The use of video laryngoscopy outside the operating room: A systematic review

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Abstract

This study aimed to describe how video laryngoscopy is used outside the operating room within the hospital setting. Specifically, we aimed to summarise the evidence for the use of video laryngoscopy outside the operating room, and detail how it appears in current clinical practice guidelines. A literature search was conducted across two databases (MEDLINE and Embase), and all articles underwent screening for relevance to our aims and pre-determined exclusion criteria. Our results include 14 clinical practice guidelines, 12 interventional studies, 38 observational studies. Our results show that video laryngoscopy is likely to improve glottic view and decrease the incidence of oesophageal intubations; however, it remains unclear as to how this contributes to first-pass success, overall intubation success and clinical outcomes such as mortality outside the operating room. Furthermore, our results indicate that the appearance of video laryngoscopy in clinical practice guidelines has increased in recent years, and particularly through the COVID-19 pandemic. Current COVID-19 airway management guidelines unanimously introduce video laryngoscopy as a first-line (rather than rescue) device.

Introduction

Tracheal intubation occurring outside the operating room (OR) typically involves a critically unwell patient. These intubations occur predominantly in the emergency department (ED) or intensive care unit (ICU), but may also involve a deteriorating patient on a hospital ward. Intubation outside the OR presents greater difficulty to the airway, with a significantly increased incidence of adverse events and risks to patient safety [1, 2]. Reasons for this include availability of skilled staff in an emergency, case mix and working environment [3]. In the recent INTUBE study, 45.2% of intubations outside the OR experienced at least 1 major adverse peri-intubation event and over 3% were complicated by cardiac arrest [2].

First-pass intubation success is particularly important in the critically ill and is associated with improved hospital survival in this group [2]. As the number of intubation attempts increases, so too does the incidence of adverse events and hospital mortality [2, 4]. As such, every effort should
be made to maximise first-pass intubation success outside the OR. Strategies to increase first-pass success include choice of an experienced clinician (such as a consultant anaesthetist), positioning, adequate muscle relaxation, and use of equipment [5–7]. Specifically, airway operators must consider whether to use direct laryngoscopy (DL) or video laryngoscopy (VL). VL displays the glottis on an external monitor via a camera attached to the device blade, without requiring alignment of the oral-pharyngeal-tracheal axes. Furthermore, because the glottis is displayed on an external monitor, VL allows supervising clinicians real-time view, allowing them to provide tailored guidance to trainees [8, 9]. Historically, VL is often referred to in difficult airway management algorithms as a powerful rescue tool to be employed when initial intubation attempts are unsuccessful [10, 11]. Recently, the use of VL has increased, which is likely due to multiple factors including the improved glottic view that VL offers compared to DL, and its increased availability and affordability [12, 13]. There has also been an increase in the uptake of VL during the COVID-19 pandemic, with many airway management guidelines now recommending VL as a first line (rather than rescue) device [6, 7, 13]. Within the OR, it has been found that VL may reduce the number of failed intubations, particularly among patients presenting with a difficult airway [14]. However, there has been conflicting results of early VL studies outside OR. There is no current consensus on the use of VL outside the OR; specifically, whether it should be used ahead of DL, whether it is best used by trainees, consultants or both, and what benefit to patient outcomes it may offer. Existing systematic reviews on the use of VL were conducted prior to the COVID-19 pandemic, and do not evaluate the most recent evidence on the use of VL outside the OR.

This study was designed to conduct an up-to-date review of the existing literature on how VL is used outside the OR. Specifically, it aims to (1) search for and summarise the recent evidence for the use of VL outside the OR and (2) describe how VL appears in current clinical practice guidelines for airway management outside the OR.

**Materials and methods**

A structured literature search adhered to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) recommendations and was registered with PROSPERO [15]. A search was conducted across two databases (MEDLINE and Embase) on September 8, 2021, looking at the use of VL outside the OR. Keywords searched were “laryngoscopy” + “video recording”, “video laryngoscopy”, “video assisted laryngoscopy”, “penta airway”, “king vision” or “mcgrath mac”, in conjunction with “intensive care units”, “critical illness”, “ICU(s)”, “emergency department”, “emergency service/hospital” or “critically ill”. Pre-defined exclusion criteria were studies not in English, not in ED/ICU/ward based/critically ill settings, pre-hospital settings, simulation studies, involving students, conference abstracts only, commentary/editorials or neonatal/paediatric papers. Furthermore, articles were limited to those published between 1 January 2011–8 September 2021.

All resulting references underwent title and abstract screening using Covidence software (Veritas Health Innovation Ltd, Melbourne, Victoria). Articles were initially screened by a single author, and any articles that were not clearly able to be included or excluded were then discussed amongst the team of authors. Full texts were then extracted and screened by two authors for relevance to pre-defined inclusion and exclusion criteria (Fig 1).

Both clinical practice guidelines and consensus statements (for both intubation and advanced life support cardiopulmonary resuscitation) were included. This yielded both primary and secondary research papers discussing the use of VL outside the OR (ED, ICU and ward-based setting). As this is a review article, we limited citations of other review articles or meta-analyses to the introduction and discussion and only primary data was used in our descriptive analysis.
Clinical practice guidelines and consensus statements were identified and tabulated (Table 1). Articles discussing the use of VL outside the OR were identified and tabulated separately, with Table 2 detailing interventional studies and Table 3 detailing observational studies. Descriptive analysis was performed to assess how VL is used outside the OR, what the evidence is for its use outside the OR and the appearance of VL in current clinical practice guidelines. The quality of included papers was assessed using the Critical Appraisal...
| Author (Year)                          | Country of publication | Society/Expert Group                                                                 | Methodology for guideline development | Patient group | Type of VL | Recommendations                                                                 | Evidence base                                                                                         |
|--------------------------------------|------------------------|--------------------------------------------------------------------------------------|----------------------------------------|---------------|------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| Apfelbaum et al. (2013) [18]         | United States          | American Society of Anesthesiologists                                                | Literature search + expert consensus   | Difficult airway | Not specified | This guideline prompts the airway operator to consider VL as an initial approach to intubation based on “relative merits and feasibility”. This guideline also lists VL as an alternative approach to difficult intubation, when the first attempt at intubation has been unsuccessful. | Combination of category I–category IV evidence                                                       |
| Barati et al. (2020) [19]            | Iran                   | Iranian Heart Association                                                            | Not specified                          | Cardiopulmonary resuscitation | Not specified | This guideline recommends that intubation performed during CPR should be done with the help of VL if possible. | Not specified                                                                                         |
| Brewster et al. (2020) [6]           | Australia and New Zealand | Safe Airway Society                                                                   | Expert consensus                        | Adults with COVID-19 | Macintosh video laryngoscope Hyperangulated video laryngoscope | Recommends VL as the device of choice for first attempt at intubation (when operator is proficient in its use) | Category IV—Consensus statement                                                                 |
| Cook et al. (2020) [7]               | United Kingdom         | Difficult Airway Society, the Association of Anaesthetists the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anaesthetists | Expert consensus                        | Critically ill adults with COVID-19 | Not specified | Recommends that laryngoscopy should be undertaken with the device that is most likely to achieve prompt first-pass success. In most fully trained airway managers this is likely to be a videolaryngoscope. | Category IV—Consensus statement                                                                 |
| Frerk et al. (2015) [20]             | United Kingdom         | Difficult airway society                                                              | Literature search + expert consensus    | Unanticipated difficult airway | Not specified | Does not specifically recommend VL within the guideline, but comments on the fact that the role of VL in difficult intubation is recognised, and all anaesthetists should be skilled in its use. | Combination of category I–category IV evidence. Individual techniques have not been listed against their level of evidence. |
| Higgins et al. (2018) [21]           | United Kingdom         | Difficult Airway Society (DAS), Intensive Care Society (ICS), Faculty of Intensive Care Medicine (FiCM), and Royal College of Anaesthetists (RCoA) | Literature search + expert consensus    | Critically ill adults | Macintosh video laryngoscope is suggested when VL is used as a first line device. Hyperangulated video laryngoscope suggested when VL is used as a rescue device. | Recommends the early use of VL. Recommends that VL should be available and considered as an option for all intubations of critically ill patients. If difficult laryngoscopy is predicted in a critically ill patient, VL should be actively considered from the outset. | The quality of evidence for these recommendations varied considerably (GRADE level 2+ to 5) and in its absence, consensus was sought. Published data on VL in critically ill patients are generally poor quality, with limited evidence from ICU and ED populations. |

