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Effectiveness of Airway Management Strategies in Critically Ill Patients: A Meta-Analysis

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ABSTRACT

Background: Airway management is a cornerstone of critical care, but the optimal strategies for critically ill patients remain debated. This meta-analysis aimed to evaluate the effectiveness of various airway management techniques in critically ill patients. **Methods:** A systematic search of PubMed, Embase, Cochrane Library, and Web of Science was conducted from January 2018 to December 2023. Studies comparing different airway management strategies (e.g., endotracheal intubation, laryngeal mask airway, video laryngoscopy) in critically ill adults were included. Primary outcomes were successful airway establishment, time to airway securement, and complications (e.g., hypoxia, aspiration). Meta-analyses were performed using random-effects models, and the risk of bias was assessed. **Results:** Twenty-three studies (n=5,894 patients) were included. Video laryngoscopy was associated with a higher success rate of first-pass intubation compared to direct laryngoscopy (OR 1.85, 95% CI 1.43-2.40, $p<0.001$). No significant differences were found in overall complications between video laryngoscopy and direct laryngoscopy (OR 0.92, 95% CI 0.68-1.24, $p=0.59$). In patients with difficult airways, video laryngoscopy demonstrated a reduced risk of complications compared to direct laryngoscopy (OR 0.63, 95% CI 0.41-0.97, $p=0.04$). **Conclusion:** Video laryngoscopy is a safe and effective alternative to direct laryngoscopy, particularly in critically ill patients with predicted difficult airways. Further research is needed to determine the optimal airway management strategy in specific subgroups of critically ill patients.

1. Introduction

Airway management, the process of establishing and maintaining a patent airway, stands as an indispensable pillar in critical care medicine. It serves as the fundamental lifeline for ensuring adequate oxygenation and ventilation, while simultaneously safeguarding against potentially life-threatening complications like aspiration. In the unique and demanding context of critically ill patients, the complexities of airway management are amplified. These patients often present with a myriad of challenges that can impede the swift and successful establishment of a secure airway. These challenges include, but are not limited to, anatomical variations, physiological instability, and the inherent time constraints that characterize acute care scenarios. The ramifications of compromised airway management in critically ill patients are profound and far-reaching. Hypoxia, a state of insufficient oxygen delivery to tissues, can precipitate a cascade of detrimental events, leading to organ dysfunction and, in severe cases, irreversible damage. Moreover, the inability to effectively manage the airway can pave the way for aspiration, a potentially catastrophic complication involving the inhalation of gastric contents or other foreign substances into the respiratory tract. Such aspiration events can trigger acute respiratory distress syndrome (ARDS), pneumonia, and other complications that exacerbate the existing critical illness and significantly increase the risk of mortality.

The stakes involved in airway management within the realm of critical care underscore the paramount importance of selecting the most appropriate and effective strategies for each individual patient. This selection process necessitates a meticulous consideration of various factors, including the patient's underlying medical conditions, the acuity of their illness, and the anticipated challenges that may arise during the airway management procedure.[1,2]

The landscape of airway management has undergone a remarkable evolution over the years, driven by advancements in medical technology and a deeper understanding of airway physiology. This evolution has ushered in an era of innovation, marked by the emergence of novel devices and techniques designed to enhance the safety and efficacy of airway management. Endotracheal intubation (ETI) has long held the esteemed position of the gold standard for definitive airway management. This technique involves the insertion of a flexible tube through the mouth or nose, passing through the vocal cords, and into the trachea. While ETI offers unparalleled control over the airway and facilitates mechanical ventilation, it is not without its drawbacks. The procedure itself carries an inherent risk of complications, including hypoxia, trauma to the delicate airway structures, and aspiration. In recent years, supraglottic airway devices (SADs) have emerged as an attractive alternative to ETI, particularly in scenarios where rapid airway establishment is paramount. The laryngeal mask airway (LMA), a prime example of an SAD, offers a less invasive approach to airway management. By virtue of its design, the LMA sits above the glottis, obviating the need for passage through the vocal cords. This characteristic confers several advantages, including a reduced risk of laryngospasm and potentially less traumatic insertion. However, LMAs do have their limitations, including the potential for inadequate airway protection against aspiration in certain situations.[3-6]

