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SYSTEMATIC REVIEW/META-ANALYSIS

Airway

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

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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

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1 | INTRODUCTION

1.1 | Background

Video laryngoscopes are increasingly the most common devices used for tracheal intubation in US emergency departments (EDs).[1] Video laryngoscopy (VL) has consistently been reported to improve glottic visualization compared with direct laryngoscopy (DL).[2–4] When incorporated into high-volume training programs, there is some evidence that emergency medicine residents acquire airway skills better with a video laryngoscope.[5]

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.[2–4,6–8] 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.

2 | 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.[9]

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 nonstandard 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 nonstandard (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	Connell Energy Technology Co.	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
Truview	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.[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.[11] used proceduralist self-report to characterize screen

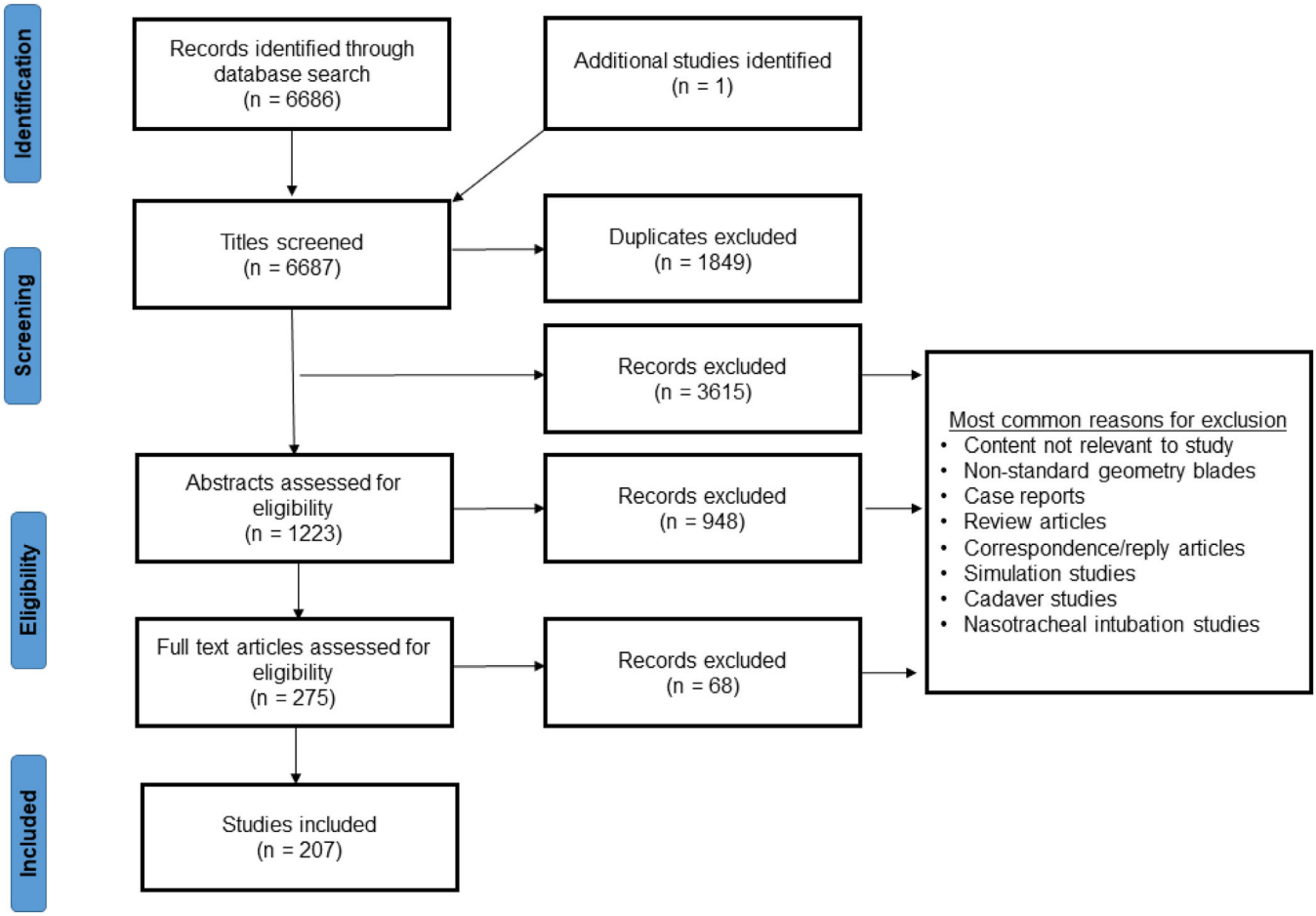

FIGURE 1 Summary of the selection process for the systematic review

visualization as screen never used, screen viewed for entire attempt, or screen viewed during passage of tube/bougie into glottis.

In addition to the 21 studies in which outcome data were explicitly reported, in 11 additional studies the approach to video screen visualization could be inferred based on screen availability to the proceduralist. In an additional 16 studies, methodologic data were available via a protocol in the methods section for how visualization was expected to be performed without reporting data collection on how the proceduralist actually interacted with the video screen. No identified study reported more specific patterns of video screen visualization, including duration of video screen viewing, proportion of attempts spent viewing the screen, and gaze switches between the video screen and the patient.

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.[10] and Driver et al.[11] Only 2 studies were based on video review, both overhead/external. Law et al.[12] 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.

3.4 | Risk of bias

In total, the 48 studies in which outcome or methodologic data were reported were assessed for risk of bias. The majority of assessed studies (n = 40) were categorized as high risk of bias. Eight studies were categorized as low risk and zero studies were categorized as unclear risk.

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[34]	Interventional	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[37]	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[42]	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[47]	Interventional	Pre-hospital	All	C-Mac	Screen visualization reported in yes/no fashion.	Self-report	High risk
Cavus et al., 2018[48]	Randomized trial	Pre-hospital	>18	C-Mac, AP Advance	Screen visualization reported in yes/no fashion.	Self-report	High risk
Cengiz and Yilmaz, 2019[49]	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[57]	Interventional	ICU	≥18	McGrath Mac	Screen visualization reported in yes/no fashion.	Self-report	High risk
De Jong et al., 2021[58]	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[62]	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[63]	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[64]	Observational	ED	≥18	C-Mac	Screen visualization reported in yes/no fashion.	Overhead video review	Low risk
Driver et al., 2018[11]	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[69]	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[75]	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[79]	Observational	Pre-hospital	All	McGrath Mac	Screen visualization reported in yes/no fashion.	Self-report	High 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)
Guyette et al., 2013[10]	Interventional	Pre-hospital	≥18	C-Mac	Screen visualization reported as only screen, mostly screen, mostly direct or only direct	Self-report	High risk
Hackell et al., 2009[88]	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[91]	Interventional	OR	≥18	Storz DCI	Protocol prescribed direct and indirect glottic visualization with video laryngoscope.	Self-report	High risk
Hossfeld et al., 2015[92]	Observational	Pre-hospital	All	C-Mac	Protocol prescribed direct and indirect glottic visualization with video laryngoscope.	Self-report	High risk
Hossfeld et al., 2016[93]	Observational	Pre-hospital	All	C-Mac	Protocol prescribed direct and indirect glottic visualization with video laryngoscope	Self-report	High risk
Hossfeld et al., 2020[94]	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[95]	Interventional	OR	≥12	C-Mac	Video screen unavailable to proceduralist	Intraoral video recordings	Low risk
Hwang et al., 2018[96]	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[106]	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[107]	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[116]	Observational	Pre-hospital	All	C-Mac	Screen visualization reported in yes/no fashion.	Intraoral video and self-report	High 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)
Lascarrou et al., 2017[6]	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[12]	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[133]	Randomized trial	Pre-hospital	≥18	C-Mac	Screen visualization reported in yes/no fashion.	Self-report	High risk
Marrel et al., 2007[136]	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[138]	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[144]	Observational	ED	≥18	C-Mac	Screen visualization reported in yes/no fashion.	Self-report	High 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)
Normand et al., 2018[155]	Observational	OR	>18	McGrath Mac	Protocol prescribed direct glottic visualization performed with video laryngoscope 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[157]	Randomized trial	Delivery Room/NICU	Neonates	Modified Miller	Video screen unavailable to proceduralist	Intraoral video recordings	Low risk
O'Shea et al., 2018[158]	Observational	NICU	Neonates	Modified Miller	Video screen unavailable to proceduralist	Intraoral video recordings	Low risk
Piepho et al., 2011[164]	Interventional	OR	≥18	C-Mac	Protocol prescribed indirect laryngoscopy only. No other visualization patterns reported.	Unclear	High risk
Pieters et al., 2018[166]	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[170]	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[171]	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[175]	Randomized trial	OR	Adults	Glidescope direct, C-Mac	Video screen unavailable to proceduralist	Direct observation	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)
Sakles et al., 2012[176]	Observational	ED	All	C-Mac	Screen visualization reported in yes/no fashion.	Self-report	High risk
Sakles et al., 2015[179]	Observational	ED	All	C-Mac	Screen visualization reported in yes/no fashion.	Self-report	High risk
Sakles et al., 2016[181]	Observational	ED	Adults	C-Mac	Screen visualization reported in yes/no fashion.	Self-report	High risk
Saran et al., 2019[183]	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[192]	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[199]	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[205]	Interventional	OR	<10	Modified Miller VL	Video screen unavailable to proceduralist	Self-report	Low risk
Zhang et al., 2021[213]	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[15]	Observational	Pre-hospital	≤18	C-Mac	Not reported		
Aggarwal et al., 2019[16]	Randomized trial	OR	25-60	C-Mac	Not reported		
Ahmed et al., 2017[17]	Randomized trial	OR	20-60	C-Mac	Not reported		
Akbar et al., 2015[18]	Randomized trial	OR	18-60	C-Mac	Not reported		
Akbas et al., 2019[19]	Randomized trial	OR	18-65	McGrath MAC, C-MAC	Not reported		

