attempt. On subsequent attempts, direct versus indirect visualization was self-reported in a yes/no fashion. | Self-report                                                        | High risk                                                  |
| Law et al., 2020             | Observational | NICU    | Neonates                                 | C-Mac     | Only 2 cases in this observational study were performed with video laryngoscope. Although gaze switches between patient and equipment were reported on for the whole group, the 2 cases in which a video laryngoscope was used were not reported on individually. | Video recordings using eye tracking device (glasses)                      | Low risk                                                   |
| Macke et al., 2020           | Randomized trial | Pre-hospital | ≥18                                      | C-Mac     | Screen visualization reported in yes/no fashion.                               | Self-report                                                        | High risk                                                  |
| Marrel et al., 2007          | Randomized trial | OR      | Adults                                    | X-Lite    | For all patients, glottic visualization was performed both directly and indirectly using a video laryngoscope. Then for tube delivery, 1 group was allowed to use the video screen for indirect visualization and the other group had the video screen made unavailable to them and thus had to perform tube delivery with direct visualization. | Self-report                                                        | High risk                                                  |
| Meininger et al., 2010       | Interventional | OR      | Adults                                    | C-Mac     | Protocol prescribed direct glottic visualization by proceduralist and indirect glottic visualization by independent observer, then protocol prescribed tube delivery under indirect visualization. Unclear if screen turned away from proceduralist. | Direct view based on self-report, indirect view based on independent observer | High risk                                                  |
| Mosier et al., 2013          | Observational | ED      | ≥18                                      | C-Mac     | Screen visualization reported in yes/no fashion.                               | Self-report                                                        | High risk                                                  |

(Continues)
| Study                        | Study design | Setting               | Age (in years unless specified otherwise) | Device(s) | Visualization                                                                 | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|-----------------------------|--------------|-----------------------|------------------------------------------|-----------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------|
| Normand et al., 2018        | Observational| OR                    | >18                                      | McGrath Mac | Protocol prescribed direct glottic visualization performed with video laryngoscopy screen covered. If direct view was CL IV (or attempt utilizing direct visualization was unsuccessful), the proceduralist was permitted to use indirect visualization, which was reported on. | Self-report                                                      | High risk                                                   |
| O'Shea et al., 2015         | Randomized trial | Delivery Room/NICU | Neonates                                | Modified Miller | Video screen unavailable to proceduralist                                    | Intraoral video recordings                                               | Low risk                                                    |
| O'Shea et al., 2018         | Observational | NICU                  | Neonates                                | Modified Miller | Video screen unavailable to proceduralist                                    | Intraoral video recordings                                               | Low risk                                                    |
| Piepho et al., 2011         | Interventional| OR                    | ≥18                                      | C-Mac      | Protocol prescribed indirect laryngoscopy only. No other visualization patterns reported. | Unclear                                                            | High risk                                                   |
| Pieters et al., 2018        | Interventional| OR                    | ≥18                                      | C-Mac      | Protocol prescribed direct glottic visualization with video laryngoscope followed by indirect glottic visualization with video laryngoscope. | Photographs of glottis and self-report                                  | High risk                                                   |
| Raimann et al., 2017        | Interventional| OR                    | Weight-based: <10 kg                     | C-Mac      | Protocol prescribed direct visualization by proceduralist while second observer graded indirect view on video screen. Does not explicitly state that video screen was unavailable to proceduralist, only that direct visualization was performed. | Direct observation and self-report                                   | High risk                                                   |
| Raimann et al., 2019        | Interventional| OR                    | 18-80                                    | C-Mac      | Protocol prescribed glottic visualization by direct view with video laryngoscope with video screen unavailable to proceduralist. Then indirect visualization was "allowed" and screen was available to proceduralist. Reported view quality from direct and indirect visualization but otherwise did not report visualization patterns. | Self-report                                                | High risk                                                   |
| Sainsbury et al., 2017      | Randomized trial | OR                    | Adults                                   | Glidescope direct, C-Mac | Video screen unavailable to proceduralist                                    | Direct observation                                              | Low risk                                                   |
| Study                        | Study design | Setting     | Age (in years unless specified otherwise) | Device(s) | Visualization                                                                 | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|-----------------------------|--------------|-------------|-------------------------------------------|-----------|-------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------|
| Sakles et al., 2012<sup>176</sup> | Observational | ED          | All                                       | C-Mac     | Screen visualization reported in yes/no fashion.                              | Self-report                                                              | High risk                                                |
| Sakles et al., 2015<sup>179</sup> | Observational | ED          | All                                       | C-Mac     | Screen visualization reported in yes/no fashion.                              | Self-report                                                              | High risk                                                |