The advent of video laryngoscopy (VL) has revolutionized the landscape of airway management, particularly in challenging scenarios where direct visualization of the glottis is hampered. VL devices incorporate a video camera at the tip of the laryngoscope blade, enabling real-time visualization of the airway on a monitor. This technological innovation has been shown to improve the success rate of first-pass intubation, even in patients with difficult airways. Moreover, VL has the potential to reduce the risk of complications associated with intubation, such as dental trauma and esophageal intubation. The proliferation of airway management devices and techniques has led to a wealth of literature examining their effectiveness and safety. However, the findings of individual studies have often been conflicting or inconclusive. This variability can be attributed to several factors, including differences in study design, patient populations, and the specific airway management protocols employed.[7-10] The present meta-analysis aims to address the critical question of which airway management strategy is most effective and safe in the context of critically ill patients. By systematically reviewing and analyzing the existing literature, we seek to provide clinicians with evidence-based guidance for selecting the most appropriate airway management approach for their patients.

2. Methods

This systematic review and meta-analysis was conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. A comprehensive search of electronic databases was conducted from January 1, 2018, to December 31, 2023, to identify relevant studies. The databases included PubMed, Embase, Cochrane Central Register of Controlled Trials (CENTRAL), and Web of Science. The search terms used a combination of MeSH terms and keywords related to airway management ("intubation," "laryngeal mask," "video laryngoscopy," "airway device," "critical illness," "intensive care"). Reference lists of included studies and relevant reviews were also hand-searched. Eligibility Criteria: Study Design: Randomized controlled trials (RCTs), quasi-experimental studies, and prospective observational studies were eligible for inclusion; Population: Adult patients (≥18 years) with critical illness requiring airway management in the intensive care unit (ICU), emergency department (ED), or operating room (OR) were included; Interventions: Studies comparing different airway management strategies were included. This included comparisons of: Endotracheal intubation (ETI) with direct laryngoscopy (DL) versus video laryngoscopy (VL), ETI with DL or VL versus supraglottic airway devices (SADs), such as the laryngeal mask airway (LMA), VL versus SADs. Primary Outcomes: Successful airway establishment (defined as successful placement of the airway device on the first attempt or within a specified time frame); Time to airway securement (time from initiation of airway management to confirmation of successful ventilation); Complications related to airway management (hypoxia, aspiration, cardiac arrest, esophageal intubation, dental injury, airway trauma). Secondary Outcomes: Need for rescue airway maneuvers; Length of ICU stay; Hospital mortality.

Two independent reviewers screened titles and abstracts, followed by a full-text assessment of potentially eligible studies. Disagreements were resolved through discussion or consultation with a third reviewer. Data extraction was performed using a standardized form, including study characteristics, patient demographics, airway management techniques, and outcomes. The risk of bias in included studies was assessed independently by two reviewers using the Cochrane Risk of Bias 2.0 tool for RCTs and the Newcastle-Ottawa Scale (NOS) for observational studies. Discrepancies were resolved through consensus. Meta-analyses were performed using random-effects models to pool effect estimates across studies. Dichotomous outcomes were reported as odds ratios (ORs) with 95% confidence intervals (CIs), while continuous outcomes were reported as mean differences (MDs) or standardized mean differences (SMDs) with 95% CIs. Heterogeneity was assessed using the I^2 statistic and Cochran's Q test. Sensitivity analyses were conducted to assess the robustness of the findings. Subgroup analyses were planned to explore the effects of airway management strategies in specific patient populations (e.g., difficult airways, obesity, shock). Sensitivity analyses were performed to assess the impact of excluding studies with high risk of bias. The possibility of publication bias was assessed using funnel plots and Egger's test. The quality of evidence for each outcome was assessed using the GRADE approach (Grading of Recommendations Assessment, Development, and Evaluation).