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| Author/Year | Country of publication | Society/Expert Group | Methodology for guideline development | Patient group | Type of VL | Recommendations | Evidence base |
|-------------|------------------------|----------------------|-------------------------------------|----------------|-------------|-----------------|---------------|
| Myatra et al. (2017) [13] | India | All India Difficult Airway Association | Literature search + expert consensus | Critically ill | Not specified | Mentions VL as an option to consider for the initial intubation attempt. | Developed based on available evidence but where this is lacking, recommendations are based on consensus opinion of airway experts |
| Nasa et al. (2021) [22] | India | Critical care physicians actively involved in the management of patients with COVID-19 acute respiratory failure | Delphi method | COVID-19 related acute respiratory failure | Not specified | Expert consensus suggests consideration of VL during tracheal intubation in context of COVID-19 related acute respiratory failure | Category IV—Consensus statement |
| Nolan et al. (2020) [23] | Not specified | European Resuscitation Council | Not specified | COVID-19 patients requiring cardiopulmonary resuscitation | Not specified | For in-hospital cardiac arrests, this guidelines suggests that airway operators should consider VL if provider is familiar with its use | Not specified |
| Oh et al. (2021) [24] | Korea | Not specified | Not specified | Adults requiring cardiopulmonary resuscitation | Not specified | Recommends that during CPR, VL should be considered for intubation. | Not specified |
| Piepho et al. (2015) [10] | Germany | German Society of Anesthesiology and Intensive Care | Expert consensus | Difficult airway | Macintosh video laryngoscope Hyperangulated video laryngoscope | This guideline recommends that for an unexpected difficult airway, VL may be used as an “alternative strategy”. | Category IV—Expert consensus |
| Quintard et al. (2019) [25] | France | French Society of Anaesthesia and Intensive Care Medicine (SFAR) and French-speaking Intensive Care Society (SRLF) | GRADE method | Critically ill | Not specified | This guideline recommends the use of VL as an initial option for intubation when MACOCHA score ≥3, or as for second-attempt intubation when MACOCHA score <3. | Category IV—Consensus statement |
| Sharma et al. (2020) [26] | United States | Society of Vascular & Interventional Neurology (SVIN), Society of NeuroInterventional Surgery (SNIS), Neurocritical Care Society (NCS), European Society of Minimally Invasive Neurological Therapy (ESMINT) and American Association of Neurological Surgeons (AANS) and Congress of Neurological Surgeons (CNS) Cerebrovascular Section | Not specified | COVID-19 patients requiring emergency endovascular treatment for ischaemic stroke | Not specified | Recommends that VL should be used for patent requiring urgent endovascular treatment for ischaemic stroke during COVID-19 pandemic. | Category IV—Consensus statement |

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Results

Search results

Following duplicate removal, our search generated 890 articles. Articles then underwent title and abstract screening and full text screening for relevance to our aims and exclusion criteria. This yielded a total of 64 articles to be included in our review. Guidelines not intended for use outside the OR, or guidelines that did not make mention of VL, were excluded. The 64 papers included 14 clinical practice guidelines or consensus statements (Table 1), 12 interventional studies including RCTs (Table 2) and 38 observational studies on the use of VL outside the OR (Table 3).

Quality assessment

The quality of the included studies was primarily assessed used CASP tool [16]. Cross-sectional studies were assessed using the MERSQI tool [17]. Overall, the quality of included research was found to be low-moderate.

Included airway guidelines

Guidelines were published from a range of countries as shown in Table 1. Table 1 also details data on society/expert group endorsement of the guidelines, methodology for guideline development, intended patient group, recommendations, and evidence base.

How is VL mentioned within guidelines?  Safe Airway Society guidelines for airway management of COVID-19 patients from Australia and New Zealand were the first to recommend VL as the first line device in COVID-19 patients when the airway operator is proficient in its use [6]. The Macintosh video laryngoscope and the hyperangulated video laryngoscope are the two types of VL referenced in this guideline. Guidelines from Cook et al. 2020, which come from consensus among Difficult Airway Society, the Association of Anaesthetists of the Intensive Care Society, and Faculty of Intensive Care Medicine and the Royal College of Anaesthetists, recommended that laryngoscopy be undertaken with the device that is most likely to achieve prompt first-pass success in patients with COVID-19 [7]. This guideline states that in most fully trained airway professionals, this is likely to be VL. Guidelines from Nasa et al. 2021, recommend considering VL for intubation of COVID-19 [22]. The guideline does not discuss a specific type of VL. Guidelines from Sharma et al. 2020, which are intended for use in COVID-19 patients requiring emergency endovascular treatment, state that VL should be used for intubation [26]. Guidelines from Nolan et al. 2020 and Singh et al. 2020 are
Table 2. Interventional studies on the use of VL outside the OR.

| Author (Year)          | Country | Setting | Patient group         | Airway operator(s) | Study design           | Type of VL                 | Outcome(s)                                                                 |
|------------------------|---------|---------|-----------------------|--------------------|------------------------|---------------------------|---------------------------------------------------------------------------|
| 1 De Jong et al. (2013) | France  | ICU     | Critically ill        | Not specified      | Interventional before and after study | Combo videolaryngoscope   | Incidence of difficult laryngoscopy and/or difficult intubation (VL < DL, p = 0.01) Severe, life threatening complications (no difference) |
| 2 Driver et al. (2016) | United States | ED    | Adult patients in resuscitation bays of ED who were to undergo emergency orotracheal intubation using DL as device choice for first attempt. | Emergency medicine trainees Emergency medicine physicians | RCT                     | C-MAC                      | First-pass success (no statistically significant difference between VL and DL) Duration of intubation attempt (no difference between DL and VL) Aspiration pneumonia (no difference between DL and VL) Hospital length of stay (no difference between DL and VL) |
| 3 Gao et al. (2018)    | China   | ICU     | Critically ill        | ICU physicians     | Randomised non-blinded trial | Med. Adult type Video Laryngoscope VL300M, Zhejiang UE Medical Corp | First-pass success (no statistically significant difference between DL and VL) |
| 4 Griesdale et al. (2012) | Canada | Not specified | Critically ill | Non-anesthesiology residents or medical students | Pilot randomised trial | GlideScope | Cormark-Lehane grade 1 glottic view (VL 85%, DL 30%, p<0.001) Clinical outcomes (no difference between DL and VL) |
| 5 Groombridge et al. (2021) | Australia | ED    | All ED intubations | ED consultants, ED registrars, anesthetic consultants, anesthetic registrars, ICU consultants, ICU registrars | Interventional study | Storz C-MAC | VL was more likely to be used for ED intubations during the COVID-19 pandemic compared to prior to the COVID-19 pandemic. |
| 6 Ilbagi et al. (2021) | Iran    | ED      | Adult patients undergoing intubation in ED | Novice physicians | Randomised trial | GlideScope | Hemodynamic changes (VL > VL, p < 0.001) |
| 7 Janz et al. (2016)   | United States | ICU   | Critically ill        | Not specified      | Randomised, parallel-group pragmatic trial | McGrath Video Laryngoscope GlideScope | First-pass success (VL 68.9% vs DL 65.8%; p = 0.68). Glottic view (VL > DL). Time to intubation, lowest arterial oxygen saturation, complications and in-hospital mortality (no difference between VL and DL) |
| 8 Kim et al. (2016)    | Korea   | ED      | Patients undergoing CPR | Experienced operators | Prospective randomised controlled study | GlideScope | Intubation success during CPR (no significant difference between VL and DL). Speed of intubation during CPR (no significant difference between VL and DL). Saldes Complications of intubation during CPR (no significant difference between VL and DL). Completion of intubation without interruption of chest compressions (VL > DL). |
| 9 Lakticova et al. (2015) | United States | ICU   | Critically ill        | Not specified      | Controlled non-randomised trial | GlideScope | Oesophageal intubations (VL (0.4%) < DL (19%), Difficult intubation rate (VL 7%) < DL 22%). |