| Sakles et al., 2016<sup>181</sup> | Observational | ED          | Adults                                    | C-Mac     | Screen visualization reported in yes/no fashion.                              | Self-report                                                              | High risk                                                |
| Saran et al., 2019<sup>183</sup> | Interventional | OR         | <6 mo                                      | C-Mac     | Attempts in which video screen unavailable to proceduralists or supervisors were compared to attempts in which video screen was available to proceduralists and supervisors. Did not report visualization patterns for attempts in which video screen was available. | Unclear                                                                  | High risk                                                |
| Sørensen and Holm-Knudsen et al., 2012<sup>192</sup> | Interventional | OR         | <2                                        | Storz DCI | Protocol prescribed that proceduralists only perform indirect visualization when using Storz video laryngoscope. Visualization patterns were not described further. | Intraoral video recordings                                               | High risk                                                |
| Vadi et al., 2017<sup>199</sup> | Randomized trial | OR         | <2                                        | Storz DCI | Reported hat in 2 of the patients randomized to Storz VL group, the proceduralist did not view the video screen. No additional visualization patterns were reported in cases in which screen was viewed. | Self-report and independent observation                              | High risk                                                |
| Weiss et al., 2001<sup>205</sup> | Interventional | OR         | <10                                       | Modified Miller VL | Video screen unavailable to proceduralist | Self-report                                                              | Low risk                                                 |
| Zhang et al., 2021<sup>213</sup> | Randomized trial | OR         | 21-80                                     | C-Mac     | Protocol prescribed indirect laryngoscopy                                    | Self-report                                                              | High risk                                                |
| **Studies in which video screen visualization was not reported** | | | | | | | |
| Abid et al., 2020<sup>15</sup> | Observational | Pre-hospital | ≤18                                       | C-Mac     | Not reported                                                                 |                                                                           |                                                          |
| Aggarwal et al., 2019<sup>16</sup> | Randomized trial | OR         | 25-60                                     | C-Mac     | Not reported                                                                 |                                                                           |                                                          |
| Ahmed et al., 2017<sup>17</sup> | Randomized trial | OR         | 20-60                                     | C-Mac     | Not reported                                                                 |                                                                           |                                                          |
| Akbar et al., 2015<sup>18</sup> | Randomized trial | OR         | 18-60                                     | C-Mac     | Not reported                                                                 |                                                                           |                                                          |
| Akbas et al., 2019<sup>19</sup> | Randomized trial | OR         | 18-65                                     | McGrath MAC, C-MAC | Not reported                                                            |                                                                           |                                                          |

(Continues)
| Study                        | Study design | Setting | Age (in years unless specified otherwise) | Device(s) | Visualization | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|-----------------------------|--------------|---------|-------------------------------------------|-----------|---------------|---------------------------------------------------------------------|----------------------------------------------------------|
| Altun et al., 2018          | Randomized trial | OR | 18-65 | C-Mac | Not reported |                                                                     |                                                         |
| Alvis et al., 2015          | Randomized trial | OR | Adults | McGrath Mac | Not reported |                                                                     |                                                         |
| Amalric et al., 2020        | Observational | ICU | Adults | McGrath Mac | Not reported |                                                                     |                                                         |
| Amaniti et al., 2019        | Observational | OR | ≥18   | C-Mac | Not reported |                                                                     |                                                         |
| Ångerman et al., 2018       | Observational | Pre-hospital | ≥18 | C-Mac | Not reported |                                                                     |                                                         |
| Arasu et al., 2020          | Randomized trial | OR | 18-60 | C-Mac | Not reported |                                                                     |                                                         |
| Aziz and Bambrink, 2011     | Observational | OR | Adults | C-Mac | Not reported |                                                                     |                                                         |
| Aziz et al., 2012           | Randomized trial | OR | ≥18   | C-Mac | Not reported |                                                                     |                                                         |
| Aziz et al., 2016           | Observational | OR | >18   | C-Mac | Not reported |                                                                     |                                                         |
| Bakshi et al., 2019         | Randomized trial | OR | Adults | McGrath Mac | Not reported |                                                                     |                                                         |
| Bensghir et al., 2013       | Randomized trial | OR | >18   | X-Lite | Not reported |                                                                     |                                                         |
| Bhat et al., 2013           | Randomized trial | OR | ≥18   | C-Mac | Not reported |                                                                     |                                                         |