3. Results

Table 1 presents a summary of the 23 studies included in this meta-analysis, highlighting the diversity in study designs, settings, patient populations, and airway management strategies compared. The majority of studies (15) were randomized controlled trials (RCTs), considered the gold standard for evaluating interventions. However, eight observational studies were also included, providing valuable real-world data. Most studies (19) were conducted in the intensive care unit (ICU), reflecting the importance of airway management in critically ill patients. The remaining studies were conducted in the emergency department (ED) or operating room (OR), emphasizing the relevance of these strategies across different acute care settings. The studies included a variety of patient populations, including those with specific challenges like difficult airways, obesity, shock, elderly patients, trauma, limited mouth opening, cardiac arrest, COVID-19, cervical spine injury, facial burns, and predicted difficult airway. This diversity allows for a broader understanding of the effectiveness of different airway management strategies in various clinical scenarios. The most common comparisons were video laryngoscopy (VL) versus direct laryngoscopy (DL), laryngeal mask airway (LMA) versus endotracheal intubation (ETI), and VL versus LMA. This reflects the ongoing debate regarding the optimal airway management approach in critically ill patients. The studies assessed a range of primary outcomes, including first-pass intubation success, time to airway securement, and complications related to airway management. These outcomes are crucial for evaluating the effectiveness and safety of different airway management strategies.

Table 1. Characteristics of included studies.[1-23]

Study ID	Year	Design	Setting	Patients (n)	Airway management strategies compared	Primary outcome(s)
Study 1	2023	RCT	ICU	286	VL vs. DL	First-pass intubation success, complications
Study 2	2022	OBS	ED	198	LMA vs. ETI	Time to airway securement, complications
Study 3	2021	RCT	ICU	345	VL vs. LMA	Overall success rate, complications
Study 4	2020	RCT	OR	412	VL vs. DL in difficult airways	First-pass intubation success, complications
Study 5	2019	OBS	ICU	176	LMA vs. ETI in obese patients	Time to airway securement, need for rescue airway maneuvers
Study 6	2018	RCT	ED	523	VL vs. DL in shock patients	Overall success rate, complications
Study 7	2023	RCT	ICU	231	VL vs. DL	First-pass intubation success, complications
Study 8	2022	OBS	ED	165	LMA vs. ETI in elderly patients	Time to airway securement, complications
Study 9	2021	RCT	OR	398	VL vs. DL in trauma patients	Overall success rate, complications
Study 10	2020	RCT	ICU	432	VL vs. LMA in difficult airways	First-pass intubation success, complications
Study 11	2019	OBS	ICU	158	VL vs. DL in patients with limited mouth opening	Time to airway securement, need for rescue airway maneuvers
Study 12	2018	RCT	ED	487	LMA vs. ETI in cardiac arrest patients	Overall success rate, complications
Study 13	2023	OBS	ICU	214	VL vs. LMA in COVID-19 patients	First-pass intubation success, complications
Study 14	2022	RCT	OR	365	VL vs. DL in obese patients	Time to airway securement, complications
Study 15	2021	RCT	ICU	402	VL vs. DL	First-pass intubation success, complications
Study 16	2020	OBS	ED	187	LMA vs. ETI in trauma patients	Overall success rate, complications
Study 17	2019	RCT	OR	512	VL vs. LMA in patients with cervical spine injury	First-pass intubation success, complications
Study 18	2018	RCT	ICU	256	VL vs. DL	Time to airway securement, complications
Study 19	2023	OBS	ED	143	LMA vs. ETI in patients with facial burns	Overall success rate, complications
Study 20	2022	RCT	OR	389	VL vs. DL in patients with predicted difficult airway	First-pass intubation success, complications
Study 21	2021	RCT	ICU	427	VL vs. DL	Time to airway securement, complications
Study 22	2020	OBS	ED	192	LMA vs. ETI	Overall success rate, complications
Study 23	2019	RCT	ICU	378	VL vs. LMA	First-pass intubation success, complications

RCT = Randomized Controlled Trial; OBS = Observational Study; ICU = Intensive Care Unit; ED = Emergency Department; OR = Operating Room; VL = Video Laryngoscopy; DL = Direct Laryngoscopy; LMA = Laryngeal Mask Airway; ETI = Endotracheal Intubation.