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specifically recommended for COVID-19 patients requiring cardiopulmonary resuscitation (CPR). Both of these guidelines state that VL should be used if the airway operator is familiar with its use [23, 27]. CPR guidelines from Barati et al. 2020 also recommend that intubation performed during CPR should be done with VL if possible [19]. Piepho et al. 2015 recommended that VL be used as an “alternative strategy” for management of an unexpectedly difficult airway [10]. All other included guidelines recommended early use of VL or the use of VL, rather than only as a rescue device.

### Non-guideline research papers on VL

Articles were published from a broad range of countries, with settings including one or multiple of ED, ICU and ward-based settings (see Tables 2 and 3). A majority of the included non-guideline papers were relevant to an ED setting (60%) [4, 9, 29, 32, 33, 35, 39, 41, 42, 44–54, 60, 62, 64, 66–70, 75, 76]. There were 21 included non-guideline papers (42%) which were relevant to an ICU setting [28, 30, 34, 36–38, 40, 43, 53, 55–59, 61, 63, 65, 71–74]. The most common patient group was critically ill. Included papers were heterogeneous in terms of airway operator(s) discussed or investigated in the research. Our results include both interventional studies (Table 2) and observational studies (Table 3). Observational studies were the most common (38/50, 76%). Type of VL discussed was also varied, and included Mcgrath MAC, GlideScope, C-MAC (standard blade, D-blade or straight blade), Airtraq, WuScope, AWS, Bullard, Lightward, Karl Storz Video Macintosh Laryngoscope, Stroz C-MAC, V-MAC, flexible fibre optics, hyperangulated VL, standard geometry VL, Olympus, Clarus video system, Truview, Med. Adult type Video Laryngoscope, King Vision, UEScope, Airway Scope, Ambu-Pentax and VividTrac.

There were several different outcomes assessed across the 50 included non-guideline papers. Outcomes included first-pass intubation success, overall intubation success, severe complications of intubation, oesophageal intubation rates, glottic view, frequency of VL use, incidence of difficult intubation and clinical outcomes including hospital length of stay and inhospital mortality. If outcomes were associated with a statistically significant p-value, this is shown in Tables 2 / 3 for interventional and observational studies respectively.
| Author (Year) | Country | Setting | Patient group | Airway operator(s) | Study design | Type of VL | Outcome(s) |
|---------------|---------|---------|---------------|-------------------|--------------|------------|------------|
| Amalric et al. (2020) [40] | France | ICU | Critically ill | Novice operators (1–5 previous experience with VL) vs expert operators (>15 previous experiences with VL) | Observational study | McGrath MAC | First pass success using VL (87% for expert operators and <50% for novice operators) Complications of intubation including severe hypoxemia (VL < DL, p<0.001). |
| April et al. (2017) [41] | United States | ED | All patients intubated in ED (71% trauma) | ED physicians | Observational study | Not specified | First pass success (VL 90.9% vs DL 73.0%) |
| Aziz (2013) [42] | United States | Pre-hospital ED | Trauma | Not specified | Not specified | Glidescope Airtraq WuScope AWS C-MAC Bullard Lightward | Glottic view (VL > DL). Use of VL is growing. |
| Brewster et al. (2021) [43] | Australia and New Zealand | ICU | COVID-19 patients | ICU directors | Observational study | Not specified | VL was used 94% of the time during the airway management of patients with COVID-19. |
| Brown et al. (2010) [44] | United States | ED | All adults requiring intubation in ED (74% medical, 26% trauma, 1% unknown) | Interns, residents and emergency physicians | Observational study | Karl Storz Video Macintosh Laryngoscope | Glottic view (80% with DL and 93% with VL, p<0.0001) |
| Brown et al. (2015) [45] | United States | ED | ED patients requiring intubation (both medical and trauma) | ED physicians and trainees | Observational study | C-MAC V-MAC GlideScope Flexible fibre optics | First-pass success (increased 6% during the past decade and is highest when a C-MAC video laryngoscope is chosen as the first device) |
| Brown et al. (2020) [46] | United States | ED | ED patients requiring intubation | Not specified | Observational study | Hyperangulated VL Standard geometry VL | First-attempt success was significantly higher with all VL (90.9%, 95% CI = 88.7 to 93.1) versus all DL* (81.1%, 95% CI = 78.7 to 83.5) *DL in this study refers to DL augmented by laryngeal manipulation, ramped patient positioning and the use of a bougie compared to unaided VL |
| Carlson et al. (2015) [47] | United States | ED | Adults with gastrointestinal bleeding | Not | Observational study | Not specified | First pass success (no difference between VL and DL) Glottic view (no difference between VL and DL) Need to change device (no difference between VL and DL) |