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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)
Altun et al., 2018[20]	Randomized trial	OR	18-65	C-Mac	Not reported		
Alvis et al., 2015[21]	Randomized trial	OR	Adults	McGrath Mac	Not reported		
Amalric et al., 2020[22]	Observational	ICU	Adults	McGrath Mac	Not reported		
Amaniti et al., 2019[23]	Observational	OR	≥18	C-Mac	Not reported		
Ångerman et al., 2018[24]	Observational	Pre-hospital	≥18	C-Mac	Not reported		
Arasu et al., 2020[25]	Randomized trial	OR	18-60	C-Mac	Not reported		
Aziz and Bambrink, 2011[26]	Observational	OR	Adults	C-Mac	Not reported		
Aziz et al., 2012[27]	Randomized trial	OR	≥18	C-Mac	Not reported		
Aziz et al., 2016[28]	Observational	OR	>18	C-Mac	Not reported		
Bakshi et al., 2019[29]	Randomized trial	OR	Adults	McGrath Mac	Not reported		
Bensghir et al., 2013[30]	Randomized trial	OR	>18	X-Lite	Not reported		
Bhat et al., 2013[31]	Randomized trial	OR	≥18	C-Mac	Not reported		
Bhat et al., 2015[32]	Randomized trial	OR	≥18	C-Mac	Not reported		
Blajic et al., 2019[33]	Randomized trial	OR	All	C-Mac	Not reported		
Boehringer et al., 2015[35]	Observational	Pre-hospital	All	C-Mac	Not reported		
Breeman et al., 2020[36]	Observational	Pre-hospital	≥18	McGrath MAC	Not reported		
Brown et al., 2015[38]	Observational	ED	≥15	C-Mac, Video Macintosh	Not reported		
Brown et al., 2020[7]	Observational	ED	>14	Multiple Standard Geometry VLs	Not reported		
Brück et al., 2015[39]	Randomized trial	OR	>18	C-Mac	Not reported		
Burjek et al., 2017[40]	Observational	OR	<18	C-Mac	Not reported		
Burnett et al., 2014[41]	Interventional	Pre-hospital	≥18	C-Mac	Not reported		

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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)
Çaparlar et al., 2019[43]	Randomized trial	OR	18-65	C-Mac	Not reported		
Carlson et al., 2012[44]	Observational	Pre-hospital	All	C-Mac	Not reported		
Cavus et al., 2010[45]	Interventional	OR	>18	C-Mac	Not reported		
Cavus et al., 2011[46]	Randomized trial	OR	≥18	C-Mac	Not reported		
Chan et al., 2021[50]	Observational	ED	≥21	C-Mac	Not reported		
Chandrashekaraiah et al., 2017[51]	Randomized trial	OR	18-65	C-Mac	Not reported		
Cheong et al., 2018[52]	Observational	OR	Adults	C-Mac	Not reported		
Colak et al., 2019[53]	Randomized trial	OR	≥65	McGrath Mac	Not reported		
Corso et al., 2020[54]	Observational	ED	Adults	I-view	Not reported		
Couto et al., 2020[55]	Observational	ED	1-18	McGrath Mac	Not reported		
Couto et al., 2021[56]	Interventional	ED	1-18	McGrath Mac	Not reported		
Deguchi et al., 2016[59]	Randomized trial	OR	20-85	McGrath Mac	Not reported		
Desai et al., 2015[60]	Observational	ED	≥18	C-Mac	Not reported		
Dey et al., 2020[61]	Randomized trial	ICU	≥18	C-Mac	Not reported		
Driver et al., 2019[65]	Observational	ED	All	C-Mac	Not reported		
Driver et al., 2020[66]	Observational	ED	≥14	C-Mac, Glidescope Mac blades	Not reported		
Eberlein et al., 2019[67]	Observational	Pre-hospital	All	McGrath Mac	Not reported		
Eisenberg et al., 2016[68]	Observational	ED	0-18	C-Mac	Not reported		
Ezhar et al., 2018[70]	Randomized trial	OR	18-60	C-Mac	Not reported		
Fiadjoe et al., 2016[71]	Observational	OR	<18	C-Mac	Not reported		
Fogg et al., 2012[72]	Observational	ED	Did not specify	C-Mac	Not reported		
Fogg et al., 2016[73]	Observational	ED	All	C-Mac	Not reported		

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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)
Garcia-Marcinkiewicz et al., 2020[74]	Randomized trial	OR	<12 months	C-Mac	Not reported		
Gaszynski, 2017[76]	Observational	OR	Adults	McGrath Mac	Not reported		
Gaszynski, 2021[77]	Randomized trial	OR	Did not specify	McGrath Mac, I-view	Not reported		
Giraudon et al., 2017[78]	Randomized trial	OR	Weight-based: 10-20 kg	McGrath Mac	Not reported		
Goksu et al., 2016[80]	Randomized trial	ED	>16	C-Mac	Not reported		
Grant et al., 2021[81]	Observational	ED	All	C-Mac	Not reported		
Green-Hopkins et al., 2015[82]	Observational	ED	<21	C-Mac	Not reported		
Grunwell et al., 2017[13]	Observational	ICU	Children	C-Mac	Not reported		
Guerra-Hernández et al., 2020[83]	Interventional	OR	Adults	Hybrid 1.0 VDL	Not reported		
Gümüş et al., 2014[84]	Randomized trial	OR	18-65	Storz DCI	Not reported		
Gupta et al., 2013[85]	Randomized trial	OR	18-65	C-Mac	Not reported		
Gupta et al., 2015[86]	Observational	OR	All	C-Mac	Not reported		
Gupta et al., 2020[87]	Randomized trial	OR	18-60	C-Mac	Not reported		
Hoşten et al., 2012[89]	Randomized trial	OR	Adults	Storz DCI	Not reported		
Hodgetts et al., 2011[90]	Randomized trial	OR	≥18	C-Mac	Not reported		
Hypes et al., 2016[97]	Observational	ICU	Adults	C-Mac, McGrath Mac	Not reported		
Hypes et al., 2017[98]	Observational	ICU	Adults	C-Mac, McGrath Mac	Not reported		
Ing et al., 2017[99]	Randomized trial	OR	18-80	McGrath Mac	Not reported		
Ives et al., 2021[100]	Observational	ICU	Neonates	C-Mac	Not reported		
Jain et al., 2016[101]	Randomized trial	OR	18-60	C-Mac	Not reported		

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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)
Javaher-forooshzadeh and Gharacheh, 2020[102]	Randomized trial	OR	1-5	Infant view	Not reported		
Ji et al., 2018[103]	Randomized trial	OR	>18	C-Mac	Not reported		
Jones et al., 2013[104]	Observational	Non-OR or ED	Adults	C-Mac	Not reported		
Joshi et al., 2017[105]	Observational	ICU	Adults	C-Mac, McGrath Mac	Not reported		
Kaji et al., 2019[8]	Observational	ED	<16	C-Mac	Not reported		
Kaur et al., 2020[108]	Randomized trial	OR	20-70	McGrath Mac	Not reported		
Kerrey et al., 2015[109]	QI	ED	Children	C-Mac	Not reported		
Kido et al., 2015[110]	Randomized trial	OR	20-85	McGrath Mac	Not reported		
Kilicaslan et al., 2014[111]	Observational	OR	>18	C-Mac	Not reported		
Kim et al., 2016[112]	Randomized trial	OR	3-7	McGrath Mac	Not reported		
Kim et al., 2018[113]	Randomized trial	OR	1-10	McGrath MAC	Not reported		
Kleine-Brueggeney et al., 2016[114]	Randomized trial	OR	≥18	McGrath Mac	Not reported		
Kleine-Brueggeney et al., 2017[115]	Randomized trial	OR	Adults	AP advance	Not reported		
Komasawa et al., 2017[117]	Randomized trial	OR	20-85	McGrath Mac	Not reported		
Kontouli et al., 2013[118]	Interventional	OR	≥18	C-Mac	Not reported		
Koylu Gencay et al., 2019[119]	Randomized trial	OR	<2	C-Mac	Not reported		
Kreutziger et al., 2019[120]	Randomized trial	Pre-hospital	≥18	McGrath Mac	Not reported		
Law et al., 2015[121]	Observational	OR	Adults	C-Mac	Not reported		

(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)
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)