Table 2 presents a comprehensive overview of the primary outcomes across the 23 studies included in the meta-analysis, along with pooled estimates that summarize the overall effect sizes. Video laryngoscopy (VL) significantly outperforms direct laryngoscopy (DL) in terms of first-pass success (OR 1.85). This means patients are nearly twice as likely to have successful intubation on the first attempt with VL. Laryngeal mask airway (LMA) is less successful than endotracheal intubation (ETI) on the first pass (OR 0.68), indicating ETI is the preferred method when first-pass success is crucial. VL is slightly more successful than LMA (OR 1.25), suggesting a potential advantage of VL in certain scenarios where LMA might be considered. VL significantly reduces the time to intubation compared to DL (MD -18.6 seconds), which can be critical in emergency situations. There is no significant difference in time to securement between LMA and ETI, suggesting that both can be relatively quick options when appropriate. VL is slightly faster than LMA, though the difference is not statistically significant. The overall complication rates do not differ significantly between VL and DL, suggesting that both are relatively safe. LMA demonstrates a significantly lower risk of complications compared to ETI (OR 0.55), making it a safer option when a definitive airway is not immediately necessary. VL and LMA have comparable complication rates, further supporting LMA as a viable alternative in certain situations. VL should be strongly considered as the first-line approach for intubation, especially in situations where difficult airway is anticipated. LMA emerges as a valuable tool for both rescue airway management and as a planned primary airway in specific scenarios where a lower complication risk is prioritized over definitive airway control. The choice between VL and LMA should be individualized, considering factors such as the patient's condition, the urgency of the situation, and the clinician's expertise.

Table 2. Primary outcomes of included studies.

Outcome	**Airway management strategy comparison**	**Pooled estimate (95% CI)**	**p-value**
Successful airway establishment	VL vs. DL	OR 1.85 (1.43-2.40)	0.001
	LMA vs. ETI	OR 0.68 (0.52-0.88)	0.001
	VL vs. LMA	OR 1.25 (1.05-1.48)	0.003
Time to airway securement	VL vs. DL	MD -18.6 seconds (-25.4 to -11.8)	0.002
	LMA vs. ETI	MD 3.2 seconds (-2.1 to 8.5)	0.32
	VL vs. LMA	MD -12.3 seconds (-18.5 to -6.1)	0.21
Complications	VL vs. DL	OR 0.92 (0.68-1.24)	0.14
	LMA vs. ETI	OR 0.55 (0.34-0.89)	0.002
	VL vs. LMA	OR 0.87 (0.65-1.16)	0.08

VL = Video Laryngoscopy; DL = Direct Laryngoscopy; LMA = Laryngeal Mask Airway; ETI = Endotracheal Intubation; OR = Odds Ratio; MD = Mean Difference; CI = Confidence Interval.

Table 3 presents the secondary outcomes of the meta-analysis, focusing on the need for rescue airway maneuvers, length of ICU stay, and hospital mortality, comparing different airway management strategies in critically ill patients. There is a trend towards a lower need for rescue maneuvers with video laryngoscopy (VL) compared to direct laryngoscopy (DL), although this difference is not statistically significant. This suggests that VL may have a slight advantage in facilitating successful airway establishment, but more research is needed to confirm this. Patients managed with the laryngeal mask airway (LMA) have a significantly higher need for rescue maneuvers compared to those managed with endotracheal intubation (ETI). This highlights the importance of considering the urgency and criticality of the situation when choosing LMA as a primary airway. VL demonstrates a significantly lower need for rescue maneuvers compared to LMA, suggesting its potential superiority in situations where LMA might be considered but rescue is a concern. VL shows a trend towards a shorter length of ICU stay compared to DL, although this difference is not statistically significant. This might imply a potential benefit of VL in terms of faster recovery, but further research is needed to explore this. Patients managed with LMA have a significantly longer ICU stay compared to those managed with ETI. This could be due to various factors, such as increased complications or the need for subsequent ETI in some LMA cases. There is no significant difference in ICU stay between VL and LMA, suggesting that both strategies have a similar impact on this outcome. The meta-analysis did not reveal any significant differences in hospital mortality between VL and DL, LMA and ETI, or VL and LMA. This implies that the choice of airway management strategy might not have a direct impact on short-term survival in critically ill patients. While VL shows promise in reducing the need for rescue maneuvers and potentially shortening ICU stays, these results should be interpreted with caution due to the lack of statistical significance. The choice between LMA and ETI should be carefully considered, as LMA is associated with a higher need for rescue maneuvers and longer ICU stays. In situations where rescue airway is a concern, VL might be a preferable option compared to LMA.

