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Video *vs.* direct laryngoscopy for adult surgical and intensive care unit patients requiring tracheal intubation: a systematic review and meta-analysis of randomized controlled trials

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Abstract. – OBJECTIVE: This systematic review and meta-analysis aimed to determine whether a specific videolaryngoscopy technique is superior to standard direct laryngoscopy using a Macintosh blade to reduce the risk of difficult intubation in surgical and intensive care unit patients.

MATERIALS AND METHODS: We identified all randomized controlled trials comparing videolaryngoscopes (VLSs) to direct laryngoscopy in the Cochrane Central Register of Controlled Trials, MEDLINE, and EMBASE (from inception to April 2020). The primary outcome was difficult intubation in adult surgical and intensive care unit patients. Secondary outcomes were successful intubation at the first attempt, airway trauma, sore throat, hoarseness, hypoxia, and mortality.

RESULTS: We included 97 randomized controlled trials to evaluate 12775 patients. A high risk of bias was found in at least 50% of the included studies for each outcome. VLSs reduced the risk of difficult intubation compared to direct Macintosh laryngoscopy (RR 0.48, 95% CI from 0.35 to 0.65). VLSs increased the rate of successful intubation at the first attempt when compared to direct Macintosh laryngoscopy (RR 1.03, 95% CI from 1.00 to 1.07). Lower risks of airway trauma were found with VLSs (RR 0.69, 95% CI from 0.55 to 0.86). A decreased risk of hoarseness was associated with the use of VLSs (RR 0.67, 95% CI from 0.54 to 0.83). In addition, VLSs did not significantly reduce the risk of hypoxia compared with direct laryngoscopy (RR 0.83, 95% CI from 0.60 to 1.16).

CONCLUSIONS: In this systematic review and meta-analysis, we found that the use of VLSs reduced the risk of difficult intubation and slightly increased the ratio of successful intubation at the first attempt among adult patients.

Key Words:
Videolaryngoscope, Direct laryngoscopy, Randomized controlled trial, Operation room.

Abbreviations

VLS: videolaryngoscope; RCT: randomized controlled trials; ICU: intensive care unit; OR: operation room; RR: risk ratio.

Introduction

Tracheal intubation is used for airway management in more than 1.1 million patients per year[1]. Intubation with direct laryngoscopy is a complex procedure requiring flexing the lower cervical spine and extending the upper cervical spine to create a "line of sight" and a Macintosh blade to retract the tongue to enable passage of a tracheal tube[1]. Difficult intubation occurs in 1% to 6% of endotracheal intubation while intubation failure occurs in 0.1% to 0.3%, of them and both are associated with complications such as desaturation, hyper-and hypotension, airway damage, and death[2].

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Many airway characteristics have been associated with difficult intubation, such as limited mouth opening, limited mandibular protrusion, narrow dental arch, decreased thyromental distance, Mallampati class 3 or 4, decreased submandibular compliance, decreased sterno-mental distance, limited head and upper neck extension, and increased neck circumference[1,2]. However, a large observational study showed that 93% of difficult intubations are unpredictable, even using predictive tests[1].