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)
Moussa et al., 2016[146]	Randomized trial	ICU	Neonates	C-Mac	Not reported		
Mutlak et al., 2014[147]	Observational	OR	Weight-based: ≤10	Storz C-MAC	Not reported		
Naito et al., 2016[148]	Observational	Pre-hospital	All	C-Mac	Not reported		
Nakanishi et al., 2018[149]	Randomized trial	OR	20-85	McGrath Mac	Not reported		
Narayan et al., 2018[150]	Interventional	OR	Did not specify	Modified Mac VL	Not reported		
Nausheen et al., 2019[151]	Observational	Pre-hospital	All	C-Mac	Not reported		
Ng et al., 2012[152]	Randomized trial	OR	>18	C-Mac	Not reported		
Ninan et al., 2016[153]	Randomized trial	OR	≥18	C-Mac	Not reported		
Noppens et al., 2012[154]	Interventional	ICU	Adults	C-Mac	Not reported		
O'Connell et al., 2019[156]	Observational	ED	<21	C-Mac	Not reported		
Okamoto et al., 2019[159]	Observational	ED	≥18	C-Mac	Not reported		
Pacheco et al., 2019[160]	Observational	ED	<18	C-Mac	Not reported		
Pallin et al., 2016[161]	Observational	ED	≤15	C-Mac	Not reported		
Paul Weng et al., 2020[162]	Observational	ED	All	C-Mac	Not reported		
Peyton et al., 2021[163]	Observational	OR	<18	C-Mac, Storz DCI, Glidescope Direct, Mcgrath Mac	Not reported		
Pieters et al., 2015[165]	Randomized trial	OR	≥18	C-Mac	Not reported		
Pouppirt et al., 2018[167]	Observational	NICU	Neonates	C-Mac	Not reported		
Purugganan et al., 2012[168]	Observational	OR	>18	C-Mac, McGrath Mac	Not reported		

(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)
Puthenveettil et al., 2021[169]	Randomized trial	OR	18-60	C-Mac	Not reported		
Rajasekhar et al., 2020[172]	Randomized trial	OR	18-60	C-Mac	Not reported		
Rhode et al., 2016[172]	QI	Pre-hospital	≥15	McGrath Mac	Not reported		
Rope et al., 2008[173]	Observational	OR	Did not specify	X-Lite	Not reported		
Rowland et al., 2019[174]	Observational	OR	All	C-Mac	Not reported		
Sakles et al., 2014[177]	Observational	ED	≥18	C-Mac	Not reported		
Sakles et al., 2015[178]	Observational	ED	≥18	C-Mac	Not reported		
Sakles et al., 2016[180]	Observational	ED	≥18	C-Mac	Not reported		
Sakles et al., 2017[182]	Observational	ED	All	C-Mac	Not reported		
Sarkılar et al., 2015[184]	Randomized trial	OR	>18	C-Mac	Not reported		
Schalk et al., 2012[185]	Interventional	ED	Adults	C-Mac	Not reported		
Serocki et al., 2010[186]	Interventional	OR	≥18	Storz DCI	Not reported		
Shravanalakshmi et al., 2017[187]	Randomized trial	OR	18-60	C-Mac	Not reported		
Singh et al., 2017[188]	Randomized trial	OR	1-6	C-Mac	Not reported		
Sinha et al., 2016[189]	Randomized trial	OR	Weight-based: 3-15 kg	C-Mac Miller	Not reported		
Sinha et al., 2019[190]	Interventional	OR	4-14	C-Mac	Not reported		
Sinha et al., 2019[191]	Observational	OR	≤60 weeks corrected gestational age	C-Mac	Not reported		
Steel et al., 2021[193]	QI	Pre-hospital	All	McGrath Mac	Not reported		
Sulser et al., 2016[194]	Randomized trial	ED	18-99	C-Mac	Not reported		
Suzuki et al., 2019[195]	Observational	ED	All	McGrath Mac	Not reported		

(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)
Swain et al., 2020[196]	Interventional	OR	18-65	C-Mac	Not reported		
Thion et al., 2018[197]	Randomized trial	OR	18-80	McGrath Mac	Not reported		
Vadi et al., 2016[198]	Randomized trial	OR	<2	Storz DCI	Not reported		
Van Oeveren et al., 2017[200]	Observational	ED	All	C-Mac	Not reported		
Vanderhal et al., 2009[201]	Observational	Delivery Room/NICU	Neonates	Modified Miller VL	Not reported		
Vassiliadis et al., 2015[202]	Observational	ED	All ages	C-Mac	Not reported		
Vlatten et al., 2009[203]	Randomized trial	OR	≤4	Storz DCI	Not reported		
Wallace et al., 2015[204]	Randomized trial	OR	>16	McGrath MAC	Not reported		
Wong et al., 2017[206]	Observational	OR	≥21	McGrath Mac	Not reported		
Yatim et al., 2015[207]	Randomized trial	OR	Did not specify, primarily adults	C-Mac	Not reported		
Yokose et al., 2016[208]	Observational	OR	≥18	McGrath Mac	Not reported		
Yoon et al., 2020[209]	Randomized trial	OR	20-80	McGrath Mac	Not reported		
Yoon et al., 2020[210]	Observational	OR	20-80	McGrath Mac	Not reported		
Yumul et al., 2016[211]	Randomized trial	OR	18-80	C-Mac	Not reported		
Yumul et al., 2016[212]	Randomized trial	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.[6–8,13] 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 (ie, 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.[14] 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 (ie, 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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REFERENCES

1. April MD, Arana A, Reynolds JC, et al. Peri-intubation cardiac arrest in the emergency department: a National Emergency Airway Registry (NEAR) study. *Resuscitation*. 2021;162:403-411.
2. Lewis SR, Butler AR, Parker J, Cook TM, Smith AF. Video laryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation. *Cochrane Database Syst Rev*. 2016;11:CD011136.
3. Abdelgadir IS, Phillips RS, Singh D, Moncreiff MP, Lumsden JL. Video laryngoscopy versus direct laryngoscopy for tracheal intubation in children (excluding neonates). *Cochrane Database Syst Rev*. 2017;5:Cd011413.
4. Lingappan K, Arnold JL, Fernandes CJ, Pammi M. Video laryngoscopy versus direct laryngoscopy for tracheal intubation in neonates. *Cochrane Database Syst Rev*. 2018;6:CD009975.
5. Sakles JC, Mosier J, Patanwala AE, Dicken J. Learning curves for direct laryngoscopy and GlideScope(R) video laryngoscopy in an emergency medicine residency. *West J Emerg Med*. 2014;15(7):930-937.
6. Lascarrou JB, Boisrame-Helms J, Bailly A, et al. Video laryngoscopy vs direct laryngoscopy on successful first-pass orotracheal intubation among ICU patients: a randomized clinical trial. *JAMA*. 2017;317(5):483-493.
7. Brown CA, Kaji AH, Fantegrossi A, et al. Video laryngoscopy compared to augmented direct laryngoscopy in adult emergency department tracheal intubations: a National Emergency Airway Registry (NEAR) Study. *Acad Emerg Med*. 2020;27(2):100-108.
8. Kaji AH, Shover C, Lee J, et al. Video versus direct and augmented direct laryngoscopy in pediatric tracheal intubations. *Acad Emerg Med*. 2019;27(5):394-402.
9. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med*. 2009;6(7):e1000100.