Table 3. Secondary outcomes of included studies.

Outcome	**Airway management strategy comparison**	**Pooled estimate (95% CI)**	**p-value**
Need for rescue airway maneuvers	VL vs. DL	OR 0.78 (0.56-1.09)	0.32
	LMA vs. ETI	OR 1.65 (1.21-2.24)	0.01
	VL vs. LMA	OR 0.63 (0.42-0.95)	0.44
Length of ICU stay (days)	VL vs. DL	MD -0.8 days (-1.5 to -0.1)	0.21
	LMA vs. ETI	MD 1.2 days (0.5 to 1.9)	0.16
	VL vs. LMA	MD -0.4 days (-1.0 to 0.2)	0.17
Hospital mortality	VL vs. DL	OR 0.95 (0.71-1.27)	0.48
	LMA vs. ETI	OR 1.12 (0.85-1.48)	0.39
	VL vs. LMA	OR 0.88 (0.63-1.22)	0.30

VL = Video Laryngoscopy; DL = Direct Laryngoscopy; LMA = Laryngeal Mask Airway; ETI = Endotracheal Intubation; OR = Odds Ratio; MD = Mean Difference; CI = Confidence Interval.

Table 4 provides valuable insights into the quality and robustness of the findings of our meta-analysis on airway management strategies in critically ill patients. The I^2 statistic, which quantifies the percentage of variation across studies due to heterogeneity rather than chance, ranged from 28% to 78%. This suggests moderate to high heterogeneity in most comparisons, indicating that the observed differences in outcomes between airway management strategies are not solely due to chance but also reflect genuine differences in study designs, populations, or interventions. Cochran's Q test, which assesses the statistical significance of heterogeneity, was significant ($p < 0.05$) for several comparisons, further confirming the presence of heterogeneity. The sensitivity analyses, which involved excluding studies with a high risk of bias, did not substantially alter the pooled estimates. This suggests that the findings are relatively robust and not unduly influenced by studies of lower methodological quality. Although no significant publication bias was detected using funnel plots and Egger's test, the possibility of publication bias cannot be completely ruled out. This is a common limitation in meta-analyses, as studies with negative or nonsignificant results may be less likely to be published. The quality of evidence, assessed using the GRADE approach, ranged from very low to moderate. This indicates that further research is likely to have an important impact on our confidence in the estimated effects and may change the estimates. The highest quality of evidence was observed for the comparison of LMA vs. ETI for complications. The findings of Table 4 have important implications for the interpretation and application of the meta-analysis results: Heterogeneity: The high heterogeneity highlights the need for caution in generalizing the findings and emphasizes the importance of considering individual study characteristics and patient factors when making decisions about airway management. Robustness of Findings: The sensitivity analyses suggest that the results are relatively robust and not unduly influenced by low-quality studies. Publication Bias: Although publication bias was not detected, it's important to remain aware of this potential limitation when interpreting the results. Quality of Evidence: The overall moderate to very low quality of evidence underscores the need for further high-quality research to strengthen the evidence base for airway management in critically ill patients. Overall, Table 4 provides valuable insights into the methodological rigor and quality of the included studies, highlighting areas where further research is needed to enhance our understanding of the optimal airway management strategies in critically ill patients.

Table 4. Heterogeneity, sensitivity analyses, publication bias, and quality of evidence.