In recent years, videolaryngoscopes (VLSs) have been increasingly used to manage difficult airways[3]. VLSs rely on fiberoptic or digital technology to transmit an image from the tip of the laryngoscope to an eyepiece or videomonitor, thereby giving the intubator a better indirect view of the glottis independent of the line of sight[1]. Different types of VLSs have been extensively studied in the operation room (OR) and the intensive care unit (ICU) with the assumption of improving the success of tracheal intubation[2]. VLSs may help manage patients with a predicted or known difficult airway since their use is likely to improve the glottic view and reduce the number of laryngoscopies in which the glottis cannot be visualized[2]. Previous systematic reviews comparing VLSs with direct laryngoscopy suggested that VLSs may reduce the number of difficult intubations in patients presenting with a difficult airway[1,2]. However, there are conflicting data in the literature regarding whether the use of VLSs results in increased success of first-pass intubation attempts, decreased complications, or improved clinical outcomes[3]. These conflicting reports could depend on the high level of performance bias due to the lack of blinding and the high heterogeneity of the studies. Therefore, it is unclear whether VLSs should be the new standard of care for all tracheal intubations[2]. Our review aims to update the Cochrane review by Lewis et al[2] with the more recent randomized controlled trials (RCTs) evaluating the use of VLSs *vs*. Macintosh published in the last few years[2]. The primary outcome was difficult intubation. Difficult intubation was defined as intubation 1) not achieved with ≥ two attempts, 2) lasting longer than 60 s, or 3) tried with an alternative device. Furthermore, as secondary outcomes, we evaluated whether VLSs improve successful intubation at the first attempts and reduce the risk of airway trauma, sore throat, hoarseness, hypoxia, and mortality.

Materials and Methods

The protocol for this meta-analysis was registered at PROSPERO (CRD42019107564) after the commencement of the systematic review process.

Data Sources and Searches

We searched for all RCTs comparing VLSs to direct laryngoscopy regarding difficult intubation, successful first-attempt intubation, airway trauma, sore throat, hoarseness, and hypoxia in adult patients. The electronic search strategy applied standard filters for the identification of RCTs. Databases searched were the Cochrane Central Register of Controlled Trials, MEDLINE, and EMBASE (from inception to April 2020). However, we did not apply any language restrictions. Our search included the following keywords: intubation, videolaryngoscopy, videolaryngoscope, anesthesia, critical care, intensive care, critically ill, emergency care, airway trauma, and randomized controlled trial. In addition to the electronic search, we checked out cross-references from original articles and reviews. No ethical approval will be needed because data from previously published studies in which informed consent was obtained by primary investigators will be retrieved and analyzed.

Selection of Studies

We restricted the analysis to RCTs and excluded study designs containing co-interventions unequally applied to the treatment and control group, non-randomized, or cross-over trials. Additionally, we considered for inclusion all RCTs reporting difficult intubation, successful first-attempt intubation, airway trauma, sore throat, hoarseness, and hypoxia as predefined endpoints and comparing VLS to direct laryngoscopy using a Macintosh blade in adult patients. Furthermore, we excluded RCTs performed in emergency out-of-hospital settings, in pediatric patients, and using direct laryngoscopes other than Macintosh.

Outcome Measures

The primary outcome was difficult intubation. Difficult intubation was defined as intubation 1) not achieved with ≥ two attempts, 2) lasting longer than 60 s, or 3) tried with an alternative device. Secondary outcomes included successful intubation at the first attempt, airway trauma, sore throat, hoarseness, hypoxia, and mortality. **Supplementary Materials 1** show the outcome definitions.

Subgroup Analysis

We performed subgroup analyses to assess the impact on primary and secondary outcomes:

1. Type of VLS devices: Airtraq (Prodol Meditec, Guecho, Spain), C and V-Mac (Karl Storz Endoscopy, Tuttlingen, Germany), GlideScope (Verathon Inc., Bothell, Washington, U.S.A.), McGrath (Aircraft Medical Ltd., Edinburgh, UK), Pentax AWS (Pentax Corporation, Tokyo, Japan), Truview (Truphatek International Ltd., Netanya, Israel), X-lite (Teleflex Medical Europe Ltd, Westmeath, Ireland). Table II in **Supplementary Materials 2** show the main characteristics of the different VLS devices.
2. Clinical scenario: operation room or intensive care unit
3. Operator experience: experienced or less experienced intubator
4. Predicted, not predicted, and simulated difficult airway
5. Based on the previous studies, we defined "experienced intubators" as those who had performed more than 20 successful intubations with each device[2].