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| Author (Year) | Country | Setting | Patient group | Airway operator(s) | Study design | Type of VL | Outcome(s) |
|--------------|---------|---------|---------------|-------------------|-------------|------------|------------|
| Chan et al. (2021) | Singapore | ED | Majority medical indications | Majority postgraduate year 5 trainees, fellows and attending physicians | Observational study | Claus video system C-MAC standard blade C-MAC D blade C-MAC straight blade McGrath video laryngoscope | First-pass success (no statistically significant difference between VL and DL) VL was the most commonly used device for emergency department intubations. |
| Cho et al. (2015) | Korea | ED | Trauma | ED physicians (junior and senior) Physicians from other specialties (residents only) | Observational study | Multiple including: GlideScope Airtraq Truview | First pass success in difficult airway trauma patients (no statistically significant difference between VL and DL) |
| Choi et al. (2015) | Korea | ED | Adults requiring intubation in ED (without cardiac arrest) | ED physicians (junior and senior) Physicians from other specialties | Observational study | GlideScope | First-pass intubation success (no statistically significant difference between VL and DL) |
| Dodd et al. (2019) | United States | ED | Adults intubated in ED | Emergency physicians | Observational study | C-MAC | First-pass success (not significantly different when the screen was viewed (195/207; 94% [95%CI 91–97]) compared to when the screen was not viewed (284/301; 94% [95%CI 92–97]). |
| Driver et al. (2020) | United States | ED | Patients aged over 14 intubated in ED | Emergency medicine postgraduate year 3 or 4, fellow, or attending physician | Observational study | Standard-Geometry VL (C-MAC Macintosh blades and the GlideScope Titanium Mac or disposable DirectView MAC blades) Hyperangulated VL (LoPro and GVL) | First pass success (no association between standard geometry VL and hyperangulated VL) |
| Green et al. (2017) | Canada | ED ICU | Not specified | Emergency physicians ICU physicians | Observational study | Not specified | Most emergency physicians and ICU physicians use direct laryngoscopy with a Macintosh blade as a primary device. |
| Hart & Goldstein (2020) | South Africa | ED | All patients requiring airway intervention in ED | Interns Medical officers Registrars Other (Medical students, paramedic students and trauma nurse trainees) | Observational study | GlideScope | First pass success (No difference between VL (81.7%) and DL (73.3%) (p-value 0.079)). Glottic view (VL > DL). |
| Hawkins et al. (2021) | United States | All patients undergoing emergency intubation outside the operating room. Patients with COVID-19. | Anaesthesiology residents, EM residents, anaesthesiologists, CRNA, emergency physicians and non-emergency physicians | Observational study | Not specified | VL was used significantly more in COVID-19 cases compared to non-COVID-19 cases | (Continued) |
| Author (Year)          | Country  | Setting          | Patient group                  | Airway operator(s)                       | Study design           | Type of VL                  | Outcome(s)                                                                 |
|-----------------------|----------|------------------|--------------------------------|------------------------------------------|------------------------|-----------------------------|-----------------------------------------------------------------------------|
| Hypes et al. (2016)   | United States | ICU              | Critically ill                  | Pulmonary-critical care<br>Critical care medicine<br>Emergency medicine<br>Family medicine<br>Anaesthesia<br>Surgery | Observational study    | GlideScope<br>C-MAC<br>King Vision<br>McGrath MAC | First-pass intubation success (achieved in 81.7% of patients intubated with VL, whereas >1 attempt was needed in 18.3%). Incidence on complications (greater when first-pass success not achieved) |
| Hypes et al. (2017)   | United States | ICU              | Critically ill                  | Non-anesthetists                         | Observational study    | GlideScope<br>C-MAC<br>King Vision<br>McGrath MAC | First-pass success (VL (80.4%) > DL (65.4%, p < 0.001))<br>Arterial oxygen desaturation (VL (18.3%) < DL (25.9%), p = 0.04)<br>Oesophageal intubation (VL (2.1%) < DL (6.6%), p = 0.008) |
| Joshi et al. (2017)   | United States | ICU              | Critically ill                  | Not specified                            | Observational study    | GlideScope<br>C-MAC<br>Mcgrath MAC<br>King Vision | First pass success using VL (reduced in the presence of blood in the airway, airway oedema, cervical immobility, and obesity). |
| Kory et al. (2013)    | United States | ICU              | Critically ill                  | Less experienced operators               | Observational study    | GlideScope                 | First-pass intubation success (VL (91%) > DL (68%), p<0.01). Rate of intubations requiring ≥3 attempts (VL (4%) < DL (20%), p < 0.01). Unintended esophageal intubations (VL (0%) < DL (14%), p < 0.01). Average number of attempts required for successful tracheal intubation (1.2 ± 0.56 for VL vs 1.7 ± 1.1 for DL, p < 0.01). |
| Mallick et al. (2020) | India     | ED               | Patients presenting to ED requiring definitive airway management | Not specified                            | Observational study    | KingVision                 | Mean time to intubate (no statistically significant difference between VL and DL). First-pass success (no statistically significant difference between VL and DL). |
| Martin et al. (2020)  | France    | ICU              | Critically ill                  | ICU physicians                           | Observational survey   | MacGrath<br>Airtraq<br>GlideScope | The use of VL was reserved for difficult intubation in a majority of cases, rather than being used as a first line intubation device. |
| Michaillidou et al. (2015) | United States | ED               | Trauma                          | Medical students, paramedics, PGY1-4 and attending | Observational study    | Not specified | Overall intubation success rate (VL 88% vs DL 83%, p = 0.05) |

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Table 3. (Continued)

| Author (Year) | Country | Setting | Patient group | Airway operator(s) | Study design | Type of VL | Outcome(s) |
|---------------|---------|---------|---------------|-------------------|--------------|------------|------------|
| 24 Mosier et al. (2013) [63] | United States | ICU | Critically ill Residents, Pulm/CCM or CCM fellows, attending intensivists | Residents, Pulm/CCM or CCM fellows, attending intensivists | Observational study | GlideScope C-MAC | First-pass success (VL > DL (78.6% vs 60.7%)). Ultimate success (VL > DL (98.3% vs 91.2%)). Oesophageal intubation (VL < DL (1.3% vs 12.5%)). |
| 25 Mosier et al. (2013) [64] | United States | ED | Patients intubated with C-MAC or GlideScope VL in ED | Emergency medicine residents | Observational study | GlideScope C-MAC | First-pass success (No statistically significant difference between C-MAC VL and GlideScope VL). |
| 26 Noppens et al. (2012) [65] | Germany | ICU | Critically ill patients with at least one predictor for difficult intubation | Junior physicians (<3 years clinical experience), senior physicians (>3 years clinical experience) and anaesthesiologists | Observational study | C-MAC | First-pass success (VL > DL, 79% vs 55%, p = 0.03). Glottic view (VL > DL, p < 0.0001). |
| 27 Okamoto et al. (2018) [66] | United States | ED | Cardiac arrest | Not specified | Observational study | C-MAC McGrath Airway Scope GlideScope | First attempt success (VL (78%) > DL (70%), p < 0.001). Glottic view (VL > DL, p < 0.001). Oesophageal intubation (VL < DL, p = 0.01). |
| 28 Weng et al. (2021) [9] | Hong Kong | ED | Patients in emergency department requiring intubation | Attending and non-attending ED physicians | Observational study | GlideScope McGrath C-MAC | Overall first-pass success (VL < DL). First-pass success among non-attending emergency physicians (VL > DL). First-pass success among attending emergency physicians (VL < DL). |
| 29 Sakles et al. (2012) [67] | United States | ED | All patients requiring intubation in ED | Not specified | Observational study | GlideScope | First-pass success (VL > DL, p = 0.03). Success rate when more than 1 attempt requires (DL > VL, p = 0.003). Overall intubation success rate (no statistically significant difference between VL and DL). Oesophageal intubation (VL < DL, p = 0.005). |
| 30 Sakles et al. (2014) [68] | United States | ED | Patients with difficult airway characteristics | Emergency medicine PGY 1–3 and attendings | Observational study | GlideScope C-MAC | First-pass success in patients with difficult airway characteristics (VL > DL). |
| 31 Sakles et al. (2014) [4] | United States | ED | Trauma | Not specified | Observational study | GlideScope | First-pass success using VL (75.6% in first year of study compared to 92.1% in seventh year of study, p = 0.008). |

(Continued)
First-pass success. First-pass success was an outcome measure in 30/50 (60%) of included papers [4, 9, 29, 30, 34, 38, 40, 41, 45–52, 54, 56–60, 63–68, 70, 74]. There were 23 papers that directly compared VL and DL in terms of first-pass success. VL was found to be superior to DL in terms of first-pass intubation success in 13/23 (56.5%) of these studies [9, 38, 40, 41, 46, 56, 57, 59, 63, 65, 67, 68]. There was no significant difference between VL and DL in terms of first-pass intubation success in 11/23 (47.8%) of these studies [9, 29, 30, 34, 37, 47–50, 54, 60]. Weng et al. (2020) found that first-pass success was improved with VL compared to DL among non-attending emergency physicians, but not amongst attending emergency physicians and hence is included in both groups here [9].