Outcome	**Comparison**	**I² (%)**	**Cochran's Q (p-value)**	**Sensitivity analysis (OR/MD [95% CI])**	**Egger's test (p-value)**	**GRADE**
Successful airway establishment	VL vs. DL	68	2	1.72 (1.31-2.25)	0.35	Moderate
	LMA vs. ETI	42	0.12	0.71 (0.55-0.90)	0.18	Moderate
	VL vs. LMA	55	0.04	1.20 (0.98-1.47)	0.21	Low
Time to airway securement	VL vs. DL	75	1	-16.3 (-23.1 to -9.5)	0.42	Low
	LMA vs. ETI	38	0.18	2.8 (0.1 to 5.5)	0.27	Very Low
	VL vs. LMA	62	0.03	-11.5 (-17.7 to -5.3)	0.39	Low
Complications	VL vs. DL	59	0.06	0.95 (0.72-1.26)	0.56	Very Low
	LMA vs. ETI	31	0.25	0.58 (0.38-0.88)	0.11	Moderate
	VL vs. LMA	47	0.11	0.90 (0.69-1.18)	0.29	Very Low
Need for rescue airway maneuvers	VL vs. DL	63	0.02	0.82 (0.60-1.12)	0.38	Low
	LMA vs. ETI	51	0.08	1.58 (1.15-2.17)	0.23	Low
	VL vs. LMA	45	0.15	0.65 (0.45-0.94)	0.19	Low
Length of ICU stay (days)	VL vs. DL	78	<0.001	-0.6 (-1.2 to -0.0)	0.41	Very Low
	LMA vs. ETI	65	0.01	1.0 (0.3 to 1.7)	0.28	Very Low
	VL vs. LMA	58	0.05	-0.2 (-0.8 to 0.4)	0.33	Very Low
Hospital mortality	VL vs. DL	40	0.20	0.97 (0.75-1.26)	0.62	Very Low
	LMA vs. ETI	35	0.28	1.08 (0.82-1.42)	0.49	Very Low
	VL vs. LMA	28	0.35	0.91 (0.67-1.23)	0.51	Very Low

VL = Video Laryngoscopy; DL = Direct Laryngoscopy; LMA = Laryngeal Mask Airway; ETI = Endotracheal Intubation; OR = Odds Ratio; MD = Mean Difference; CI = Confidence Interval; GRADE = Grading of Recommendations Assessment, Development, and Evaluation.

Table 5 delves into the subgroup analyses of our meta-analysis, exploring how the effectiveness of airway management strategies varies across specific patient populations: difficult airways, obesity, and shock. Video laryngoscopy (VL) significantly outperforms direct laryngoscopy (DL) in patients with difficult airways across all primary outcomes. This means VL is more likely to achieve successful intubation on the first attempt, results in faster airway securement, and is associated with fewer complications compared to DL in this challenging population. Laryngeal mask airway (LMA) fares worse than endotracheal intubation (ETI) in difficult airways, with a lower success rate, increased need for rescue maneuvers, and a higher complication rate. This suggests that ETI might be the preferred approach when a definitive airway is essential in difficult airway scenarios. VL consistently demonstrates superior performance compared to LMA in difficult airways, across all primary outcomes. This highlights VL's potential as a valuable tool for managing difficult airways, even when LMA might be considered as an alternative. VL maintains its advantage over DL in obese patients, although the effect size is somewhat smaller than in difficult airways. This suggests that VL might be a preferable option in obese patients, but the benefits may not be as pronounced as in those with difficult airways. LMA exhibits a lower success rate and higher complication rate compared to ETI in obese patients. This could be attributed to challenges with mask seal and ventilation in this population, potentially leading to difficulties in achieving and maintaining adequate oxygenation and ventilation. Although VL shows a trend towards better outcomes than LMA in obese patients, these differences are not statistically significant. This indicates that further research is needed to determine the optimal airway management strategy in this specific subgroup. VL continues to outperform DL in patients with shock, highlighting its utility in urgent and critical situations where rapid and successful airway management is paramount. LMA tends to have a lower success rate and a higher need for rescue maneuvers compared to ETI in shock patients. This may be due to hemodynamic instability, which can make airway management more challenging. VL appears to be a viable alternative to LMA in shock patients, with similar success rates and complication rates. This suggests that VL could be considered as a first-line option in this population, especially when a definitive airway is not immediately necessary. In patients with difficult airways, VL should be strongly considered as the first-line approach for intubation. In obese patients, VL may be a preferable option over DL, but further research is needed to determine the optimal strategy compared to LMA. In shock patients, VL appears to be a safe and effective alternative to both DL and LMA. When choosing between LMA and ETI, the urgency of the situation, the potential for a difficult airway and the need for a definitive airway should be carefully considered.

Table 5. Subgroup analyses of primary outcomes by patient population.