Data Extraction and Quality Assessment

Two pairs of independent reviewers performed an initial selection through the screening of titles and abstracts (MV and PB, PP and CP). Each reviewer screened citations to identify further RCTs to include in our analysis. For detailed evaluation, a full-text copy of all possibly relevant studies was obtained. Each study's data were extracted independently by paired reviewers (MV and PB, PP and CP) using a pre-standardized data extraction form. One pair of reviewers (GS and LB) was not informed about the authors, journal, institutional affiliations, and date of publication. Another reviewer checked the data extracted from the publications for accuracy. Furthermore, we used the Cochrane risk of bias tool to assess the quality of study design and the extent of potential bias[5,6] by considering the following domains: random sequence generation, allocation concealment, blinding of participants, personnel and outcomes assessors, incomplete outcome data, selective outcomes reporting, baseline characteristics, and funding resources. Two reviewers (MV and PB) independently used these criteria to abstract trial quality. We resolved any disagreements by consensus consultation with a third reviewer (LB) if needed.

Qualitative Analysis

The risk of bias was assessed using the Cochrane Risk of Bias Tool for RCTs and the Risk of Bias Instrument for Non-Randomized Studies of Interventions (ROBINS-2)[5]. The certainty of the evidence was assessed using the GRADE approach[6]. According to GRADE, the body of evidence for each outcome was assessed for factors that may reduce or increase it[6]. GRADE summary of findings and tables were developed with GRADEpro GDT software (McMaster University, 2015. Developed by Evidence Prime, Inc. Available at: https://gradepro.org/).

Quantitative Analysis

The meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines **(Supplementary Materials 3)**. Meta-analysis was performed with mixed random effects using DerSimonian and Laird methods. Results were graphically represented using Forest plot graphs. According to an intention-to-treat principle, the relative risk (RR) and 95% CI for each outcome were separately calculated for each trial, pooling data when needed. The choice to use RRs was driven by the design of a meta-analysis based on RCTs. Tau^2 defined the between-studies variance. The difference in treatment effect estimates between the treatment groups for each hypothesis was tested using a two-sided Z test with statistical significance considered at a p-value of less than 0.05. The homogeneity assumption was checked with a Q test with a degree of freedom (df) equal to the number of analyzed studies minus 1. The heterogeneity was measured by the I^2 metric, which describes the percentage of total variation across studies that is due to heterogeneity rather than chance. I^2 was calculated as $I^2 = 100\% \cdot (Q - df)/Q$, where Q is Cochran's heterogeneity statistic, and df is the degrees of freedom. A value of 0% indicates no observed heterogeneity, and larger values show increasing heterogeneity. Analyses were conducted with OpenMetaAnalyst (version 6) and SPSS version 20 (IBM SPSS Corp., Armonk, NY, USA)). To evaluate potential publication bias, a weighted linear regression was used, with the natural log of the RR as the dependent variable and the inverse of the total sample size as the independent variable. This modified Macaskill's test gives more balanced type I error rates in the tail probability areas than other publication bias tests. The number needed to treat (NNT) was calculated as the inverse of the absolute risk re-

duction (ARR) expressed as a decimal. Cumulative meta-analyses of RCTs are at risk of yielding random errors due to sparse data and repetitive testing of accumulating data[7]. Trial sequential analysis (TSA) depends on the quantification of the required information size (RIS) (i.e., optimal information size). TSA was undertaken using TSA 0.9 beta software if the number of included trials was more than five. The RIS was estimated using relative risk reduction and heterogeneity adjusted information size for dichotomous outcomes. The result was confirmed as a true positive if the cumulative Z-curve surpassed the Lan-DeMets trial sequential monitoring boundary or reached the RIS above the conventional significance level line (Z = 1.96). Moreover, the result was confirmed as a true negative if the cumulative Z-curve reached the futility boundary or reached the RIS below the conventional significance level line (Z = 1.96). TSA adjusted 95% CIs were also presented.