10. Guyette FX, Farrell K, Carlson JN, Callaway CW, Phrampus P. Comparison of video laryngoscopy and direct laryngoscopy in a critical care transport service. *Prehosp Emerg Care*. 2013;17(2):149-154.
11. Driver BE, Prekker ME, Klein LR, et al. Effect of use of a Bougie vs endotracheal tube and stylet on first-attempt intubation success among patients with difficult airways undergoing emergency intubation: a randomized clinical trial. *JAMA*. 2018;319(21):2179-2189.
12. Law BHY, Schmölzer GM. Analysis of visual attention and team communications during neonatal endotracheal intubations using eye-tracking: an observational study. *Resuscitation*. 2020;153:176-182.
13. Grunwell JR, Kamat PP, Miksa M, et al. Trend and outcomes of video laryngoscope use across PICUs. *Pediatr Crit Care Med*. 2017;18(8):741-749.
14. Kaji AH, Schriger D, Green S. Looking through the retrospectoscope: reducing bias in emergency medicine chart review studies. *Ann Emerg Med*. 2014;64(3):292-298.
15. Abid ES, McNamara J, Hall P, et al. The impact of video laryngoscopy on endotracheal intubation success by a pediatric/neonatal critical care transport team. *Prehosp Emerg Care*. 2021;25(3):325-332.
16. Aggarwal H, Kaur S, Baghla N. Hemodynamic response to orotracheal intubation: comparison between Macintosh, McCoy, and C-MAC video laryngoscope. *Anesth Essays Res*. 2019;13(2):308-312.
17. Ahmed SM, Doley K, Athar M, Raza N, Siddiqi OA, Ali S. Comparison of endotracheal intubation time in neutral position between C-Mac. *Indian J Anaesth*. 2017;61(4):338-343.
18. Akbar SH, Ooi JS. Comparison between C-MAC video-laryngoscope and Macintosh direct laryngoscope during cervical spine immobilization. *Middle East J Anaesthesiol*. 2015;23(1):43-50.
19. Akbas S, Okzan AS, Karaaslan E. A comparison of McGrath MAC versus C-MAC video laryngoscopes in morbidly obese patients undergoing bariatric surgery: a randomized, controlled clinical trial. *Bariatr Surg Pract Patient Care*. 2019;14(1).
20. Altun D, Ali A, Çamcı E, Özonur A, Seyhan T. Haemodynamic response to four different laryngoscopes. *Turk J Anaesthesiol Reanim*. 2018;46(6):434-440.
21. Alvis BD, Hester D, Watson D, Higgins M, St Jacques P. Randomized controlled trial comparing the McGrath MAC video laryngoscope with the King Vision video laryngoscope in adult patients. *Minerva Anestesiol*. 2016;82(1):30-35.
22. Amalric M, Larcher R, Brunot V, et al. Impact of video laryngoscopy expertise on first-attempt intubation success in critically ill patients. *Crit Care Med*. 2020;48(10):e889-e896.
23. Amaniti A, Papakonstantinou P, Gkinas D, et al. Comparison of laryngoscopic views between-MAC™ and conventional laryngoscopy in patients with multiple preoperative prognostic criteria of difficult intubation. An observational cross-sectional study. *Medicina (Kaunas)*. 2019;55(12):760.
24. Ångerman S, Kirves H, Nurmi J. A before-and-after observational study of a protocol for use of the C-MAC video laryngoscope with a Frova introducer in pre-hospital rapid sequence intubation. *Anaesthesia*. 2018;73(3):348-355.
25. Arasu M, Rudingwa P, Satyaprakash MVS, Panneerselvam S, Kuberan A. Comparison of conventional C-MAC video laryngoscope guided intubation by anesthesia trainees with and without Frova endotracheal introducer: a randomized clinical trial. *J Anaesthesiol Clin Pharmacol*. 2020;36(4):483-488.
26. Aziz M, Brambrink A. The Storz C-MAC video laryngoscope: description of a new device, case report, and brief case series. *J Clin Anesth*. 2011;23(2):149-152.
27. Aziz MF, Dillman D, Fu R, Brambrink AM. Comparative effectiveness of the C-MAC video laryngoscope versus direct laryngoscopy in the setting of the predicted difficult airway. *Anesthesiology*. 2012;116(3):629-636.
28. Aziz MF, Brambrink AM, Healy DW, et al. Success of intubation rescue techniques after failed direct laryngoscopy in adults: a retrospective comparative analysis from the multicenter perioperative outcomes group. *Anesthesiology*. 2016;125(4):656-666.
29. Bakshi SG, Gawri A, Divatia JV. McGrath MAC video laryngoscope versus direct laryngoscopy for the placement of double-lumen tubes: a randomised control trial. *Indian J Anaesth*. 2019;63(6):456-461.
30. Bensghir M, Chouikh C, Bouhabba N, et al. Comparison between the Airtraq, X-Lite, and direct laryngoscopes for thyroid surgery: a randomized clinical trial. *Can J Anaesth*. 2013;60(4):377-384.
31. Bhat R, Sanickop C, Dhorigoll M, Umrani V, Suresh S. Comparison of ease of intubation in right and left lateral position using C-MAC video laryngoscope. *Anaesth Pain Intensive Care*. 2013;17:162-165.
32. Bhat R, Sanickop CS, Patil MC, Umrani VS, Dhorigol MG. Comparison of Macintosh laryngoscope and C-MAC video laryngoscope for intubation in lateral position. *J Anaesthesiol Clin Pharmacol*. 2015;31(2):226-229.
33. Blajic I, Hodzovic I, Lucovnik M, Mekis D, Novak-Jankovic V, Stopar Pintaric T. A randomised comparison of C-MAC™ and King Vision® videolaryngoscopes with direct laryngoscopy in 180 obstetric patients. *Int J Obstet Anesth*. 2019;39:35-41.
34. Boedeker BH, Berg BW, Bernhagen M, Murray WB. Direct versus indirect laryngoscopic visualization in human endotracheal intubation: a tool for virtual anesthesia practice and teleanesthesiology. *Stud Health Technol Inform*. 2008;132:31-36.
35. Boehringer B, Choate M, Hurwitz S, Tilney PV, Judge T. Impact of video laryngoscopy on advanced airway management by critical care transport paramedics and nurses using the CMAC pocket monitor. *Biomed Res Int*. 2015;2015:821302.
36. Breeman W, Van Vledder MG, Verhofstad MHJ, Visser A, Van Lieshout EMM. First attempt success of video versus direct laryngoscopy for endotracheal intubation by ambulance nurses: a prospective observational study. *Eur J Trauma Emerg Surg*. 2020;46(5):1039-1045.
37. Brown CA, Bair AE, Pallin DJ, Laurin EG, Walls RM, Investigators NEARN. Improved glottic exposure with the video Macintosh laryngoscope in adult emergency department tracheal intubations. *Ann Emerg Med*. 2010;56(2):83-88.
38. Brown CA, Bair AE, Pallin DJ, Walls RM. Investigators NI. Techniques, success, and adverse events of emergency department adult intubations. *Ann Emerg Med*. 2015;65(4):363-370.
39. Brück S, Trautner H, Wolff A, et al. Comparison of the C-MAC(®) and GlideScope(®) video laryngoscopes in patients with cervical spine disorders and immobilisation. *Anaesthesia*. 2015;70(2):160-165.
40. Burjek NE, Nishisaki A, Fiadjoe JE, et al. Video laryngoscopy versus fiber-optic intubation through a supraglottic airway in children with a difficult airway: an analysis from the multicenter pediatric difficult intubation registry. *Anesthesiology*. 2017;127(3):432-440.
41. Burnett AM, Frascone RJ, Wewerka SS, et al. Comparison of success rates between two video laryngoscope systems used in a prehospital clinical trial. *Prehosp Emerg Care*. 2014;18(2):231-238.
42. Byhahn C, Iber T, Zacharowski K, et al. Tracheal intubation using the mobile C-MAC video laryngoscope or direct laryngoscopy for patients with a simulated difficult airway. *Minerva Anestesiol*. 2010;76(8):577-583.
43. Çaparlar CÖA, Sezer GB, Ergil E, Dogan J, ŞANAL A. A comparison of C-MAC videolaryngoscope and Macintosh laryngoscope in intraocular pressure changes, throat pain, intubation time and hemodynamic variables. *Eur Res J*. 2019;5:745-750.
44. Carlson JN, Quintero J, Guyette FX, Callaway CW, Menegazzi JJ. Variables associated with successful intubation attempts using video laryngoscopy: a preliminary report in a helicopter emergency medical service. *Prehosp Emerg Care*. 2012;16(2):293-298.
45. Cavus E, Kieckhaefer J, Doerges V, Moeller T, Thee C, Wagner K. The C-MAC video laryngoscope: first experiences with a new device for video laryngoscopy-guided intubation. *Anesth Analg*. 2010;110(2):473-477.