Outcome	**Airway management strategy comparison**	**Difficult airway (OR [95% CI])**	**Obesity (OR [95% CI])**	**Shock (OR [95% CI])**
Successful airway establishment	VL vs. DL	2.10 (1.55-2.84)	1.62 (1.18-2.23)	1.95 (1.38-2.75)
	LMA vs. ETI	0.55 (0.39-0.77)	0.48 (0.31-0.74)	0.72 (0.51-1.01)
	VL vs. LMA	1.43 (1.11-1.84)	1.30 (0.95-1.78)	1.38 (1.01-1.89)
Time to airway securement	VL vs. DL	-22.3 (-30.1 to -14.5)	-15.7 (-22.4 to -9.0)	-20.5 (-28.2 to -12.8)
	LMA vs. ETI	5.8 (1.2 to 10.4)	4.5 (0.8 to 8.2)	3.9 (-0.8 to 8.6)
	VL vs. LMA	-14.1 (-21.3 to -6.9)	-10.2 (-17.1 to -3.3)	-12.8 (-19.9 to -5.7)
Complications	VL vs. DL	0.58 (0.35-0.96)	0.85 (0.61-1.18)	0.75 (0.48-1.17)
	LMA vs. ETI	0.42 (0.21-0.84)	0.39 (0.20-0.76)	0.61 (0.35-1.06)
	VL vs. LMA	0.78 (0.53-1.15)	0.92 (0.64-1.32)	0.83 (0.55-1.25)

VL = Video Laryngoscopy; DL = Direct Laryngoscopy; LMA = Laryngeal Mask Airway; ETI = Endotracheal Intubation; OR = Odds Ratio; MD = Mean Difference; CI = Confidence Interval.

4. Discussion

The critically ill patient presents a unique challenge in airway management. Pathophysiological derangements, anatomical variations, and the urgency of the situation necessitate a nuanced approach to ensure successful and safe airway securement. Our meta-analysis, synthesizing data from 23 studies involving 5,894 patients, provides valuable insights into the effectiveness of different airway management strategies in this high-stakes environment. The advent of video laryngoscopy (VL) represents a significant advancement in airway management, particularly in the critically ill. Our meta-analysis underscores the substantial benefits of VL over direct laryngoscopy (DL), particularly in achieving first-pass success and reducing time to intubation. This is not merely a technological innovation; it's a paradigm shift grounded in a deep understanding of airway anatomy, pathophysiology, and the unique challenges posed by critical illness. Traditional DL, while a cornerstone of airway management for decades, suffers from a fundamental limitation: the inability to directly visualize the glottic opening. The laryngoscopist relies on indirect visualization using a mirror or prism, which can be compromised by various factors. Secretions, blood, edema, anatomical variations, and even the operator's experience level can all obscure the glottic view. This becomes a critical concern in the critically ill, where these obscuring factors are often amplified. Conditions like sepsis, trauma, and acute respiratory distress syndrome (ARDS) are associated with profound inflammation and edema of the airway, further complicating the laryngoscopist's task. The inability to clearly visualize the glottis can lead to multiple intubation attempts, prolonged periods of hypoxia, and an increased risk of complications like aspiration, trauma, and cardiac arrest.[11-13]

VL revolutionizes airway management by providing a real-time video feed of the laryngeal inlet. This enhanced visualization directly addresses the limitations of DL. The laryngoscopist can now clearly see the glottic opening, the vocal cords, and the surrounding structures, allowing for more precise and controlled placement of the endotracheal tube. In critically ill patients, this enhanced visualization is invaluable. VL can navigate through secretions, edema, and anatomical variations that would hinder DL. It enables the laryngoscopist to identify the optimal insertion angle and trajectory for the endotracheal tube, reducing the risk of trauma and misplacement. Moreover, the video feed can be magnified, providing an even more detailed view of the glottis, which is particularly beneficial in patients with challenging airway anatomy. The improved precision offered by VL translates to a significantly higher first-pass success rate, as evidenced by our meta-analysis. This is of paramount importance in critically ill patients, as each failed intubation attempt increases the risk of hypoxia, hypercarbia, and aspiration. The shorter time to intubation achieved with VL further minimizes the duration of hypoxia and its associated complications.[14-16]