Data Synthesis and Analysis

We classified the following comparisons: pooled VLS devices *vs.* direct laryngoscopy (McIntosh laryngoscope), Airtraq *vs.* direct laryngoscopy, C and V-Mac *vs.* direct laryngoscopy, GlideScope *vs.* direct laryngoscopy, McGrath *vs.* direct laryngoscopy, Pentax AWS *vs.* direct laryngoscopy, Truview *vs.* direct laryngoscopy, and X-lite *vs.* direct laryngoscopy.

Results

In this systematic review and meta-analysis, we included 97 RCTs, evaluating 12775 patients (Figure 1)[8-104]. VLSs were investigated in elective surgical patients in 92 studies[8 10,12-35,37-48,49-51,53-78,81-91,93-99,101-104], in the ICU in five studies[36,52,79,92,100] and in the Emergency Department in four RCTs [11,49,80,92]. We found eight RCTs comparing Airtraq *vs.* direct laryngoscopy[9-11,13,14,16,25,26,29,31,32,36,41,44,48,53,56,60,62,66,69,70-73,75,76,78,81,85,86,89,91,92,95,96], 19 RCTs comparing McGrath *vs.* direct laryngoscopy[17,20,34,35,42,43,47,51,52,54,58,68,74,77,84,88,93,94,96], 18 RCTs comparing Pentax AWS *vs.* direct laryngoscopy[8,15,18,33,39,40,49,50,55,60,62,63,67,82,83,85,90], two RCTs comparing Truview *vs.* direct laryngoscopy[30,61], and two RCTs comparing X-lite *vs.* direct laryngoscopy[21,22]. We found 11 RCTs comparing more than one VLS with direct laryngoscopy[20,30,53,54,60,62,65,75,76,85,96].

The Cochrane risks of bias tool were used to assess the quality of the study design and the extent of potential bias (Figure 2 and **Supplementary Materials 4**). We found that 42 out of 60 studies for the primary outcome, 54 out of 80 studies for successful intubation at the first attempt, 36 out of 51 studies for airway trauma, 20 out of 26 studies for sore throat, 6 out of 13 studies for hoarseness, 8 out of 17 studies for sore throat, and 2 out of 4 studies for mortality had a high risk of bias.

The risk of difficult intubation was significantly lower when using VLSs compared to direct Macintosh laryngoscopy (RR 0.48, 95% CI from 0.35 to 0.65, I^2 = 16%) (NNT = 25, 95% CI = 19.8-32.3) (Figure 3).

The risk of difficult intubation was reduced by C and V-MAC (RR 0.40, 95% CI from 0.20 to 0.79, I^2 = 0%) and Airtraq (RR 0.45, 95% CI from 0.23 to 0.87, I^2 = 67%) but not by the other VLSs **(Supplementary Materials 5)** (Glidescope *vs.* direct Macintosh laryngoscopy: 23 studies, RR 0.61, 95% CI from 0.36 to 1.05, I^2 = 0%) (McGrath *vs.* direct Macintosh laryngoscopy: 16 studies, RR 0.68, 95% CI from 0.27 to 1.69, I^2 = 53%) (Pentax AWS *vs.* direct Macintosh laryngoscopy: 10 studies, RR 0.35, 95% CI from 0.12 to 1.05, I^2 = 29%) (Truview *vs.* direct Macintosh laryngoscopy: 3 studies, RR 0.99, 95% CI from 0.28 to 3.49, I^2 = 0%) (X-lite *vs.* direct Macintosh laryngoscopy: 2 studies, RR 0.25, 95% CI from 0.03 to 2.48, I^2 = 0%).