Overall intubation success. Overall intubation success rate was a measured outcome in four of the included studies, with none of these reporting a difference in overall intubation success using VL compared to DL [35, 62, 63, 67].
Glottic view. There were 8 included studies that assessed glottic view as an outcome measure. Of these, 7/8 (87.5%) report that VL is associated with improved glottic view compared to DL [31, 34, 42, 44, 54, 65, 66]. Carlson et al. reported that there was no difference in glottic view when using VL compared to DL [47].

Oesophageal intubation rate. There were 4 studies that looked at rate of oesophageal intubations, with 100% of these reporting less oesophageal intubations with VL compared to DL [36, 63, 66, 67].

Incidence of difficult intubation. Difficult intubation was an outcome measure in 2 of the included studies, both of which found that the incidence of difficult intubation was less with VL compared to DL [28, 36].

Frequency of VL use. There were 10 included studies that report on the frequency of VL use [32, 42, 43, 48, 53, 55, 61, 71–73]. Aziz et al. (2013) reports that the frequency of VL use is growing, as the device is becoming more affordable and more readily available [42]. Results from Brewster et al. (2021), Groombridge (2021) and Hawkins (2021) all suggest that the use of VL has increased with the COVID-19 pandemic [32, 43, 55]. In contrast, Green et al. (2017) and Seisa et al (2018) report that DL remains a more commonly used airway device [53, 71].

Complications of intubation. There were eight included studies that discussed complications of intubation using VL. Overall, the results of these studies were varied. Four (50%) of these studies found that there was a difference between VL and DL in terms of complication rates [37, 39, 40, 57], whereas four (50%) did not [28, 29, 34, 35].

Clinical outcomes. Clinical outcomes including hospital length of stay and in-hospital mortality rates were measured in only three included studies. There was no statistically significant difference in hospital length of stay, in-hospital mortality or overall mortality found in these studies [29, 31, 34].

Discussion

This study aimed to provide an up-to-date review of the role of VL in intubation of the critically ill outside the OR. We identified 64 research papers from the past 10 years on the use of VL outside the OR, including 14 clinical practice guidelines.

In terms of first-pass success, some of our included papers (n = 13) showed increased first pass success with VL compared to DL; however, a similar number of papers (n = 11) showed no difference in first-pass success between VL and DL. Weng et al. (2020) found that VL was associated with improved first past success amongst non-attending physicians, but this difference was not seen amongst attending physicians [9]. This suggests that the usefulness of VL in helping to achieve first pass success may be operator dependent. This finding is in keeping with the existing literature, with a review article and meta-analysis from Arulkumaran et al. (2018) demonstrating that first-pass success was increased when VL was used in ICU and amongst novice/trainee clinicians [8]. Furthermore, a review article from Howson et al. (2020) also showed that first-pass success was higher with VL compared to DL in junior operators, but the difference was not seen amongst senior operators [77].

Although some results suggest that VL may improve first-pass intubation success, our results indicate that VL is yet to be shown to improve overall intubation success. We found that VL is likely to improve glottic view, and reduce the incidence of oesophageal intubations; however, the degree to which this view is improved and how this improves clinical outcomes remains unclear. Further research is required to directly determine this.

Most worthy of discussion when reflecting on both first pass success and improved glottic view with VL is the type of VL blade used. There has been a move in recent years towards a Macintosh blade by most VL manufacturers, with an increased focus on the use VL with a
hyperangulated blade (HAVL). The papers included in this study have a heterogenous group of video laryngoscopes and blades. HAVL may indeed further improve glottic view, but first-pass success may differ depending on the volume of practice and training in HAVL by the operator [43, 78]. Future research should focus on these outcomes with the use of VL, whilst drawing a distinction between conventional VL blades and HAVL, as well as the use of HAVL in novice versus experienced operator hands.

Our results show that the frequency of VL use outside the OR appears to be increasing in recent years, and particularly through the COVID-19 pandemic. This may be due to VL becoming more affordable and more readily available in both the ICU and ED. Although the exact frequency of VL use outside the OR is uncertain, some studies in our review suggest that the frequency of VL use has increased dramatically during the COVID-19 pandemic [2]. This is likely in response to published clinical practice guidelines on airway management for COVID-19 patients outside the OR unanimously supporting the use of VL in COVID-19 patients, and the perception of safety presented by the increased distance between the airway operator and the patient that VL offers [6]. However, as the COVID-19 pandemic has evolved, we have learnt that the virus is transmitted more by aerosols than my contact, so increased distance between the patient’s airway and the airway operator is perhaps less protective than initially thought. Furthermore, VL is recognised as a powerful training tool, as it allows a supervisor to view to airway in real time and provide real time guidance to a trainee airway operator [9].

Our results were varied in terms of the impact of VL on complications of intubation. Some studies showed that complications such as severe hypoxemia were lower when VL was used, whilst others showed that this complication actually increased with the use of VL. There were 3 studies that looked at clinical outcomes for patients including hospital length of stay and in-hospital mortality rates. There was no statistically significant difference in hospital length of stay, in-hospital mortality or overall mortality found in our included studies. However, the recently published INTUBE study has since also demonstrated an increased likelihood or first-pass success through the use of VL outside the OR [2]. This success correlated with a reduced primary adverse event outcome, being a composite outcome measure that included cardiovascular instability (42.6%), severe hypoxemia (9.3%) and cardiac arrest in 3.1%. Patients in that study with a primary adverse event had an increased hospital mortality (40.7% vs 26.3%) [2]. This should prompt ongoing research to look at specific patient outcomes associated with the use of VL in this patient group.

The primary limitation of this paper is the heterogenous nature of the included papers. Research varied in terms of country of publication, setting, patient group, airway operator(s), study design and type of VL assessed. Specifically, observational studies are analysed alongside RCTs and other interventional studies, which limits the strength of our conclusions. Outcome measures also varied significantly. Most included studies are observational and have a small sample size. In addition, most of the included clinical practice guidelines do not provide a detailed description of their evidence base, or their methodology for guideline development. They also do not describe the use of the same VL manufacturer or blade type. Limited research has been described specifically on the use and benefit of HAVL in this group.

**Conclusion**

Ultimately, our results suggest that the use of VL outside the OR has increased in recent years, and particularly through the COVID-19 pandemic. The early use of VL is recommended in most published clinical practice guidelines and is unanimously recommended for management of COVID-19 intubations. It appears that VL is likely to improve glottic view and
decrease incidence of oesophageal intubations; however, it remains unclear as to how this contributes to first-pass success. Within the limitations of our research, we found that VL has yet to show significant improvement in overall intubation success or clinical outcomes such as mortality outside the OR. More directed research is required to further characterise the use of VL outside the OR, the type of blade used and the clinical outcomes associated with its use.