46. Cavus E, Thee C, Moeller T, Kieckhaefer J, Doerges V, Wagner K. A randomised, controlled crossover comparison of the C-MAC videolaryngoscope with direct laryngoscopy in 150 patients during routine induction of anaesthesia. *BMC Anesthesiol*. 2011;11:6.
47. Cavus E, Callies A, Doerges V, et al. The C-MAC video laryngoscope for prehospital emergency intubation: a prospective, multicentre, observational study. *Emerg Med J*. 2011;28(8):650-653.
48. Cavus E, Janssen S, Reifferscheid F, et al. Video laryngoscopy for physician-based, prehospital emergency intubation: a prospective, randomized, multicenter comparison of different blade types using A.P. Advance, C-MAC system, and King vision. *Anesth Analg*. 2018;126(5):1565-1574.
49. Cengiz S, Yilmaz S. The effect of intubation with video and conventional laryngoscopy on hemodynamic response. *J Cardio-Vasc-Thorac Anaesth Intensive Care Soc*. 2019;25(1):31-42.
50. Chan GWH, Chai CY, Teo JSY, Tjio CKE, Chua MT, Brown CA III. Emergency airway management in a Singapore centre: a registry study. *Ann Acad Med Singap*. 2021;50(1):42-51.
51. Chandrashekaraiah MM, Shah VH, Pandey VC, Adeel S. Evaluation of ease of intubation using C-MAC vs Macintosh laryngoscope in patients with the application of manual inline axial stabilization—A randomized comparative study. *Sri Lankan J Anaesthesiol*. 2017;25(1):8-12.
52. Cheong GPC, Kannan A, Koh KF, Venkatesan K, Seet E. Prevailing practices in airway management: a prospective single-centre observational study of endotracheal intubation. *Singapore Med J*. 2018;59(3):144-149.
53. Colak F, Ozgul U, Erdogan MA, et al. Comparison of hemodynamic responses and QTc intervals to tracheal intubation with the McGRATH MAC video laryngoscope and the Macintosh direct laryngoscope in elderly patients. *Kaohsiung J Med Sci*. 2019;35(2):116-122.
54. Corso RM, Cortese G, Cataldo R, et al. Emergency tracheal intubation in COVID-19 patients with the I-view video laryngoscope. *Minerva Anestesiol*. 2021;87(5):617-618.
55. Couto TB, Reis AG, Farhat SCL, Carvalho VEL, Schvartsman C. Changing the view: video versus direct laryngoscopy for intubation in the pediatric emergency department. *Medicine (Baltimore)*. 2020;99(38):e22289.
56. Couto TB, Reis AG, Farhat SCL, Carvalho VEL, Schvartsman C. Changing the view: impact of simulation-based mastery learning in pediatric tracheal intubation with video laryngoscopy. *J Pediatr (Rio J)*. 2021;97(1):30-36.
57. De Jong A, Clavieras N, Conseil M, et al. Implementation of a combo video laryngoscope for intubation in critically ill patients: a before-after comparative study. *Intensive Care Med*. 2013;39(12):2144-2152.
58. De Jong A, Pouzeratte Y, Laplace A, et al. Macintosh video laryngoscope for intubation in the operating room: a comparative quality improvement project. *Anesth Analg*. 2021;132(2):524-535.
59. Deguchi S, Komasawa N, Kido H, Ueno T, Minami T. Impact of pillow height on double-lumen endotracheal tube intubation with McGRATH MAC: a prospective randomized clinical trial. *J Clin Anesth*. 2016;34:339-343.
60. Desai B, Rogers J, Eason-Bates H, Weeks Graham E. Has video laryngoscopy improved first-pass and overall intubation success in the university of Florida health emergency department? *J Eme Med Int Care*. 2016;2(1):108.
61. Dey S, Pradhan D, Saikia P, Bhattacharyya P, Khandelwal H, Adarsha KN. Intubation in the intensive care unit: C-MAC video laryngoscope versus Macintosh laryngoscope. *Med Intensiva (Engl Ed)*. 2020;44(3):135-141.
62. Dodd KW, Prekker ME, Robinson AE, Buckley R, Reardon RF, Driver BE. Video screen viewing and first intubation attempt success with standard geometry video laryngoscope use. *Am J Emerg Med*. 2018;37(7):1336-1339.
63. Driver BE, Prekker ME, Moore JC, Schick AL, Reardon RF, Miner JR. Direct versus video laryngoscopy using the C-MAC for tracheal intubation in the emergency department, a randomized controlled trial. *Acad Emerg Med*. 2016;23(4):433-439.
64. Driver B, Dodd K, Klein LR, et al. The Bougie and first-pass success in the emergency department. *Ann Emerg Med*. 2017;70(4):473-478.
65. Driver BE, Scharber SK, Horton GB, Braude DA, Simpson NS, Reardon RF. Emergency department management of out-of-hospital laryngeal tubes. *Ann Emerg Med*. 2019;74(3):403-409.
66. Driver BE, Prekker ME, Reardon RF, Fantegrossi A, Walls RM, Brown CA. Comparing emergency department first-attempt intubation success with standard-geometry and hyperangulated video laryngoscopes. *Ann Emerg Med*. 2020;76(3):332-338.
67. Eberlein CM, Luther IS, Carpenter TA, Ramirez LD. First-pass success intubations using video laryngoscopy versus direct laryngoscopy: a retrospective prehospital ambulance service study. *Air Med J*. 2019;38(5):356-358.
68. Eisenberg MA, Green-Hopkins I, Werner H, Nagler J. Comparison between direct and video-assisted laryngoscopy for intubations in a pediatric emergency department. *Acad Emerg Med*. 2016;23(8):870-877.
69. Elattar H, Abdel-Rahman I, Ibrahim M, et al. A randomized trial of the glottic views with the classic Miller, Wis-Hipple and C-MAC (video laryngoscope and direct views) straight size 1 blades in young children. *J Clin Anesth*. 2020;60:57-61.
70. Ezhar Y, D'Aragon F, Echave P. Hemodynamic responses to tracheal intubation with Bonfils compared to C-MAC video laryngoscope: a randomized trial. *BMC Anesthesiol*. 2018;18(1):124.
71. Fiadjoe JE, Nishisaki A, Jagannathan N, et al. Airway management complications in children with difficult tracheal intubation from the Pediatric Difficult Intubation (PeDI) registry: a prospective cohort analysis. *Lancet Respir Med*. 2016;4(1):37-48.
72. Fogg T, Annesley N, Hitos K, Vassiliadis J. Prospective observational study of the practice of endotracheal intubation in the emergency department of a tertiary hospital in Sydney, Australia. *Emerg Med Australas*. 2012;24(6):617-624.
73. Fogg T, Alkhouri H, Vassiliadis J. The Royal North Shore Hospital Emergency Department airway registry: closing the audit loop. *Emerg Med Australas*. 2016;28(1):27-33.
74. Garcia-Marcinkiewicz AG, Kovatsis PG, Hunyady AI, et al. First-attempt success rate of video laryngoscopy in small infants (VISI): a multicentre, randomised controlled trial. *Lancet*. 2020;396(10266):1905-1913.
75. García-Pintos MF, Erramouspe PJ, Schandera V, et al. Comparison of video versus direct laryngoscopy: a prospective prehospital air medical services study. *Air Med J*. 2021;40(1):45-49.
76. Gaszyński T. The visualization of glottis during intubation's efforts in super obese patients: a comparison of total track video intubating laryngeal mask and McGrath MAC video laryngoscope. *J Clin Monit Comput*. 2017;31(6):1329-1332.
77. Gaszynski T. A randomized controlled study on the visual grading of the glottis and the hemodynamics response to laryngoscopy when using I-View and MacGrath Mac videolaryngoscopes in super obese patients. *J Clin Monit Comput*. 2021;35(2):279-283.
78. Giraudon A, Bordes-Demolis M, Blondeau B, et al. Comparison of the McGrath. *Anaesth Crit Care Pain Med*. 2017;36(5):261-265.
79. Glasheen J, Hooper J, Donohue A, et al. Successful endotracheal intubation following a failed first attempt during aeromedical retrieval. *Emerg Med J*. 2020;37(5):314-318.
80. Goksu E, Kilic T, Yildiz G, Unal A, Kartal M. Comparison of the C-MAC video laryngoscope to the Macintosh laryngoscope for intubation of blunt trauma patients in the ED. *Turk J Emerg Med*. 2016;16(2):53-56.
81. Grant S, Pellatt RA, Shirran M, et al. Safety of rapid sequence intubation in an emergency training network. *Emerg Med Australas*. 2021;33(5):857-867.

82. Green-Hopkins I, Werner H, Monuteaux MC, Nagler J. Using video-recorded laryngoscopy to evaluate laryngoscopic blade approach and adverse events in children. *Acad Emerg Med*. 2015;22(11):1283-1289.
83. Guerra-Hernández M, Vidaña-Martínez G, Camacho-Juárez J, et al. Novel video-laryngoscope with wireless image transmission via Wi-Fi towards a smartphone. *Electronics*. 2020;9:1629.
84. Gümüş N, Dilek A, Ülger F, et al. Comparison of LMA CTrach and video laryngoscope in endotracheal intubation. *Turk J Anaesthesiol Reanim*. 2014;42(5):251-256.
85. Gupta N, Rath GP, Prabhakar H. Clinical evaluation of C-MAC video laryngoscope with or without use of stylet for endotracheal intubation in patients with cervical spine immobilization. *J Anesth*. 2013;27(5):663-670.
86. Gupta B, Prasad A, Ramchandani S, Singhal M, Mathur P. Facing the airway challenges in maxillofacial trauma: a retrospective review of 288 cases at a level I trauma center. *Anesth Essays Res*. 2015;9(1):44-50.
87. Gupta S, Thakur JR, Lega A, Monga T. A prospective observational study comparing three different techniques of intubation using C-MAC video laryngoscope. *Indian J Public Health Res Dev*. 2020;11:955-959.
88. Hackell RS, Held LD, Stricker PA, Fiadjoe JE. Management of the difficult infant airway with the Storz video laryngoscope: a case series. *Anesth Analg*. 2009;109(3):763-766.
89. Hoşten T, Gürkan Y, Ozdamar D, Tekin M, Solak M, Toker K. Comparison of the Laryngeal Mask Airway (CTrach(TM)) and direct coupled interface-video laryngoscope for endotracheal intubation: a prospective, randomized, clinical study. *Balkan Med J*. 2012;29(3):268-272.
90. Hodgetts V, Danha R, Mendonca C, Hillerman C. A randomized comparison of C-MAC video laryngoscope versus macintosh laryngoscope for tracheal intubation. *J Anesth Clin Res*. 2011;2:9.
91. Hofstetter C, Scheller B, Flondor M, et al. Video laryngoscopy versus direct laryngoscopy for elective endotracheal intubation. *Anaesthesist*. 2006;55(5):535-540.
92. Hossfeld B, Frey K, Doerges V, Lampl L, Helm M. Improvement in glottic visualisation by using the C-MAC PM video laryngoscope as a first-line device for out-of-hospital emergency tracheal intubation: an observational study. *Eur J Anaesthesiol*. 2015;32(6):425-431.
93. Hossfeld B, Jongebloed A, Lampl L, Helm M. Out-of-hospital airway management in trauma patients: experiences with the C-MAC® video laryngoscope. *Unfallchirurg*. 2016;119(6):501-507.
94. Hossfeld B, Thierbach S, Allgoewer A, Gaessler H, Helm M. First pass success of tracheal intubation using the C-MAC PM video laryngoscope as first-line device in prehospital cardiac arrest compared with other emergencies: an observational study. *Eur J Anaesthesiol*. 2020;38(8):806-812.
95. Howard-Quijano KJ, Huang YM, Matevosian R, Kaplan MB, Steadman RH. Video-assisted instruction improves the success rate for tracheal intubation by novices. *Br J Anaesth*. 2008;101(4):568-572.
96. Hwang SY, Lee SU, Lee TR, et al. Usefulness of C-MAC video laryngoscope in direct laryngoscopy training in the emergency department: a propensity score matching analysis. *PLoS One*. 2018;13(12):e0208077.
97. Hypes CD, Stolz U, Sakles JC, et al. Video laryngoscopy improves odds of first-attempt success at intubation in the intensive care unit. A propensity-matched analysis. *Ann Am Thorac Soc*. 2016;13(3):382-390.
98. Hypes C, Sakles J, Joshi R, et al. Failure to achieve first attempt success at intubation using video laryngoscopy is associated with increased complications. *Intern Emerg Med*. 2017;12(8):1235-1243.
99. Ing R, Liu N, Chazot T, et al. Nociceptive stimulation during Macintosh direct laryngoscopy compared with McGrath Mac video laryngoscopy: a randomized trial using indirect evaluation using an automated administration of propofol and remifentanil. *Medicine (Baltimore)*. 2017;96(38):e8087.
100. Ives R, Beh A, Otunla T, Ponnusamy V. Routine use of video laryngoscopy in neonatal unit. *Arch Dis Child Fetal Neonatal Ed*. 2021;106(1):111-112.
101. Jain D, Bala I, Gandhi K. Comparative effectiveness of McCoy laryngoscope and CMAC(®) video laryngoscope in simulated cervical spine injuries. *J Anaesthesiol Clin Pharmacol*. 2016;32(1):59-64.
102. Javaherforooshzadeh F, Gharacheh L. The comparison of direct laryngoscopy and video laryngoscopy in pediatric airways management for congenital heart surgery: a randomized clinical trial. *Anesth Pain Med*. 2020;10(3):e99827.
103. Ji SM, Lee JG, Kim S, Seo H, Lee BJ. The effect of low-dose rocuronium on rapid tracheal intubation using a video laryngoscope: a randomized double blind controlled study. *Medicine (Baltimore)*. 2018;97(22):e10921.
104. Jones BM, Agrawal A, Schulte TE. Assessing the efficacy of video versus direct laryngoscopy through retrospective comparison of 436 emergency intubation cases. *J Anesth*. 2013;27(6):927-930.
105. Joshi R, Hypes CD, Greenberg J, et al. Difficult airway characteristics associated with first-attempt failure at intubation using video laryngoscopy in the intensive care unit. *Ann Am Thorac Soc*. 2017;14(3):368-375.
106. Jungbauer A, Schumann M, Brunkhorst V, Börgers A, Groeben H. Expected difficult tracheal intubation: a prospective comparison of direct laryngoscopy and video laryngoscopy in 200 patients. *Br J Anaesth*. 2009;102(4):546-550.
107. Kaplan MB, Hagberg CA, Ward DS, et al. Comparison of direct and video-assisted views of the larynx during routine intubation. *J Clin Anesth*. 2006;18(5):357-362.
108. Kaur G, Gupta S, Mehta N, Dhingra JS. Comparative evaluation of McGrath MAC, truview video laryngoscopes and macintosh laryngoscope for endotracheal intubation in patients undergoing surgery under general anaesthesia. *Anesth Essays Res*. 2020;14(1):20-24.
109. Kerrey BT, Mittiga MR, Rinderknecht AS, et al. Reducing the incidence of oxyhaemoglobin desaturation during rapid sequence intubation in a paediatric emergency department. *BMJ Qual Saf*. 2015;24(11):709-717.
110. Kido H, Komasawa N, Matsunami S, Kusaka Y, Minami T. Comparison of McGRATH MAC and Macintosh laryngoscopes for double-lumen endotracheal tube intubation by anesthesia residents: a prospective randomized clinical trial. *J Clin Anesth*. 2015;27(6):476-480.
111. Kilicaslan A, Topal A, Tavlan A, Erol A, Otelcioglu S. Effectiveness of the C-MAC video laryngoscope in the management of unexpected failed intubations. *Braz J Anesthesiol*. 2014;64(1):62-65.
112. Kim EH, Lee JH, Song IK, Kim JT, Kim BR, Kim HS. Effect of head position on laryngeal visualisation with the McGrath MAC video laryngoscope in paediatric patients: a randomised controlled trial. *Eur J Anaesthesiol*. 2016;33(7):528-534.
113. Kim JE, Kwak HJ, Jung WS, Chang MY, Lee SY, Kim JY. A comparison between McGrath MAC video laryngoscopy and Macintosh laryngoscopy in children. *Acta Anaesthesiol Scand*. 2018;62(3):312-318.
114. Kleine-Brueggeney M, Greif R, Schoettker P, Savoldelli GL, Nabecker S, Theiler LG. Evaluation of six video laryngoscopes in 720 patients with a simulated difficult airway: a multicentre randomized controlled trial. *Br J Anaesth*. 2016;116(5):670-679.
115. Kleine-Brueggeney M, Buttenberg M, Greif R, Nabecker S, Theiler L. Evaluation of three unchannelled video laryngoscopes and the Macintosh laryngoscope in patients with a simulated difficult airway: a randomised, controlled trial. *Anaesthesia*. 2017;72(3):370-378.
116. Knapp J, Eberle B, Bernhard M, Theiler L, Pietsch U, Albrecht R. Analysis of tracheal intubation in out-of-hospital helicopter emergency medicine recorded by video laryngoscopy. *Scand J Trauma Resusc Emerg Med*. 2021;29(1):49.