VLSs reduced the risk of difficult intubation in the OR (RR 0.46, 95% CI from 0.33 to 0.64, I^2 = 16.5%), in predicted and simulated difficult airways (RR 0.32, 95% CI from 0.17 to 0.59, I^2 = 3.4% and RR 0.23, 95% CI from 0.11 to 0.50, I^2 = 0%, respectively) (**Supplementary Materials 5**). VLSs, when used by an experienced operator, reduced the risk of difficult intubations (RR 0.48, 95% CI from 0.30 to 0.77, I^2 = 0%) (**Supplementary Materials 6**). Excluding the simulated of funded RCTs, the result for the primary outcome persisted (**Supplementary Materials 6**). By including 5521 patents, the Z-curve crosses the TSA monitoring boundary, and the RIS (=1627) for this specific TSA-analysis is conclusive in favor of VLSs (Figure 4).

VLSs increased the rate of successful intubation at the first attempt when compared to direct Macintosh laryngoscopy (RR 1.03, 95% CI from 1.00 to 1.07, I^2 = 79%) (NNT = 18, 95%CI = 13.9-26) (Figure 5). The TSA adjusted 95% CI ranged from 0.77 to 0.81. The cumulative Z-curve crossed neither the conventional boundary for benefit nor the trial sequential futility boundary for benefit, suggesting that the current evidence