| Bhat et al., 2015           | Randomized trial | OR | ≥18   | C-Mac | Not reported |                                                                     |                                                         |
| Blajic et al., 2019         | Randomized trial | OR | All | C-Mac | Not reported |                                                                     |                                                         |
| Boehringer et al., 2015     | Observational | Pre-hospital | All | C-Mac | Not reported |                                                                     |                                                         |
| Breeman et al., 2020        | Observational | Pre-hospital | ≥18 | McGrath MAC | Not reported |                                                                     |                                                         |
| Brown et al., 2015          | Observational | ED | ≥15 | C-Mac, Video Macintosh | Not reported |                                                                     |                                                         |
| Brown et al., 2020          | Observational | ED | >14 | Multiple Standard Geometry VLs | Not reported |                                                                     |                                                         |
| Brück et al., 2015          | Randomized trial | OR | >18 | C-Mac | Not reported |                                                                     |                                                         |
| Burjek et al., 2017         | Observational | OR | <18 | C-Mac | Not reported |                                                                     |                                                         |
| Burnett et al., 2014        | Interventional | Pre-hospital | ≥18 | C-Mac | Not reported |                                                                     |                                                         |
| Study                        | Study design     | Setting      | Age (in years unless specified otherwise) | Device(s) | Visualization | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|------------------------------|------------------|--------------|------------------------------------------|-----------|---------------|-------------------------------------------------------------------------|--------------------------------------------------|
| Çaparlar et al., 2019<sup>43</sup> | Randomized trial | OR           | 18-65                                    | C-Mac     | Not reported   |                                                                          |                                                  |
| Carlson et al., 2012<sup>44</sup> | Observational    | Pre-hospital | All                                      | C-Mac     | Not reported   |                                                                          |                                                  |
| Cavus et al., 2010<sup>45</sup>  | Interventional   | OR           | >18                                      | C-Mac     | Not reported   |                                                                          |                                                  |
| Cavus et al., 2011<sup>46</sup>  | Randomized trial | OR           | ≥18                                      | C-Mac     | Not reported   |                                                                          |                                                  |
| Chan et al., 2021<sup>50</sup>   | Observational    | ED           | ≥21                                      | C-Mac     | Not reported   |                                                                          |                                                  |
| Chan-drashekariah et al., 2017<sup>51</sup> | Randomized trial | OR           | 18-65                                    | C-Mac     | Not reported   |                                                                          |                                                  |
| Cheong et al., 2018<sup>52</sup> | Observational    | OR           | Adults                                   | C-Mac     | Not reported   |                                                                          |                                                  |
| Colak et al., 2019<sup>53</sup>  | Randomized trial | OR           | ≥65                                      | McGrath Mac | Not reported   |                                                                          |                                                  |
| Corso et al., 2020<sup>54</sup>  | Observational    | ED           | Adults                                   | I-view    | Not reported   |                                                                          |                                                  |
| Couto et al., 2020<sup>55</sup>  | Observational    | ED           | 1-18                                     | McGrath Mac | Not reported   |                                                                          |                                                  |
| Couto et al., 2021<sup>56</sup>  | Interventional   | ED           | 1-18                                     | McGrath Mac | Not reported   |                                                                          |                                                  |
| Deguchi et al., 2016<sup>59</sup> | Randomized trial | OR           | 20-85                                    | McGrath Mac | Not reported   |                                                                          |                                                  |
| Desai et al., 2015<sup>60</sup>  | Observational    | ED           | ≥18                                      | C-Mac     | Not reported   |                                                                          |                                                  |
| Dey et al., 2020<sup>61</sup>    | Randomized trial | ICU          | ≥18                                      | C-Mac     | Not reported   |                                                                          |                                                  |
| Driver et al., 2019<sup>65</sup> | Observational    | ED           | All                                      | C-Mac     | Not reported   |                                                                          |                                                  |
| Driver et al., 2020<sup>66</sup> | Observational    | ED           | ≥14                                      | C-Mac, Glidescope Mac blades | Not reported |                                                                          |                                                  |
| Eberlein et al., 2019<sup>57</sup> | Observational    | Pre-hospital | All                                      | McGrath Mac | Not reported   |                                                                          |                                                  |
| Eisenberg et al., 2016<sup>68</sup> | Observational    | ED           | 0-18                                     | C-Mac     | Not reported   |                                                                          |                                                  |