117. Komasawa N, Kido H, Mihara R, Minami T. Comparison of cricoid pressure effect between McGRATH® MAC and Pentax-AWS Airwayscope®: a prospective randomized trials. *Am J Emerg Med*. 2017;35(4):576-578.
118. Kontouli Z, Stroumpoulis K, Halari-baradaki E, Papadimitriou L, Iacovidou N, Xanthos T. First experience of the use of the C-MAC PM video laryngoscope in a clinical setting by anesthetic nurses: a comparison with anesthetists. *Acta Anaesthesiol Belg*. 2013;64(4):153-158.
119. Koylu Gencay Z, Begec Z, Ozgul U, Colak C. The effect of placement of a support under the shoulders on laryngeal visualization with a C-MAC miller video laryngoscope in children younger than 2 years of age. *Paediatr Anaesth*. 2019;29(8):814-820.
120. Kreutziger J, Hornung S, Harrer C, et al. Comparing the McGrath MAC video laryngoscope and direct laryngoscopy for prehospital emergency intubation in air rescue patients: a multicenter, randomized, controlled trial. *Crit Care Med*. 2019;47(10):1362-1370.
121. Law JA, Morris IR, Brousseau PA, de la Ronde S, Milne AD. The incidence, success rate, and complications of awake tracheal intubation in 1,554 patients over 12 years: an historical cohort study. *Can J Anaesth*. 2015;62(7):736-744.
122. Lee AH, Nor NM, Izaham A, Yahya N, Tang SS, Manap NA. Comparison of the bonfils intubation fibrescope versus c-mac videolaryngoscope. *Middle East J Anaesthesiol*. 2016;23(5):517-525.
123. Lees M, Seal RF, Spady D, Csanyi-Fritz Y, Robinson JL. Randomized trial of success of pediatric anesthesiologists learning to use two video laryngoscopes. *Paediatr Anaesth*. 2013;23(5):435-439.
124. Lim H, Cha YB, Ryu KH, Lee SH, Cho EA. Comparison of two different shapes of stylets for intubation with the McGrath MAC® video laryngoscope: a randomized controlled trial. *J Int Med Res*. 2020;48(10):300060520962951.
125. Lin W, Li H, Liu W, Cao L, Tan H, Zhong Z. A randomised trial comparing the CEL-100 video laryngoscope (TM) with the Macintosh laryngoscope blade for insertion of double-lumen tubes. *Anaesthesia*. 2012;67(7):771-776.
126. Lin WQ, Quan SB, Liu WJ, et al. Evaluation of the CEL-100 video laryngoscope (TM) for double-lumen tracheal tube insertion after failure using the Macintosh laryngoscope. *Anaesthesia*. 2012;67(11):1232-1236.
127. Loughnan TE, Gunasekera E, Tan TP. Improving the C-MAC video laryngoscopic view when applying cricoid pressure by allowing access of assistant to the video screen. *Anaesth Intensive Care*. 2012;40(1):128-130.
128. Loughnan A, Deng C, Dominick F, Pencheva L, Campbell D. A single-centre, randomised controlled feasibility pilot trial comparing performance of direct laryngoscopy versus video laryngoscopy for endotracheal intubation in surgical patients. *Pilot Feasibility Stud*. 2019;5:50.
129. Louka A, Stevenson C, Jones G, Ferguson J. Intubation success after introduction of a quality assurance program using video laryngoscopy. *Air Med J*. 2018;37(5):303-305.
130. Louro J, Dudaryk R, Rodriguez Y, Dutton RP, Epstein RH. Airway management at Level 1 trauma center in the era of video laryngoscopy. *Int J Crit Illn Inj Sci*. 2020;10(1):20-24.
131. Maassen R, Lee R, Hermans B, Marcus M, van Zundert A. A comparison of three video laryngoscopes: the Macintosh laryngoscope blade reduces, but does not replace, routine stylet use for intubation in morbidly obese patients. *Anesth Analg*. 2009;109(5):1560-1565.
132. Maassen RL, Pieters BM, Maathuis B, et al. Endotracheal intubation using video laryngoscopy causes less cardiovascular response compared to classic direct laryngoscopy, in cardiac patients according a standard hospital protocol. *Acta Anaesthesiol Belg*. 2012;63(4):181-186.
133. Macke C, Gralla F, Winkelmann M, et al. Increased first pass success with C-MAC video laryngoscopy in prehospital endotracheal intubation-a randomized controlled trial. *J Clin Med*. 2020;9(9):2719.
134. Mackie S, Moy F, Kamona S, Jones P. Effect of the introduction of C-MAC video laryngoscopy on first-pass intubation success rates for emergency medicine registrars. *Emerg Med Australas*. 2020;32(1):25-32.
135. Macnair D, Baraclough D, Wilson G, Bloch M, Engelhardt T. Pediatric airway management: comparing the Berci-Kaplan video laryngoscope with direct laryngoscopy. *Paediatr Anaesth*. 2009;19(6):577-580.
136. Marrel J, Blanc C, Frascarolo P, Magnusson L. Video laryngoscopy improves intubation condition in morbidly obese patients. *Eur J Anaesthesiol*. 2007;24(12):1045-1049.
137. Marsaban A, Heriwardito A, Yundha IGNAD. Cardiovascular response and backward, upward, right push maneuver during laryngoscopy: comparison between CMAC® video laryngoscopy and conventional Macintosh. *Med J Indones*. 2017;26:116-121.
138. Meininger D, Strouhal U, Weber CF, et al. Direct laryngoscopy or C-MAC video laryngoscopy? Routine tracheal intubation in patients undergoing ENT surgery. *Anaesthesist*. 2010; 59(9): 806-811.
139. Michailidou M, O'Keeffe T, Mosier JM, et al. A comparison of video laryngoscopy to direct laryngoscopy for the emergency intubation of trauma patients. *World J Surg*. 2015;39(3):782-788.
140. Miller KA, Monuteaux MC, Nagler J. Technical factors associated with first-pass success during endotracheal intubation in children: analysis of video laryngoscopy recordings. *Emerg Med J*. 2020;38(2):125-131.
141. Min BC, Park JE, Lee GT, et al. C-MAC video laryngoscope versus conventional direct laryngoscopy for endotracheal intubation during cardiopulmonary resuscitation. *Medicina (Kaunas)*. 2019;55(6):225.
142. Modir H, Moshiri E, Malekianzadeh B, Noori G, Mohammadbeigi A. Endotracheal intubation in patients with difficult airway: using laryngeal mask airway with Bougie. *Med Gas Res*. 2017;7(3):150-155.
143. Monette DL, Brown CA, Benoit JL, et al. The impact of video laryngoscopy on the clinical learning environment of emergency medicine residents: a report of 14,313 intubations. *AEM Educ Train*. 2019;3(2):156-162.
144. Mosier J, Chiu S, Patanwala AE, Sakles JC. A comparison of the GlideScope video laryngoscope to the C-MAC video laryngoscope for intubation in the emergency department. *Ann Emerg Med*. 2013;61(4):414-420. e1.
145. Mosier JM, Whitmore SP, Bloom JW, et al. Video laryngoscopy improves intubation success and reduces esophageal intubations compared to direct laryngoscopy in the medical intensive care unit. *Crit Care*. 2013;17(5):R237.
146. Moussa A, Luangxay Y, Tremblay S, et al. Video laryngoscope for teaching neonatal endotracheal intubation: a randomized controlled trial. *Pediatrics*. 2016;137(3):e20152156.
147. Mutlak H, Rolle U, Rosskopf W, et al. Comparison of the TruView infant EVO2 PCD™ and C-MAC video laryngoscopes with direct Macintosh laryngoscopy for routine tracheal intubation in infants with normal airways. *Clinics (Sao Paulo)*. 2014;69(1):23-27.
148. Naito H, Guyette FX, Martin-Gill C, Callaway CW. Video laryngoscopic techniques associated with intubation success in a helicopter emergency medical service system. *Prehosp Emerg Care*. 2016;20(3):333-342.
149. Nakanishi T, Yoshimura M, Sakamoto S, Toriumi T. Postoperative laryngeal morbidity and intubating conditions using the McGRATH™ MAC video laryngoscope with or without neuromuscular blockade: a randomised, double-blind, non-inferiority trial. *Anaesthesia*. 2018;73(8):990-996.
150. Narayan AK, Janardhan AL, Prakash A, Sahoo SK. Low-cost teaching aid: a modification of Macintosh blade into a video laryngoscope for teaching laryngoscopy and intubation. *J Anaesthesiol Clin Pharmacol*. 2018;34(4):552-554.
151. Nausheen F, Niknafs NP, MacLean DJ, et al. The HEAVEN criteria predict laryngoscopic view and intubation success for both direct and