Supporting information
S1 Checklist. PRISMA 2009 checklist. (PDF)

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References
1. Cook TM, Woodall N, Frerk C. Major complications of airway management in the UK: Results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: Anaesthesia. Br J Anaesth. 2011; 106(5):617–31. https://doi.org/10.1093/bja/aer058 PMID: 21447488
2. Russotto V, Myatra SN, Laffey JG, Tassistro E, Antolini L, Bauer P, et al. Intubation Practices and Adverse Peri-intubation Events in Critically Ill Patients from 29 Countries. JAMA—Journal of the American Medical Association. 2021 Mar 23; 325(12):1164–72. https://doi.org/10.1001/jama.2021.1727 PMID: 33755076
3. Cook TM, Woodall N, Harper J, Benger J. Major complications of airway management in the UK: Results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: Intensive care and emergency departments. Br J Anaesth. 2011; 106(5):632–42. https://doi.org/10.1093/bja/aer059 PMID: 21447489
4. Sakles JC, Mosier J, Patanwala AE, Dicken J. Improvement in GlideScope® Video Laryngoscopy performance over a seven-year period in an academic emergency department. Intern Emerg Med. 2014 Oct 2; 9(7):789–94. https://doi.org/10.1007/s11739-014-1122-3 PMID: 25164411
5. Edelman DA, Perkins EJ, Brewster DJ. Difficult airway management algorithms: a directed review. Vol. 74, Anaesthesia. Blackwell Publishing Ltd; 2019. p. 1175–85.
6. Brewster DJ, Chirmes N, Do TBT, Fraser K, Groombridge CJ, Higgs A, et al. Consensus statement: Safe Airway Society principles of airway management and tracheal intubation specific to the COVID-19 adult patient group. Medical Journal of Australia. 2020 Jun 1; 212(10):472–81. https://doi.org/10.5694/mja2.50598 PMID: 32356900
7. Cook TM, El-Boghdaddy K, McGuire B, McNarry AF, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19: Guidelines from the Difficult Airway Society, the Association of Anaesthetists the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anaesthetists. Anaesthesia. 2020 Jun 1; 75(6):785–99. https://doi.org/10.1111/anae.15054 PMID: 32221970
8. Arulkumaran N, Lowe J, Ions R, Mendoza M, Bennett V, Dunser MW. Videolaryngoscopy versus direct laryngoscopy for emergency orotracheal intubation outside the operating room: a systematic review and meta-analysis. Vol. 120, British Journal of Anaesthesia. Elsevier Ltd; 2018, p. 712–24. https://doi.org/10.1016/j.bja.2017.12.041 PMID: 2976112

9. Weng WP, Zakaria NDB, Gek Ching S, Wong E. Does video laryngoscopy or direct laryngoscopy affect first-pass success rates for intubation among attending and non-attending emergency physicians in the emergency department? Hong Kong Journal of Emergency Medicine. 2021 Sep 1; 28(5):285–90.

10. Piepho T, Cavus E, Noppens R, Byhahn C, Dörges V, Zwissler B, et al. S1 guidelines on airway management—Guideline of the German Society of Anaesthesiology and Intensive Care Medicine. Anaesthesist. 2015 Dec 1; 64:27–40.

11. Sharrock MF, Rosenblatt K. Acute Airway Management and Ventilation in the Neurocritical Care Unit. In: Current Clinical Neurology. Humana Press Inc.; 2020, p. 31–47.

12. Scott JA, Heard SO, Zayaruzny M, Walz JM. Airway Management in Critical Illness: An Update. Vol. 157, Chest. Elsevier Inc; 2020, p. 877–87.

13. Myatra SN, Ahmed SM, Kundra P, Garg R, Ramkumar V, Patwa A, et al. Republication: All India difficult airway association 2016 guidelines for tracheal intubation in the intensive care unit. Indian Journal of Critical Care Medicine. 2017 Mar 1; 21(3):146–53. https://doi.org/10.4103/ijccm.IJCCM_57_17 PMID: 28400685

14. Lewis SR, Butler AR, Parker J, Cook TM, Smith AF. Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation. Vol. 2016, Cochrane Database of Systematic Reviews. John Wiley and Sons Ltd; 2016.

15. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ. 2009;339. https://doi.org/10.1136/bmj.b2700 PMID: 19622552

16. CASP Checklists. CASP UK. 2018. https://casp-uk.net/casp-tools-checklists/

17. Cook DA, Reed DA. Appraising the Quality of Medical Education Research Methods. Academic Medicine. 2015 Aug; 90(8):1067–76.

18. Apfelbaum JL, HCCR et al. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anaesthesiologists Task Force on Management of the Difficult Airway. Anaesthesiology. 2013; 118:251–70.

19. Barati S, Garjani K, Payandemehr P, Totonchi Z, Zanganehfar M, Sadeghipour P, et al. Iranian heart association task force on cardiopulmonary resuscitation guidelines on the COVID-19 outbreak. Res Cardiovasc Med. 2020; 9(1):3.

20. Frerk C, Mitchell VS, McNarry AF, Mendoza C, Bhagrath R, Patel A, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. Br J Anaesth. 2015 Dec 1; 115(6):827–48. https://doi.org/10.1093/bja/aev371 PMID: 26556848

21. Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingham G, Gale R, et al. Guidelines for the management of tracheal intubation in critically ill adults. Vol. 120, British Journal of Anaesthesia. Elsevier Ltd; 2018, p. 207–9.

22. NASA P, Azoulay E, Khanna AK, Jain R, Gupta S, Javeri Y, et al. Expert consensus statements for the management of COVID-19-related acute respiratory failure using a Delphi method. Crit Care. 2021 Dec 1; 25(1). https://doi.org/10.1186/s13054-021-03491-y PMID: 33726819

23. Nolan JP, Monsieurs KG, Bossaert L., Böttiger BW, Greif R, Lott C, et al. European Resuscitation Council COVID-19 guidelines executive summary. Resuscitation. 2020 Aug 1; 153:45–55. https://doi.org/10.1016/j.resuscitation.2020.06.001 PMID: 32525022

24. Oh J, Cha KC, Lee JH, Park S, Kim DH, Lee BK, et al. 2020 Korean guidelines for cardiopulmonary resuscitation. part 4. adult advanced life support. Clin Exp Emerg Med. 2021; 8(5):S26–40. https://doi.org/10.15441/ceem.21.023 PMID: 34034448

25. Quintard H, l’Her E, Pottecher J, Adnet F, Constantin JM, de Jong A, et al. Experts’ guidelines of intubation and extubation of the ICU patient of French Society of Anaesthesia and Intensive Care Medicine (SFAR) and French-speaking Intensive Care Society (SRLF): In collaboration with the pediatric Association of French-speaking Anaesthesiasts and Intensivists (ADARPEF), French-speaking Group of Intensive Care and Paediatric emergencies (GFRUP) and Intensive Care physiotherapy society (SKR). Ann Intensive Care. 2019 Dec 1; 9(1).

26. Sharma D, Rasmussen M, Han R, Whalin MK, Davis M, Kofke WA, et al. Anesthetic Management of Endovascular Treatment of Acute Ischemic Stroke during COVID-19 Pandemic: Consensus Statement from Society for Neuroscience in Anesthesiology & Critical Care (SNACC). J Neurosurg Anesthesiol. 2020 Jul 1; 32(3):193–201.

27. Singh B, Garg R, Chakra Rao SSC, Ahmed S, Dlvatia J, Ramakrishnan T, et al. Indian resuscitation council (IRC) suggested guidelines for comprehensive cardiopulmonary life support (CCLS) for
suspected or confirmed coronavirus disease (COVID-19) patient. Indian J Anaesth. 2020 May 1; 64 (14):S91–6. https://doi.org/10.4103/ija.IJA_481_20 PMID: 32773845

28. de Jong A, Clavieras N, Conseil M, Coisel Y, Mouny PH, Pouzeratte Y, et al. Implementation of a combo videolaryngoscope for intubation in critically ill patients: A before-after comparative study. Intensive Care Med. 2013 Dec; 39(12):2144–52. https://doi.org/10.1007/s00134-013-3099-1 PMID: 24045887

29. 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. In: Academic Emergency Medicine. Blackwell Publishing Inc.; 2016. p. 433–9.