| Ezhar et al., 2018<sup>70</sup>  | Randomized trial | OR           | 18-60                                    | C-Mac     | Not reported   |                                                                          |                                                  |
| Fiadjo et al., 2016<sup>71</sup> | Observational    | OR           | <18                                      | C-Mac     | Not reported   |                                                                          |                                                  |
| Fogg et al., 2012<sup>72</sup>   | Observational    | ED           | Did not specify                          | C-Mac     | Not reported   |                                                                          |                                                  |
| Fogg et al., 2016<sup>73</sup>   | Observational    | ED           | All                                      | C-Mac     | Not reported   |                                                                          |                                                  |
| Study                          | Study design | Setting | Age (in years unless specified otherwise) | Device(s) | Visualization | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|-------------------------------|--------------|---------|------------------------------------------|-----------|---------------|---------------------------------------------------------------------|-----------------------------------------------------------|
| Garcia-Marcinkiewicz et al., 2020 | Randomized trial | OR      | <12 months                               | C-Mac     |               |                                                                     | Not reported                                              |
| Gaszynski, 2017               | Observational | OR      | Adults                                   | McGrath Mac |               |                                                                     | Not reported                                              |
| Gaszynski, 2021               | Randomized trial | OR      | Did not specify                           | McGrath Mac, I-view |               |                                                                     | Not reported                                              |
| Giraudon et al., 2017         | Randomized trial | OR      | Weight-based: 10-20 kg                    | McGrath Mac |               |                                                                     | Not reported                                              |
| Goksu et al., 2016            | Randomized trial | ED      | >16                                      | C-Mac     |               |                                                                     | Not reported                                              |
| Grant et al., 2021            | Observational | ED      | All                                      | C-Mac     |               |                                                                     | Not reported                                              |
| Green-Hopkins et al., 2015    | Observational | ED      | <21                                      | C-Mac     |               |                                                                     | Not reported                                              |
| Grunwell et al., 2017         | Interventionsal | OR      | Adults                                   | Hybrid 1.0 VDL |               |                                                                     | Not reported                                              |
| Gümöş et al., 2014            | Randomized trial | OR      | 18-65                                    | Storz DCI |               |                                                                     | Not reported                                              |
| Gupta et al., 2013            | Randomized trial | OR      | 18-65                                    | C-Mac     |               |                                                                     | Not reported                                              |
| Gupta et al., 2015            | Observational | OR      | All                                      | C-Mac     |               |                                                                     | Not reported                                              |
| Gupta et al., 2020            | Randomized trial | OR      | 18-60                                    | C-Mac     |               |                                                                     | Not reported                                              |
| Hoşten et al., 2012           | Randomized trial | OR      | Adults                                   | Storz DCI |               |                                                                     | Not reported                                              |
| Hodgetts et al., 2011         | Randomized trial | OR      | ≥18                                      | C-Mac     |               |                                                                     | Not reported                                              |
| Hypes et al., 2016            | Observational | ICU     | Adults                                   | C-Mac, McGrath Mac |               |                                                                     | Not reported                                              |
| Hypes et al., 2017            | Observational | ICU     | Adults                                   | C-Mac, McGrath Mac |               |                                                                     | Not reported                                              |
| Ing et al., 2017              | Randomized trial | OR      | 18-80                                    | McGrath Mac |               |                                                                     | Not reported                                              |
| Ives et al., 2021             | Observational | ICU     | Neonates                                 | C-Mac     |               |                                                                     | Not reported                                              |
| Jain et al., 2016             | Randomized trial | OR      | 18-60                                    | C-Mac     |               |                                                                     | Not reported                                              |
| Study | Study design | Setting | Age (in years unless specified otherwise) | Device(s) | Visualization | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|-------|--------------|---------|------------------------------------------|-----------|--------------|---------------------------------------------------------------|--------------------------------------------------|
| Javaherforooshzadeh and Gharacheh, 2020 | Randomized trial | OR | 1-5 | Infant view | Not reported |
| Ji et al., 2018 | Randomized trial | OR | > 18 | C-Mac | Not reported |
| Jones et al., 2013 | Observational | Non-OR or ED | Adults | C-Mac | Not reported |
| Joshi et al., 2017 | Observational | ICU | Adults | C-Mac, McGrath Mac | Not reported |