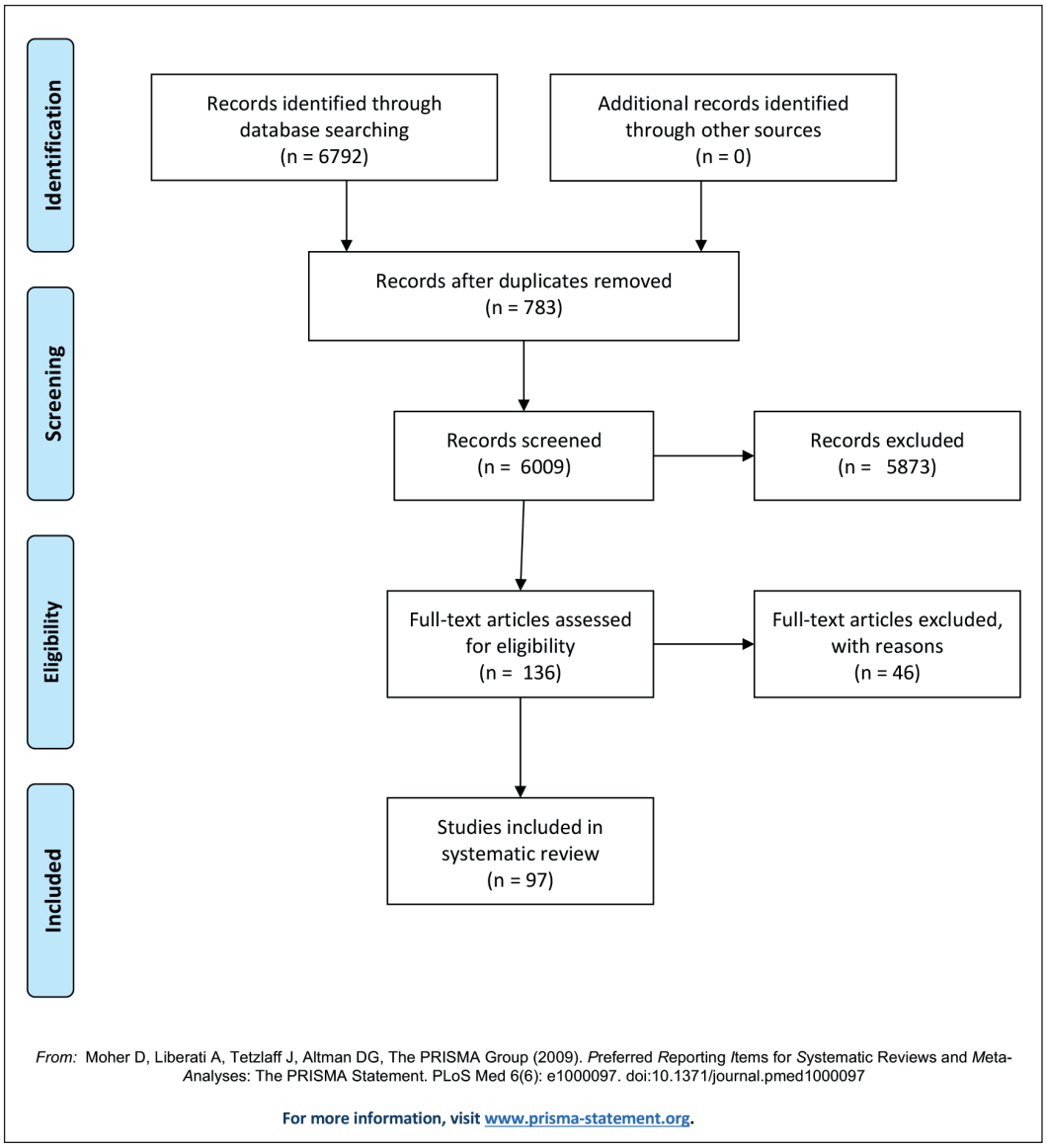

Figure 1. PRISMA flow chart of included studies.

was inconclusive (**Supplementary Materials 7**). Different analyses performed according to VLS devices, clinical scenario, operator experience, and difficult airways did not show significant results (**Supplementary Materials 8**).

Lower risks of airway trauma were found with VLSs (RR 0.69, 95% CI from 0.55 to 0.86, I^2 = 7.6%) (NNT = 41, 95%CI = 26.7-87.6) (**Supplementary Materials 9**). This result was mainly due to McGrath VLSs, which significantly decreased the risk of airway trauma compared to direct laryngoscopy (RR 0.54, 95% CI from 0.36 to 0.81, I^2 = 0%) (**Supplementary Materials 10**). Airway trauma was reduced by using VLSs in OR (RR 0.69, 95% CI from 0.54 to 0.87, I^2 = 0%), in predicted not difficult airway (RR 0.57, 95% CI from 0.38 to 0.85, I^2 = 10%), and in simulated difficult airway (RR 0.60, 95% CI from 0.39 to 0.90, I^2 = 18%) (**Supplementary Materials 10**). The TSA adjusted 95% CI ranged from 0.15 to 0.42. The TSA result showed that 3457 of the RIS of 5882 patients was accrued. The cumulative Z-curve crossed the conventional boundary for the benefit and crossed the trial sequential monitoring boundary for benefit (**Supplementary Materials 11**), indicating firm evidence of VLSs for airway trauma.

Analysis for sore throat did not reveal the advantage of using VLS compared to direct Macin-

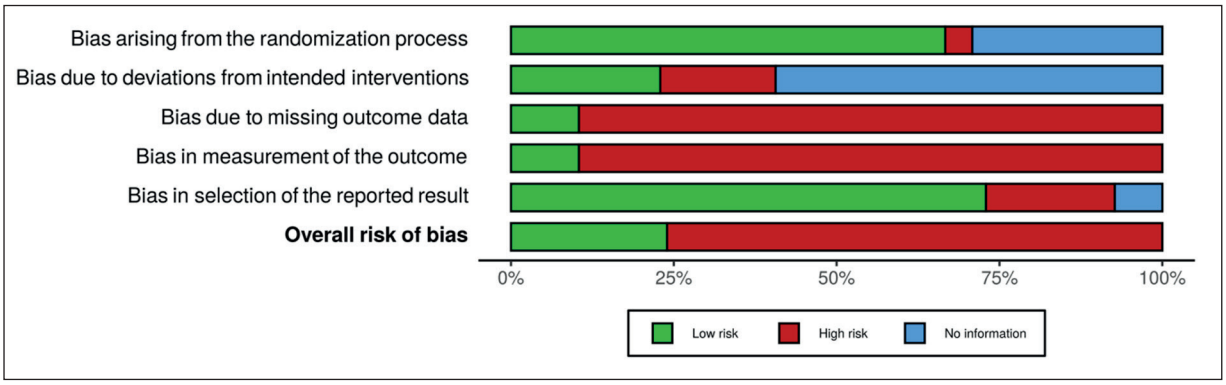

Figure 2. Risk of bias summary. Green represents a low risk of bias, yellow some concerns, and red a high risk of bias.