video laryngoscopy: a cohort analysis. *Scand J Trauma Resusc Emerg Med*. 2019;27(1):50.
152. Ng I, Hill AL, Williams DL, Lee K, Segal R. Randomized controlled trial comparing the McGrath video laryngoscope with the C-MAC video laryngoscope in intubating adult patients with potential difficult airways. *Br J Anaesth*. 2012;109(3):439-443.
153. Ninan J, RV R, Ramachandran T, George S. C-MAC video laryngoscope improves the laryngoscopic view in Mallampati class 2 and 3 patients. *Anaesth Pain Intensive Care*. 2016;20:261-265.
154. Noppens RR, Geimer S, Eisel N, David M, Piepho T. Endotracheal intubation using the C-MAC® video laryngoscope or the Macintosh laryngoscope: a prospective, comparative study in the ICU. *Crit Care*. 2012;16(3):R103.
155. Normand K, Vargas L, Burnett T, et al. Use of the McGRATH™ MAC: to view or not to view? *Anesth Perioper Med*. 2018;19:25-33.
156. O'Connell KJ, Yang S, Cheng M, et al. Process conformance is associated with successful first intubation attempt and lower odds of adverse events in a paediatric emergency setting. *Emerg Med J*. 2019;36(9):520-528.
157. O'Shea JE, Thio M, Kamlin CO, et al. Video laryngoscopy to teach neonatal intubation: a randomized trial. *Pediatrics*. 2015;136(5):912-919.
158. O'Shea JE, Loganathan P, Thio M, Kamlin COF, Davis PG. Analysis of unsuccessful intubations in neonates using video laryngoscopy recordings. *Arch Dis Child Fetal Neonatal Ed*. 2018;103(5):F408-F412.
159. Okamoto H, Goto T, Wong ZSY, et al. Comparison of video laryngoscopy versus direct laryngoscopy for intubation in emergency department patients with cardiac arrest: a multicentre study. *Resuscitation*. 2019;136:70-77.
160. Pacheco GS, Patanwala AE, Mendelson JS, Sakles JC. Clinical experience with the C-MAC and GlideScope in a pediatric emergency department over a 10-year period. *Pediatr Emerg Care*. 2021;37(12):e1098-e1103. https://doi.org/10.1097/PEC.0000000000001911
161. Pallin DJ, Dwyer RC, Walls RM, Brown CA, Investigators NI. Techniques and trends, success rates, and adverse events in emergency department pediatric intubations: a report from the national emergency airway registry. *Ann Emerg Med*. 2016;67(5):610-615.
162. Paul Weng W, Zakaria Nur D, Seow Gek C, Wong E. Does video laryngoscopy or direct laryngoscopy affect first pass success rates for intubation among attending and non-attending emergency physician in the emergency department? *Hong Kong J Emerg Med*. 2020;28(5):285-290.
163. Peyton J, Park R, Staffa SJ, et al. A comparison of video laryngoscopy using standard blades or non-standard blades in children in the Paediatric Difficult Intubation Registry. *Br J Anaesth*. 2021;126(1):331-339.
164. Piepho T, Fortmueller K, Heid FM, Schmidtmann I, Werner C, Noppens RR. Performance of the C-MAC video laryngoscope in patients after a limited glottic view using Macintosh laryngoscopy. *Anaesthesia*. 2011;66(12):1101-1105.
165. Pieters B, Maassen R, Van Eig E, Maathuis B, Van Den Dobbelsteen J, Van Zundert A. Indirect video laryngoscopy using Macintosh blades in patients with non-anticipated difficult airways results in significantly lower forces exerted on teeth relative to classic direct laryngoscopy: a randomized crossover trial. *Minerva Anestesiol*. 2015;81(8):846-854.
166. Pieters BM, Theunissen M, van Zundert AA. Macintosh blade video laryngoscopy combined with rigid bonfils intubation endoscope offers a suitable alternative for patients with difficult airways. *Anesth Analg*. 2018;126(3):988-994.
167. Pouppirt NR, Nassar R, Napolitano N, et al. Association between video laryngoscopy and adverse tracheal intubation-associated events in the neonatal intensive care unit. *J Pediatr*. 2018;201:281-284.
168. Purugganan RV, Jackson TA, Heir JS, Wang H, Cata JP. Video laryngoscopy versus direct laryngoscopy for double-lumen endotracheal tube intubation: a retrospective analysis. *J Cardiothorac Vasc Anesth*. 2012;26(5):845-848.
169. Puthenveettil N, Rahman S, Vijayaraghavan S, Suresh S, Kadapamannil D, Paul J. Comparison of aerosol box intubation with C-MAC video laryngoscope and direct laryngoscopy-A randomised controlled trial. *Indian J Anaesth*. 2021;65(2):133-138.
170. Raimann FJ, Cuca CE, Kern D, et al. Evaluation of the C-MAC miller video laryngoscope sizes 0 and 1 during tracheal intubation of infants less than 10 kg. *Pediatr Emerg Care*. 2017;36(7):312-316.
171. Raimann FJ, Dietze PE, Cuca CE, et al. Prospective trial to compare direct and indirect laryngoscopy using C-MAC PM® with Macintosh blade and D-Blade® in a simulated difficult airway. *Emerg Med Int*. 2019;2019:1067473.
172. Rajasekhar M, Yadav M, Kulkarni D, Gopinath R. Comparison of hemodynamic responses to laryngoscopy and intubation using Macintosh or McCoy or C-MAC laryngoscope during uniform depth of anesthesia monitored by entropy. *J Anaesthesiol Clin Pharmacol*. 2020;36(3):391-397.
173. Rope TC, Loughnan BA, Vaughan DJ. Video laryngoscopy–An answer to difficult laryngoscopy? *Eur J Anaesthesiol*. 2008;25(5):434-435.
174. Rowland MJ, Urman RD, Xu X, Ehrenfeld JM, Preiss DA, Vacanti JC. The impact of airway technique on anesthesia control time. *J Med Syst*. 2019;43(3):72.
175. Sainsbury JE, Telgarsky B, Parotto M, Niazi A, Wong DT, Cooper RM. The effect of verbal and video feedback on learning direct laryngoscopy among novice laryngoscopists: a randomized pilot study. *Can J Anaesth*. 2017;64(3):252-259.
176. Sakles JC, Mosier J, Chiu S, Cosentino M, Kalin L. A comparison of the C-MAC video laryngoscope to the Macintosh direct laryngoscope for intubation in the emergency department. *Ann Emerg Med*. 2012;60(6):739-748.
177. Sakles JC, Patanwala AE, Mosier JM, Dicken JM. Comparison of video laryngoscopy to direct laryngoscopy for intubation of patients with difficult airway characteristics in the emergency department. *Intern Emerg Med*. 2014;9(1):93-98.
178. Sakles JC, Mosier JM, Patanwala AE, Dicken JM, Kalin L, Javedani PP. The C-MAC® video laryngoscope is superior to the direct laryngoscope for the rescue of failed first-attempt intubations in the emergency department. *J Emerg Med*. 2015;48(3):280-286.
179. Sakles JC, Javedani PP, Chase E, Garst-Orozco J, Guillen-Rodriguez JM, Stolz U. The use of a video laryngoscope by emergency medicine residents is associated with a reduction in esophageal intubations in the emergency department. *Acad Emerg Med*. 2015;22(6):700-707.
180. Sakles JC, Mosier JM, Patanwala AE, Arcaris B, Dicken JM. First pass success without hypoxemia is increased with the use of apneic oxygenation during rapid sequence intubation in the emergency department. *Acad Emerg Med*. 2016;23(6):703-710.
181. Sakles JC, Mosier JM, Patanwala AE, Arcaris B, Dicken JM. The utility of the C-MAC as a direct laryngoscope for intubation in the emergency department. *J Emerg Med*. 2016;51(4):349-357.
182. Sakles JC, Douglas MJK, Hypes CD, Patanwala AE, Mosier JM. Management of patients with predicted difficult airways in an academic emergency department. *J Emerg Med*. 2017;53(2):163-171.
183. Saran A, Dave NM, Karnik PP. Efficacy and safety of video laryngoscopy-guided verbal feedback to teach neonatal and infant intubation. A prospective randomised cross over study. *Indian J Anaesth*. 2019;63(10):791-796.
184. Sarkılar G, Sargın M, Sarıtaş TB, et al. Hemodynamic responses to endotracheal intubation performed with video and direct laryngoscopy in patients scheduled for major cardiac surgery. *Int J Clin Exp Med*. 2015;8(7):11477-11483.