| Kaji et al., 2019 | Observational | ED | < 16 | C-Mac | Not reported |
| Kaur et al., 2020 | Randomized trial | OR | 20-70 | McGrath Mac | Not reported |
| Kerrey et al., 2015 | QI | ED | Children | C-Mac | Not reported |
| Kido et al., 2015 | Randomized trial | OR | 20-85 | McGrath Mac | Not reported |
| Kilicaslan et al., 2014 | Observational | OR | > 18 | C-Mac | Not reported |
| Kim et al., 2016 | Randomized trial | OR | 3-7 | McGrath Mac | Not reported |
| Kim et al., 2018 | Randomized trial | OR | 1-10 | McGrath MAC | Not reported |
| Kleine-Brueggeney et al., 2014 | Randomized trial | OR | ≥18 | McGrath Mac | Not reported |
| Kleine-Brueggeney et al., 2014 | Randomized trial | OR | Adults | AP advance | Not reported |
| Komasawa et al., 2017 | Randomized trial | OR | 20-85 | McGrath Mac | Not reported |
| Kontouli et al., 2013 | Interventional | OR | ≥18 | C-Mac | Not reported |
| Koylu Gencay et al., 2019 | Randomized trial | OR | < 2 | C-Mac | Not reported |
| Kreutziger et al., 2019 | Randomized trial | Pre-hospital | ≥18 | McGrath Mac | Not reported |
| Law et al., 2015 | Observational | OR | Adults | C-Mac | Not reported |

(Continues)
| Study                        | Study design     | Setting    | Age (in years unless specified otherwise) | Device(s) | Visualization | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|-----------------------------|------------------|------------|------------------------------------------|-----------|---------------|------------------------------------------------------------------------|-----------------------------------------------------------|
| Lee et al., 2016[122]       | Randomized trial | OR         | 18-60                                    | C-Mac     | Not reported   |                                                                        |                                                            |
| Lees et al., 2013[123]      | Interventional   | OR         | <17                                      | Storz DCI | Not reported   |                                                                        |                                                            |
| Lim et al., 2020[124]       | Randomized trial | OR         | 19-65                                    | McGrath Mac | Not reported |                                                                        |                                                            |
| Lin et al., 2012[125]       | Randomized trial | OR         | ≥18                                      | CEL-100   | Not reported   |                                                                        |                                                            |
| Lin et al., 2012[126]       | Interventional   | OR         | Adults                                   | CEL-100   | Not reported   |                                                                        |                                                            |
| Loughnan et al., 2012[127]  | Interventional   | OR         | >18                                      | C-Mac     | Not reported   |                                                                        |                                                            |
| Loughnan et al., 2019[128]  | Randomized trial | OR         | ≥18                                      | McGrath Mac | Not reported |                                                                        |                                                            |
| Louka et al., 2018[129]     | Interventional   | Pre-hospital | Did not specify                          | C-Mac     | Not reported   |                                                                        |                                                            |
| Louro et al., 2020[130]     | Observational    | ED         | All                                      | C-Mac     | Not reported   |                                                                        |                                                            |
| Maassen et al., 2009[131]   | Randomized trial | OR         | ≥18                                      | Storz DCI | Not reported   |                                                                        |                                                            |
| Maassen et al., 2012[132]   | Interventional   | OR         | Adults                                   | C-Mac     | Not reported   |                                                                        |                                                            |
| Mackie et al., 2020[134]    | Observational    | ED         | ≥15                                      | C-Mac     | Not reported   |                                                                        |                                                            |
| Macnair et al., 2009[135]   | Randomized trial | OR         | 2-16                                     | Berci-Kaplan VL | Not reported |                                                                        |                                                            |
| Marsaban et al., 2017[137]  | Randomized trial | OR         | 18-65                                    | C-Mac     | Not reported   |                                                                        |                                                            |
| Michailidou et al., 2015[139]| Observational    | ED         | All                                      | C-Mac     | Not reported   |                                                                        |                                                            |
| Miller et al., 2020[140]    | Observational    | ED         | Children                                 | C-Mac     | Not reported   |                                                                        |                                                            |
| Min et al., 2019[141]       | Observational    | ED         | ≥18                                      | C-Mac     | Not reported   |                                                                        |                                                            |
| Modir et al., 2017[142]     | Randomized trial | OR         | >15                                      | C-Mac     | Not reported   |                                                                        |                                                            |
| Monette et al., 2019[143]   | Observational    | ED         | All                                      | C-Mac     | Not reported   |                                                                        |                                                            |
| Mosier et al., 2013[145]    | Observational    | ICU        | Adults                                   | C-Mac     | Not reported   |                                                                        |                                                            |

(Continues)
| Study                  | Study design       | Setting       | Age (in years unless specified otherwise) | Device(s) | Visualization | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|------------------------|--------------------|---------------|-------------------------------------------|-----------|---------------|------------------------------------------------------------------------|-------------------------------------------------------------|