30. Gao Y xia, Song Y bo, Gu Z juan, Zhang J song, Chen X feng, Sun H, et al. Video versus direct laryngoscopy in patients with suspected or confirmed COVID-19 patient. Indian J Anaesth. 2020 May 1; 64 (14):S91–6. https://doi.org/10.4103/ija.IJA_481_20 PMID: 32773845

31. Griesdale DEG, Chau A, Isaac G, Ayas N, Foster D, Irwin C, et al. Video-laryngoscopy versus direct laryngoscopy in critically ill patients: A pilot randomized trial. Canadian Journal of Anesthesia. 2012 Nov; 59(11):1032–9. https://doi.org/10.1007/s12630-012-9775-8 PMID: 22932944

32. Groombridge CJ, Maini A, Olausson A, Kim Y, Fitzgerald M, Smit DV. Unintended consequences: The impact of airway management modifications introduced in response to COVID-19 on intubations in a tertiary centre emergency department. EMA—Emergency Medicine Australasia. 2021 Aug 1; 33 (4):728–33.

33. Ilbagi M, Nasr-Esfahani M. The efficacy of using video laryngoscopy on tracheal intubation by novice physicians. Iran J Otolhinolaryngol. 2021 Jan 1; 33(1):37–44. https://doi.org/10.22038/ijolr.2020.43797. 2447 PMID: 33654689

34. Janz DR, Semler MW, Lentz RJ, Matthews DT, Assad TR, Norman BC, et al. Randomized Trial of Video Laryngoscopy for Endotracheal Intubation of Critically Ill Adults. Crit Care Med. 2016 Nov 1; 44 (11):1980–7. https://doi.org/10.1097/CCM.0000000000001841 PMID: 27355526

35. Kim JW, Park SO, Lee KR, Hong DY, Baek KJ, Lee YH, et al. Video laryngoscopy vs. direct laryngoscopy: Which should be chosen for endotracheal intubation during cardiopulmonary resuscitation? A prospective randomized controlled study of experienced intubators. Resuscitation. 2016 Aug 1; 105:196–202. https://doi.org/10.1016/j.resuscitation.2016.04.003 PMID: 27095128

36. Lakticova V, Koenig SJ, Narasimhan M, Mayo PH. Video laryngoscopy is associated with increased first pass success and decreased rate of esophageal intubations during urgent endotracheal intubation in a medical intensive care unit when compared to direct laryngoscopy. J Intensive Care Med. 2015 Jan 16; 30(1):44–8. https://doi.org/10.1177/0885066614529641 PMID: 23771676

37. Lascarro JB, Boisrame-Helms J, Bailly A, le Thuaut A, Kamel T, Mercier E, et al. Video laryngoscopy vs direct laryngoscopy on successful first-pass orotracheal intubation among ICU patients: A randomized clinical trial. JAMA—Journal of the American Medical Association. 2017 Feb 7; 317(5):483–93. https://doi.org/10.1001/jama.2016.20603 PMID: 28118659

38. Silverberg MJ, Li N, Acquah SO, Kory PD. Comparison of video laryngoscopy versus direct laryngoscopy during urgent endotracheal intubation: A randomized controlled trial. Crit Care Med. 2015 Mar 4; 43(3):636–41. https://doi.org/10.1097/CCM.0000000000001751 PMID: 25479112

39. Yeatts DJ, Dutton RP, Hu PF, Chang YWW, Brown CH, Chen H, et al. Effect of video laryngoscopy on trauma patient survival: A randomized controlled trial. In: Journal of Trauma and Acute Care Surgery. 2013. p. 212–8. https://doi.org/10.1097/TA.0b013e3182931034 PMID: 23826362

40. Amalric M, Larcher R, Brunot V, Gamier F, de Jong A, Moulaire Rigollet V, et al. Impact of videolaryngoscopy expertise on first-attempt intubation success in critically ill patients. Crit Care Med. 2020;E889–96. https://doi.org/10.1097/CCM.0000000000004497 PMID: 32789622

41. April MD, Long B. Does the Use of Video Laryngoscopy Improve Intubation Outcomes? Vol. 71, Annals of Emergency Medicine. Mosby Inc.; 2018. p. e9–11.

42. Aziz M. Use of Video-assisted Intubation Devices in the Management of Patients with Trauma. Vol. 31, Anesthesiology Clinics. 2013. p. 157–66. https://doi.org/10.1016/j.anclin.2012.10.001 PMID: 23351541

43. Brewster DJ, Nickson CP, McGoughlin S, Picher D, Sarode V V., Gatward JJ. Preparation for airway management in Australia and New Zealand ICUs during the COVID-19 pandemic. PLoS One. 2021 May 1; 16(5 May). https://doi.org/10.1371/journal.pone.0251523 PMID: 33961677

44. Brown CA, Bair AE, Pallin DJ, Laurin EG, Walls RM. Improved glottic exposure with the video Macintosh laryngoscope in adult emergency department tracheal intubations. Ann Emerg Med. 2010; 56 (2):83–8. https://doi.org/10.1016/j.annemergmed.2010.01.033 PMID: 20202720

45. Brown CA, Bair AE, Pallin DJ, Walls RM. Techniques, success, and adverse events of emergency department adult intubations. Ann Emerg Med. 2015 Apr 1; 65(4):363-370.e1.

46. Brown CA, Kaji AH, Fantegrossi A, Carlson JN, April MD, Kilgo RW, et al. Video Laryngoscopy Compared to Augmented Direct Laryngoscopy in Adult Emergency Department Tracheal Intubations: A
National Emergency Airway Registry (NEAR) Study. Academic Emergency Medicine. 2020 Feb 1; 27 (2):100–8. https://doi.org/10.1111/acem.13851 PMID: 31957174

47. Carlson JN, Crofts J, Walls RM, Brown CA. Direct versus video laryngoscopy for intubating adult patients with gastrointestinal bleeding. Western Journal of Emergency Medicine. 2015; 16(7):1052–6. https://doi.org/10.5811/westjem.2015.8.28045 PMID: 26759653

48. Chan GWH, Chai CY, Teo JSY, Tjo CKE, Chu MT, Brown CA. Emergency airway management in a Singapore centre: A registry study. Ann Acad Med Singap. 2021 Jan 1; 50(1):42–51. PMID: 33623957

49. Cho YS, Cho J, Chung HS. Assessment of emergency airway management techniques in Korea using an online registration system: A multicenter study. Journal of Emergency Medicine. 2015 Jan 1; 48 (1):1–9. https://doi.org/10.1016/j.jemermed.2014.06.044 PMID: 25271178

50. Choi HJ, Kim YM, Oh YM, Kang HG, Yim HW, Jeong SH. GlideScope video laryngoscopy versus direct laryngoscopy in the emergency department: A propensity score-matched analysis. BMJ Open. 2015; 5 (5). https://doi.org/10.1136/bmjopen-2015-007884 PMID: 25968006

51. Dodd KW, Prekker ME, Robinson AE, Buckley R, Reardon RF, Driver BE. Video screen viewing and first intubation attempt success with standard geometry video laryngoscopy use. American Journal of Emergency Medicine. 2019 Jul 1; 37(7):1336–9. https://doi.org/10.1016/j.ajem.2018.10.018 PMID: 30528054

52. 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. In: Annals of Emergency Medicine. Mosby Inc.; 2020. p. 332–8.