185. Schalk R, Weber CF, Byhahn C, et al. Reintubation using the C-MAC video laryngoscope. Implementation in patients with difficult airways initially managed with in situ laryngeal tubes. *Anaesthesist*. 2012;61(9):777-782.
186. Serocki G, Bein B, Scholz J, Dörges V. Management of the predicted difficult airway: a comparison of conventional blade laryngoscopy with video-assisted blade laryngoscopy and the GlideScope. *Eur J Anaesthesiol*. 2010;27(1):24-30.
187. Shravanalakshmi D, Bidkar PU, Narmadalakshmi K, Lata S, Mishra SK, Adinarayanan S. Comparison of intubation success and Glottic visualization using King Vision and C-MAC video laryngoscopes in patients with cervical spine injuries with cervical immobilization: a randomized clinical trial. *Surg Neurol Int*. 2017;8:19.
188. Singh R, Kumar N, Jain A. A randomised trial to compare Truview PCD. *Asian J Anesthesiol*. 2017;55(2):41-44.
189. Sinha R, Sharma A, Ray BR, et al. Comparison of the success of two techniques for the endotracheal intubation with C-MAC video laryngoscope miller blade in children: a prospective randomized study. *Anesthesiol Res Pract*. 2016;2016:4196813.
190. Sinha R, Ray BR, Sharma A, et al. Comparison of the C-MAC video laryngoscope size 2 Macintosh blade with size 2 C-MAC D-Blade for laryngoscopy and endotracheal intubation in children with simulated cervical spine injury: a prospective randomized crossover study. *J Anaesthesiol Clin Pharmacol*. 2019;35(4):509-514.
191. Sinha R, Kumar KR, Kalaiyarasan RK, et al. Evaluation of performance of C-MAC. *Indian J Anaesth*. 2019;63(4):284-288.
192. Sørensen MK, Holm-Knudsen R. Endotracheal intubation with airtraq® versus storz® videolaryngoscope in children younger than two years—A randomized pilot-study. *BMC Anesthesiol*. 2012;12:7.
193. Steel A, Haldane C, Cody D. Impact of video laryngoscopy introduction into prehospital emergency medicine practice: a quality improvement project. *Emerg Med J*. 2021;38(7):549-555.
194. Sulser S, Ubmann D, Schlaepfer M, et al. C-MAC video laryngoscope compared with direct laryngoscopy for rapid sequence intubation in an emergency department: a randomised clinical trial. *Eur J Anaesthesiol*. 2016;33(12):943-948.
195. Suzuki K, Kusunoki S, Tanigawa K, Shime N. Comparison of three video laryngoscopes and direct laryngoscopy for emergency endotracheal intubation: a retrospective cohort study. *BMJ Open*. 2019;9(3):e024927.
196. Swain A, Bhagat H, Gupta V, Salunke P, Panda NB, Sahu S. Intubating laryngeal mask airway-assisted flexible bronchoscopic intubation is associated with reduced cervical spine motion when compared with C-MAC video laryngoscopy-guided intubation: a prospective randomized cross over trial. *J Neurosurg Anesthesiol*. 2020;32(3):242-248.
197. Thion LA, Belze O, Fischler M, Le Guen M. Comparison of the ease of tracheal intubation using a McGrath Mac video laryngoscope and a standard Macintosh laryngoscope in normal airways: a randomised trial. *Eur J Anaesthesiol*. 2018;35(8):631-633.
198. Vadi MG, Ghazal EA, Halverson B, Applegate RL. Comparison of indirect video laryngoscopes in children younger than two years of age: a randomized trainee evaluation study. *Middle East J Anaesthesiol*. 2016;23(4):401-410.
199. Vadi MG, Roddy KJ, Ghazal EA, Um M, Neiheisel AJ, Applegate RL. Comparison of the GlideScope Cobalt® and Storz DCI® video laryngoscopes in children younger than 2 years of age during manual in-line stabilization: a randomized trainee evaluation study. *Pediatr Emerg Care*. 2017;33(7):467-473.
200. Van Oeveren L, Donner J, Fantegrossi A, Mohr NM, Brown CA. Telemedicine-assisted intubation in rural emergency departments: a national emergency airway registry study. *Telemed J E Health*. 2017;23(4):290-297.
201. Vanderhal AL, Berci G, Simmons CF, Hagiike M. A video laryngoscopy technique for the intubation of the newborn: preliminary report. *Pediatrics*. 2009;124(2):e339-e346.
202. Vassiliadis J, Tzannes A, Hitos K, Brimble J, Fogg T. Comparison of the C-MAC video laryngoscope with direct Macintosh laryngoscopy in the emergency department. *Emerg Med Australas*. 2015;27(2):119-125.
203. Vlatten A, Aucoin S, Litz S, Macmanus B, Soder C. A comparison of the STORZ video laryngoscope and standard direct laryngoscopy for intubation in the Pediatric airway–A randomized clinical trial. *Paediatr Anaesth*. 2009;19(11):1102-1107.
204. Wallace CD, Foulds LT, McLeod GA, Younger RA, McGuire BE. A comparison of the ease of tracheal intubation using a McGrath MAC(®) laryngoscope and a standard Macintosh laryngoscope. *Anaesthesia*. 2015;70(11):1281-1285.
205. Weiss M, Schwarz U, Dillier CM, Gerber AC. Teaching and supervising tracheal intubation in paediatric patients using video laryngoscopy. *Paediatr Anaesth*. 2001;11(3):343-348.
206. Wong J, Tan Z, Wong P. Evaluation of the McGrath® MAC video laryngoscope in a tertiary teaching hospital. *Proc Singapore Healthc*. 2017;26:102-108.
207. Yatim B, Masdar A, Yusof A, Ping S, Yahya N, Maaya MM. Comparison of ease of intubation between GlideScope® and C-MAC® video laryngoscopes for novices. *Brunei Int Med J*. 2015;11(3):139-146.
208. Yokose M, Mihara T, Kuwahara S, Goto T. Effect of the McGRATH MAC® Video laryngoscope on hemodynamic response during tracheal intubation: a retrospective study. *PLoS One*. 2016;11(5):e0155566. https://doi.org/10.1371/journal.pone.0155566
209. Yoon HK, Lee HC, Park JB, Oh H, Park HP. McGrath MAC video laryngoscope versus optiscope video stylet for tracheal intubation in patients with manual inline cervical stabilization: a randomized trial. *Anesth Analg*. 2020;130(2020):870-878.
210. Yoon S, Oh H, Yoon HK, Lee HC, Park HP. Radiographic predictors of difficult McGrath MAC video laryngoscopy in patient undergoing cervical spine surgery. *J Neurosurg Anesthesiol*. 2020;34(1):57-63.
211. Yumul R, Elvir-Lazo OL, White PF, et al. Comparison of the C-MAC video laryngoscope to a flexible fiberoptic scope for intubation with cervical spine immobilization. *J Clin Anesth*. 2016;31:46-52.
212. Yumul R, Elvir-Lazo OL, White PF, et al. Comparison of three video laryngoscopy devices to direct laryngoscopy for intubating obese patients: a randomized controlled trial. *J Clin Anesth*. 2016;31:71-77.
213. Zhang J, Tan LZ, Toh H, et al. Comparing the first-attempt tracheal intubation success of the hyperangulated McGrath® X-blade vs the Macintosh-type CMAC videolaryngoscope in patients with cervical immobilization: a two-centre randomized controlled trial. *J Clin Monit Comput*. 2021; https://doi.org/10.1007/s10877-021-00746-5

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