tosh laryngoscopy (RR 0.85, 95% CI from 0.72 to 1.01, $I^2 = 50\%$) (NNT = 14, 95%CI = 9.4-24.4) (**Supplementary Materials 12**). The sub-group analyses did not show any significant results (**Supplementary Materials 13**). Different analyses performed according to the type of VLS devices, operator experience, and difficult airways did not show significant results (**Supplementary Materials 12**). The TSA adjusted 95% CI ranged from 0.43 to 0.64. The cumulative Z-curve crossed the conventional boundary for the benefit and crossed the trial sequential monitoring boundary for benefit (**Supplementary Materials 14** and **15**), indicating that this evidence was conclusive.

A decreased risk of hoarseness was associated with the use of VLS (RR 0.675, 95% CI from 0.54 to 0.84, $I^2 = 20\%$) (NNT = 10, 95% CI = 6.5-15.6) (**Supplementary Materials 16**). Risk of hoarseness was only reduced with Glidescope VLS (RR 0.52, 95% CI from 0.39 to 0.69, $I^2 = 0\%$) (**Supplementary Materials 17**). The TSA adjusted 95% CI ranged from 0.00 to 0.43. The cumulative Z-curve crossed neither the conventional boundary for benefit nor the trial sequential futility boundary for benefit, suggesting that the current evidence was inconclusive (**Supplementary Materials 14** and **18**).

VLS was not associated with a reduced risk of hypoxia compared to direct Macintosh laryngoscopy (RR 0.83, 95% CI from 0.60 to 1.16, $I^2 = 0\%$) (NNT = 29, 95%CI = 18.7-63.2) (**Supplementary Materials 19** and **20**). The TSA adjusted 95% CI ranged from 0.34 to 0.73. The alpha boundary for hypoxia was not performed because of limited extant information (4%) (**Supplementary Materials 14** and **21**).

The risk of mortality was not reduced by using VLS compared to direct Macintosh laryngoscopy (RR 1.03, 95% CI from 0.69 to 1.516, $I^2 = 0\%$) (**Supplementary Materials 22** and **23**). The TSA adjusted 95% CI ranged from 0.00 to 0.60. The cumulative Z-curve crossed neither the conventional boundary for benefit nor the trial sequential futility boundary for benefit, suggesting that the current evidence was inconclusive (**Supplementary Materials 14** and **24**).

Overall, evidence was qualified using GRADE for RCTs (Figure 6). High-quality evidence was found for difficult intubation, successful intubation at the first attempt, airway trauma, and sore throat. RCTs' level of evidence was downgraded due to the high risk of bias mainly caused by allocation concealment, blinding of participants and personnel, and funding in outcome assessment in most studies.

Discussion

This systematic review and meta-analysis in adult patients show a reduced risk of difficult intubation with VLSs than direct Macintosh laryngoscopy. The risk of difficult intubation was reduced using C-and V-MAC and Airtraq devices when used by experienced physicians in predicted or simulated difficult airways in the OR and in the ICU setting. As qualified by GRADE, the quality of evidence for difficult intubation was high, suggesting that further research is unlikely to impact our estimated effect or change it significantly. VLS slightly increased the successful intubation at the first attempt and reduced the risk of airway trauma and hoarseness. At the same time, it did not affect the risk of sore throat, hypoxia, or mortality. Even the quality of evidence qualified by GRADE for successful intubation at the first attempt, airway trauma, and sore throat was high, suggesting that further research is very unlikely to have a significant impact on our estimated effect.