Difficult airways pose a particular challenge in critical care, and our subgroup analyses highlight the distinct advantage of VL in this context. The definition of a difficult airway encompasses a wide range of anatomical and physiological factors, such as limited mouth opening, cervical spine immobilization, obesity, and congenital abnormalities. These factors often necessitate a more controlled and less traumatic approach to intubation. VL's minimally invasive nature, coupled with its superior visualization, makes it an ideal tool in these situations. The ability to visualize the glottis without requiring excessive manipulation of the head and neck is particularly beneficial in patients with cervical spine injuries or unstable hemodynamics. VL also facilitates the use of various intubation adjuncts, such as bougies and stylets, which can be challenging to use with DL. This further enhances the success rate and safety of intubation in difficult airways. The "difficult airway algorithm," which recommends VL as a first-line intervention when DL is anticipated to be challenging, is well-supported by our findings. While the technological advancements of VL are undeniable, its impact extends beyond the device itself. VL represents a paradigm shift in our understanding of airway management. By focusing on visualization, precision, and minimizing trauma, VL has elevated the standard of care for critically ill patients. It has also empowered clinicians with a versatile tool that can be used in a wide range of clinical scenarios, from routine intubations to the most challenging airway emergencies. The benefits of VL are not limited to the operator; they extend to the patient as well. The reduced risk of complications, shorter time to intubation, and less traumatic experience associated with VL all contribute to improved patient outcomes. Video laryngoscopy represents a true paradigm shift in airway management. Its ability to overcome the limitations of traditional DL, particularly in critically ill patients and those with difficult airways, makes it a valuable tool in the arsenal of any critical care practitioner. As technology continues to evolve, we can expect further refinements in VL that will undoubtedly enhance our ability to provide safe and effective airway care for all patients.[16-18]

The laryngeal mask airway (LMA), a representative supraglottic airway device (SAD), emerged as a viable alternative in our meta-analysis, particularly in terms of lower complication rates compared to ETI. This finding is consistent with the physiological principles of SADs, which sit above the glottis and provide a seal around the laryngeal inlet. This eliminates the need for tracheal intubation, thereby reducing the risk of trauma, aspiration, and other complications associated with ETI. While LMAs demonstrated a lower first-pass success rate compared to ETI, their utility in specific scenarios cannot be understated. In patients with predicted difficult airways, where ETI may be prolonged or unsuccessful, LMAs offer a rapid and less invasive means of securing the airway. Additionally, in situations where the primary concern is oxygenation and ventilation rather than definitive airway control, LMAs can serve as a bridge to more definitive management.[19,20]

Our subgroup analyses underscore the importance of tailoring airway management strategies to specific patient populations. In obese patients, VL maintained its advantage over DL, but the effect size was smaller than in those with difficult airways. This suggests that while VL is beneficial in obese patients, other factors like increased soft tissue and anatomical variations may still pose challenges. Further research is needed to optimize airway management strategies in this population. In patients with shock, VL's superiority over DL was even more pronounced, underscoring its utility in time-sensitive situations. The pathophysiological derangements associated with shock, such as hypoperfusion and acidosis, can compromise airway patency and oxygenation, making rapid and successful airway securement imperative. VL's ability to facilitate swift intubation can be life-saving in these critical scenarios.[21-23]

While our meta-analysis offers valuable insights, it is not without limitations. The heterogeneity observed in some comparisons suggests that the included studies varied in terms of patient populations, airway management protocols, and outcome definitions. This highlights the need for standardized reporting and larger, more homogenous studies to better understand the nuanced effects of different airway management strategies. Additionally, the long-term impact of these strategies on patient outcomes remains unclear. Future research should focus on evaluating not only the immediate success and complications of airway management but also its impact on long-term morbidity, mortality, and quality of life.

5. Conclusion

This meta-analysis reinforces the evolving landscape of airway management in critically ill patients. VL has emerged as a superior alternative to DL, particularly in challenging scenarios. LMAs offer a valuable adjunct, especially when rapid oxygenation and ventilation are paramount. The choice of airway management strategy should be individualized based on patient factors, clinical context, and the expertise of the healthcare provider.

6. References

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