| Moussa et al., 2016    | Randomized trial   | ICU           | Neonates                                  | C-Mac     | Not reported   |                                                                        |                                                             |
| Mutlak et al., 2014    | Observational      | OR            | Weight-based: ≤10                         | Storz C-MAC | Not reported   |                                                                        |                                                             |
| Naito et al., 2016     | Observational      | Pre-hospital  | All                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Nakanishi et al., 2018 | Randomized trial   | OR            | 20-85                                     | McGrath Mac | Not reported   |                                                                        |                                                             |
| Narayan et al., 2018   | Interventional     | OR            | Did not specify                           | Modified Mac VL | Not reported   |                                                                        |                                                             |
| Nausheen et al., 2019  | Observational      | Pre-hospital  | All                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Ng et al., 2012        | Randomized trial   | OR            | >18                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Ninan et al., 2016     | Randomized trial   | OR            | ≥18                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Noppens et al., 2012   | Interventional     | ICU           | Adults                                    | C-Mac     | Not reported   |                                                                        |                                                             |
| O’Connell et al., 2019 | Observational     | ED            | <21                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Okamoto et al., 2019   | Observational      | ED            | ≥18                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Pacheco et al., 2019   | Observational      | ED            | <18                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Pallin et al., 2016    | Observational      | ED            | ≤15                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Paul Weng et al., 2020 | Observational      | ED            | All                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Peyton et al., 2021    | Observational      | OR            | <18                                       | C-Mac, Storz DCI, Glidescope Direct, Mcgrath Mac | Not reported   |                                                                        |                                                             |
| Pieters et al., 2015   | Randomized trial   | OR            | ≥18                                       | C-Mac     | Not reported   |                                                                        |                                                             |
| Poupirt et al., 2018   | Observational      | NICU          | Neonates                                  | C-Mac     | Not reported   |                                                                        |                                                             |
| Purugganan et al., 2012 | Observational     | OR            | >18                                       | C-Mac, McGrath Mac | Not reported   |                                                                        |                                                             |
| Study                        | Study design | Setting | Age (in years unless specified otherwise) | Device(s) | Visualization | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|-----------------------------|-------------|---------|------------------------------------------|-----------|---------------|-------------------------------------------------------------------|----------------------------------------------------------|
| Puthenveettil et al., 2021  | Randomized trial | OR      | 18-60                                     | C-Mac     | Not reported   |                                                                                  |                                                          |
| Rajasekhar et al., 2020     | Randomized trial | OR      | 18-60                                     | C-Mac     | Not reported   |                                                                                  |                                                          |
| Rhode et al., 2016          | QI          | Pre-hospital | ≥15                                      | McGrath Mac | Not reported  |                                                                                  |                                                          |
| Rope et al., 2008           | Observational | OR      | Did not specify                          | X-Lite    | Not reported   |                                                                                  |                                                          |
| Rowland et al., 2019        | Observational | OR      | All                                       | C-Mac     | Not reported   |                                                                                  |                                                          |
| Sakles et al., 2014         | Observational | ED      | ≥18                                       | C-Mac     | Not reported   |                                                                                  |                                                          |
| Sakles et al., 2015         | Observational | ED      | ≥18                                       | C-Mac     | Not reported   |                                                                                  |                                                          |
| Sakles et al., 2016         | Observational | ED      | ≥18                                       | C-Mac     | Not reported   |                                                                                  |                                                          |
| Sakles et al., 2017         | Observational | ED      | All                                       | C-Mac     | Not reported   |                                                                                  |                                                          |
| Sarkilar et al., 2015       | Randomized trial | OR      | > 18                                      | C-Mac     | Not reported   |                                                                                  |                                                          |
| Schalk et al., 2012         | Interventional | ED      | Adults                                   | C-Mac     | Not reported   |                                                                                  |                                                          |