53. Green RS, Fergusson DA, Mcintyre LA, Kovacs GJ, Griesdale DE, et al. Device and Medication Preferences of Canadian Physicians for Emergent Endotracheal Intubation in Critically Ill Patients. Canadian Journal of Emergency Medicine. 2017 May 1; 19(3):186–97. https://doi.org/10.1017/cem.2016.361 PMID: 27573571

54. Hart JC, Goldstein LN. Analysis of the airway registry from an academic emergency department in South Africa. South African Medical Journal. 2020; 110(6):484–90. https://doi.org/10.7196/SAMJ.2020.v110i6.14120 PMID: 32880559

55. Hawkins A, Stapleton S, Rodriguez G, Mauricio Gonzalez R, Baker WE. Emergency tracheal intubation in patients with covid-19: A single-center, retrospective cohort study. Western Journal of Emergency Medicine. 2021 May 1; 22(3):678–86. https://doi.org/10.5811/westjem.2020.2.49665 PMID: 34125046

56. Hymes CD, Stolz U, Sakles JC, Joshi RR, Natt B, Malo J, 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 Mar 1; 13(3):382–9.

57. Hymes C, Sakles J, Joshi R, Greenberg J, Natt B, Malo J, et al. Failure to achieve first attempt success at intubation using video laryngoscopy is associated with increased complications. Intern Emerg Med. 2017 Dec 1; 12(8):1235–43. https://doi.org/10.1007/s11739-016-1549-9 PMID: 27738960

58. Joshi R, Hymes CD, Greenberg J, Snyder L, Malo J, Bloom JW, 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 Mar 1; 14(3):368–75. https://doi.org/10.1513/AnnalsATS.201606-472OC PMID: 27983871

59. Kopy P, Guevarra K, Mathew JP, Hegde A, Mayo PH. The impact of video laryngoscopy use during emergent endotracheal intubation in the critically ill. Anesth Analg. 2013 Jul; 117(1):144–9. https://doi.org/10.1213/ANE.0b013e3182917f2a PMID: 23687228

60. Malikic T, Verma A, Jaiswal S, Haldar M, Sheikh WR, Vishen A, et al. Comparison of the time to success-ful endotracheal intubation using the Macintosh laryngoscope or KingVision video laryngoscope in the emergency department: A prospective observational study. Turk J Emerg Med. 2020 Jan 1; 20 (1):22–7. https://doi.org/10.4103/tjem.Tjem_276_19 PMID: 32355898

61. Martin M, Decamps P, Seguin A, Garret C, Crosby L, Zambon O, et al. Nationwide survey on training and device utilization during tracheal intubation in French intensive care units. Ann Intensive Care. 2020 Dec 1; 10(1). https://doi.org/10.1186/s13613-019-00621-9 PMID: 31900637

62. Michailidou M, O’Keeffe T, Mosier JM, Friese RS, Joseph B, Rhee P, et al. A comparison of video laryngoscopy to direct laryngoscopy for the emergency intubation of trauma patients. World J Surg. 2015; 39 (3):782–8. https://doi.org/10.1007/s00268-014-2845-5 PMID: 25348885

63. Mosier JM, Whitmore SP, Bloom JW, Snyder LS, Graham LA, Carr GE, et al. Video laryngoscopy improves intubation success and reduces esophageal intubations compared to direct laryngoscopy in the medical intensive care unit. Crit Care. 2013 Oct 14; 17(5). https://doi.org/10.1186/cc13061 PMID: 24125064

64. 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).
65. 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 Jun 13; 16(3). https://doi.org/10.1186/cc11384 PMID: 22695007

66. Okamoto H, Goto T, Wong ZSY, Hagiwara Y, Watase H, Hasegawa K. Comparison of video laryngoscopy versus direct laryngoscopy for intubation in emergency department patients with cardiac arrest: A multicentre study. Resuscitation. 2019 Mar 1; 136:70–7. https://doi.org/10.1016/j.resuscitation.2018.10.005 PMID: 30385385

67. Sakles JC, Mosier JM, Chiu S, Keim SM. Tracheal intubation in the emergency department: A comparison of GlideScope® video laryngoscopy to direct laryngoscopy in 822 intubations. Journal of Emergency Medicine. 2012 Apr; 42(4):400–5. https://doi.org/10.1016/j.jemermed.2011.05.019 PMID: 2168899

68. 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 Feb; 9(1):39–8. https://doi.org/10.1007/s11739-013-0995-x PMID: 24002788

69. 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. Journal of Emergency Medicine. 2015 Mar 1; 48(3):280–8. https://doi.org/10.1016/j.jemermed.2014.10.007 PMID: 25498851

70. Sakles JC, Douglas MJ, Hypes CD, Patanwala AE, Mosier JM. Management of Patients with Predicted Difficult Airways in an Academic Emergency Department. Journal of Emergency Medicine. 2017 Aug 1; 53(2):163–71. https://doi.org/10.1016/j.jemermed.2017.04.003 PMID: 28606617

71. Seisa MO, Gondhi V, Demirci O, Diedrich DA, Kashyap R, Smischney NJ. Survey on the Current State of Endotracheal Intubation Among the Critically Ill. HEMAIR Investigators. Vol. 33, Journal of Intensive Care Medicine. SAGE Publications Inc.; 2018. p. 354–60. https://doi.org/10.1177/0885066616654452 PMID: 27298389

72. Silverberg MJ, Kory P. Survey of video laryngoscopy use by U.S. critical care fellowship training programs. Ann Am Thorac Soc. 2014 Oct 1; 11(8):1125–3. https://doi.org/10.1513/AnnalsATS.201405-189OC PMID: 25167930

73. Smischney NJ, Seisa MO, Heise KJ, Busack KD, Lofsgaard TO, Schroeder DR, et al. Practice of Intubation of the Critically Ill at Mayo Clinic. J Intensive Care Med. 2019 Mar 1; 34(3):204–11.

74. 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 Mar 1; 9(3). https://doi.org/10.1136/bmjopen-2018-024927 PMID: 30929937

75. Swaminathan AK, Berkowitz R, Baker A, Spyer M. Do emergency medicine residents receive appropriate video laryngoscopy training? a survey to compare the utilization of video laryngoscopy devices in emergency medicine residency programs and community emergency departments. In: Journal of Emergency Medicine. Elsevier USA; 2015. p. 613–9. https://doi.org/10.1016/j.jemermed.2014.12.029 PMID: 25648052

76. Hawkins E, Moy HP, Brice JH. Critical Airway Skills and Procedures. Vol. 31, Emergency Medicine Clinics of North America. 2013. p. 1–28. https://doi.org/10.1016/j.emc.2012.09.001 PMID: 23200327

77. Howson A, Goodliff A, Horner D. BET 2: Video laryngoscopy for patients requiring endotracheal intubation in the emergency department. Vol. 37, Emergency Medicine Journal. BMJ Publishing Group; 2020. p. 381–3. https://doi.org/10.1136/emermed-2020-209962.3 PMID: 32487710

78. Cabirni L, Landoni G, Biaiardo Radaelli M, Saleh O, Votta CD, Forminskiy E, et al. Tracheal intubation in critically ill patients: A comprehensive systematic review of randomized trials. Crit Care. 2018 Jan 20; 22(1). https://doi.org/10.1186/s13054-017-1927-3 PMID: 29351759