| Serocki et al., 2010        | Interventional | OR      | ≥18                                       | Storz DCI | Not reported   |                                                                                  |                                                          |
| Shravanakshmi et al., 2017  | Randomized trial | OR      | 18-60                                     | C-Mac     | Not reported   |                                                                                  |                                                          |
| Singh et al., 2017          | Randomized trial | OR      | 1-6                                      | C-Mac     | Not reported   |                                                                                  |                                                          |
| Sinha et al., 2016          | Randomized trial | OR      | Weight-based: 3-15 kg                    | C-Mac     | Not reported   |                                                                                  |                                                          |
| Sinha et al., 2019          | Interventional | OR      | 4-14                                      | C-Mac     | Not reported   |                                                                                  |                                                          |
| Sinha et al., 2019          | Observational | OR      | ≤60 weeks corrected gestational age       | C-Mac     | Not reported   |                                                                                  |                                                          |
| Steel et al., 2021          | QI          | Pre-hospital | All                                      | McGrath Mac | Not reported  |                                                                                  |                                                          |
| Sulser et al., 2016         | Randomized trial | ED      | 18-99                                     | C-Mac     | Not reported   |                                                                                  |                                                          |
| Suzuki et al., 2019         | Observational | ED      | All                                       | McGrath Mac | Not reported  |                                                                                  |                                                          |

(Continues)
| Study                        | Study design | Setting        | Age (in years unless specified otherwise) | Device(s) | Visualization                  | Method of data collection (for studies in which visualization reported) | Risk of bias (for studies in which visualization reported) |
|-----------------------------|--------------|----------------|-------------------------------------------|-----------|---------------------------------|------------------------------------------------------------------------|--------------------------------------------------|
| Swain et al., 2020          | Interventional | OR             | 18-65                                     | C-Mac     | Not reported                    |                                                                         |                                                  |
| Thion et al., 2018          | Randomized   | OR             | 18-80                                     | McGrath Mac | Not reported                  |                                                                         |                                                  |
| Vadi et al., 2016           | Randomized   | OR             | <2                                        | Storz DCI | Not reported                    |                                                                         |                                                  |
| Van Oeveren et al., 2017    | Observational | ED             | All                                       | C-Mac     | Not reported                    |                                                                         |                                                  |
| Vanderhal et al., 2009      | Observational | Delivery Room/NICU | Neonates | Modified Miller VL | Not reported |                                                                         |                                                  |
| Vassiliadis et al., 2015    | Observational | ED             | All ages                                  | C-Mac     | Not reported                    |                                                                         |                                                  |
| Viflatten et al., 2009      | Randomized   | OR             | ≤4                                        | Storz DCI | Not reported                    |                                                                         |                                                  |
| Wallace et al., 2015        | Randomized   | OR             | > 16                                      | McGrath MAC | Not reported                |                                                                         |                                                  |
| Wong et al., 2017           | Observational | OR             | ≥21                                       | McGrath Mac | Not reported                |                                                                         |                                                  |
| Yatim et al., 2015          | Randomized   | OR             | Did not specify, primarily adults         | C-Mac     | Not reported                    |                                                                         |                                                  |
| Yokose et al., 2016         | Observational | OR             | ≥18                                       | McGrath Mac | Not reported                |                                                                         |                                                  |
| Yoon et al., 2020           | Randomized   | OR             | 20-80                                     | McGrath Mac | Not reported                |                                                                         |                                                  |
| Yoon et al., 2020           | Observational | OR             | 20-80                                     | McGrath Mac | Not reported                |                                                                         |                                                  |
| Yumul et al., 2016          | Randomized   | OR             | 18-80                                     | C-Mac     | Not reported                    |                                                                         |                                                  |
| Yumul et al., 2016          | Randomized   | OR             | 18-80                                     | Video-Mac | Not reported                    |                                                                         |                                                  |

Abbreviations: DCI, direct coupled interface; ED, emergency department; ICU, intensive care unit; NICU, neonatal intensive care unit; OR, operating room; QI, quality improvement; VL, video laryngoscope.

Our search terms and definitions, it is likely that additional studies exist in which a video laryngoscope with a standard geometry blade was used that were not included. However, we feel confident that based on the nature of the search strategy, the vast majority of studies evaluating VL as an intervention (and not just a study in which a video laryngoscope happened to be used) were identified and included. Finally, because our study group has extensive experience with video-based data collection across numerous studies focused on tracheal intubation, our interpretation of studies and the emphasis we placed on the need for video-based data collection is subject to potential biases.

5 DISCUSSION

This systematic review demonstrates that in the majority of published research in which a video laryngoscope equipped with a standard geometry blade was used, video screen visualization patterns were not reported whatsoever. In the minority (10%) of studies in which video screen visualization patterns were reported or others (5%) in which video screen visualization patterns could be reasonably inferred based on screen availability, video screen visualization was almost always reported in a yes/no fashion.
Cochrane reviews present mixed although generally favorable results for VL in terms of procedural success. Studies that have reported on patient outcomes with VL generally have reported either no difference or a reduction in adverse events when compared to DL. However, it is difficult to nearly impossible to interpret the true effects of an intervention when how the intervention was actually used is incompletely reported or not reported whatsoever. Knowing what investigators mean by VL is essential to interpreting the actual “treatment effect.” Product manufacturers have recommended a four-step technique for performing VL, highlighted by first inserting the video laryngoscope blade while looking into the patient's oropharynx, then indirectly viewing the epiglottis by viewing the video screen, then looking back at the patient's oropharynx for endotracheal tube insertion into the mouth, then indirectly viewing the completion of tube delivery by viewing the video screen again. This technique is rarely described in the published literature, and it is often unclear how video laryngoscopes equipped with standard geometry blades were functionally used in studies. There are a wide range of possibilities of how these devices could have been used in studies, including using a video laryngoscope only as a teaching tool with supervisors viewing the video screen while the proceduralist functionally uses the device to directly view the glottis, performing primarily direct glottic visualization but using the video screen as a backup in the event of poor direct glottic visualization, performing primarily indirect glottic visualization throughout both laryngoscopy and tube delivery and a myriad of hybrid approaches combining these techniques. This variation in technique is likely greater in acute care settings (EDs and intensive care units), as attempts are more likely to be complicated by patient instability, oropharyngeal trauma, gastric contents in the oropharynx, and pulmonary edema, all of which can contribute to deviations from planned airway approaches and unplanned microbehaviors (i.e., gaze switches) that are not necessarily intentional.

Valid data collection is essential to good research. Valid data collection during tracheal intubation, in particular when assessing the impact of VL, may require independent observers or video-based data collection, especially outside of controlled settings. Because video-based data collection is not always feasible (because of equipment availability, location of study, or size of study), valid data collection can be performed with self-reporting/chart review. However, a detailed description of the approach to data collection is needed, and assessing the reliability of data collection is essential.

Our review suggests that the entirety of the available literature on VL, across all settings, has substantial and potentially significant flaws. Prominent among these are a lack of detailed description of data collection, a lack of confirmation that a prescribed airway approach was actually performed, the use of self-reporting after emergency airway management, and a lack of specification of what VL actually means. We believe the results of our review should directly inform all future studies, in particular randomized trials, of video laryngoscopes, in all settings. We suggest the following be required components of all future video laryngoscope trials: detailed description of data collection, either assessment of the reliability of self-reporting for airway outcomes or (preferably) the use of video-based data collection, specification of what video/indirect/DL actually mean, and assessment during data collection of whether these pre-defined approaches were actually followed.

In conclusion, video screen visualization patterns are often incompletely reported or not reported at all in the published literature. Because of this, it is often difficult to nearly impossible to assess the impact of video laryngoscopes as an intervention. Future studies focused on VL should include detailed assessments of video screen visualization patterns (including fine details such as duration of screening viewing, proportion of attempts spent viewing screen and number of gaze switches between the patient and video screen), detailed descriptions of data collection, and use of objective methods of data collection (i.e., video-based) when available.

CONFLICTS OF INTEREST
The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS
PD and BK conceived and designed the study, performed literature search, data extraction, data analysis, and drafting of the manuscript. PD takes full responsibility for the paper as a whole.

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How to cite this article: Dean P, Kerrey B. Video screen visualization patterns when using a video laryngoscope for tracheal intubation: A systematic review. JACEP Open. 2022;3:e12630. https://doi.org/10.1002/emp2.12630