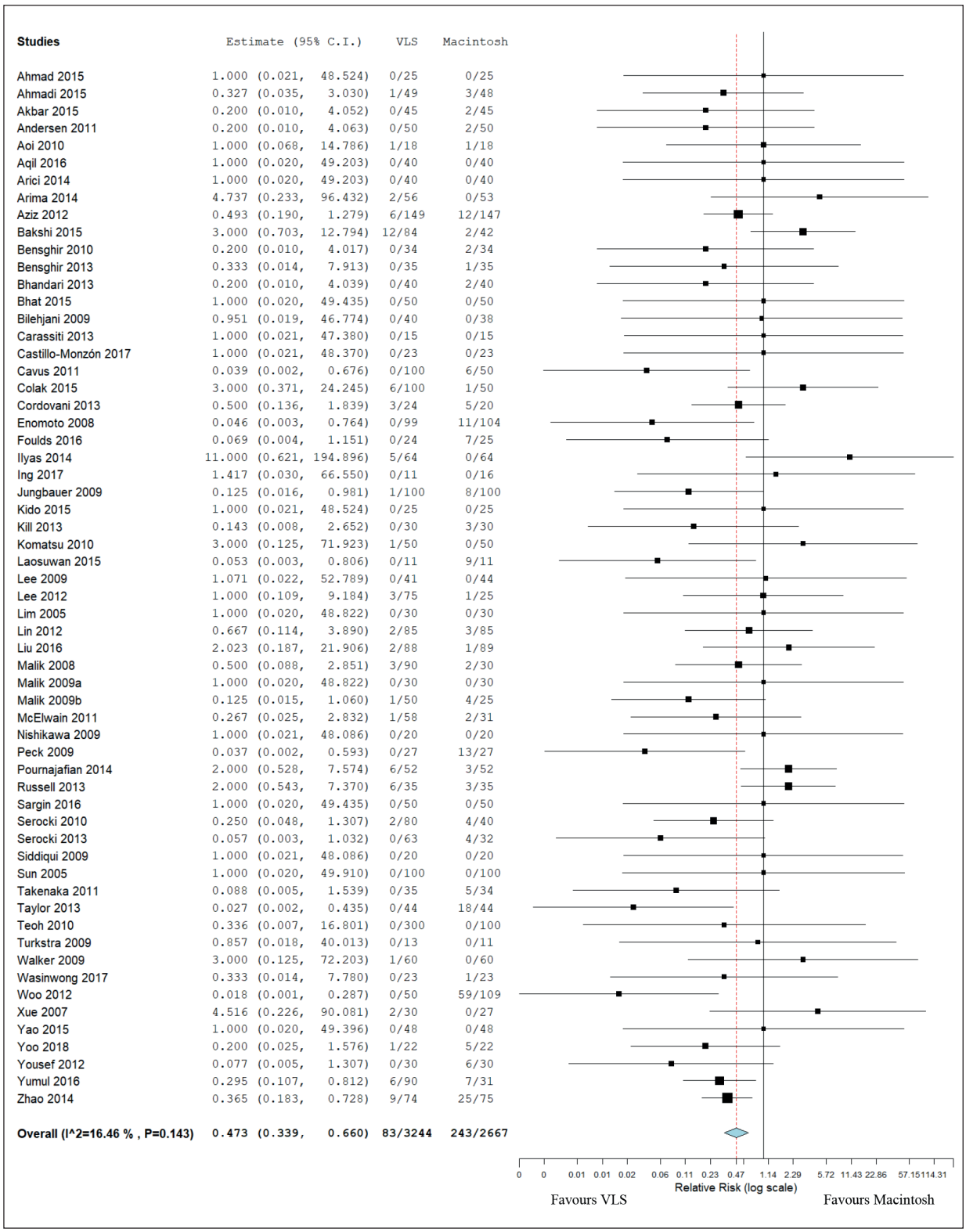

Figure 3. Forest plot for difficult intubation of VLSs *vs.* Macintosh. VLS: videolaryngoscope. C.I.: confidence interval.

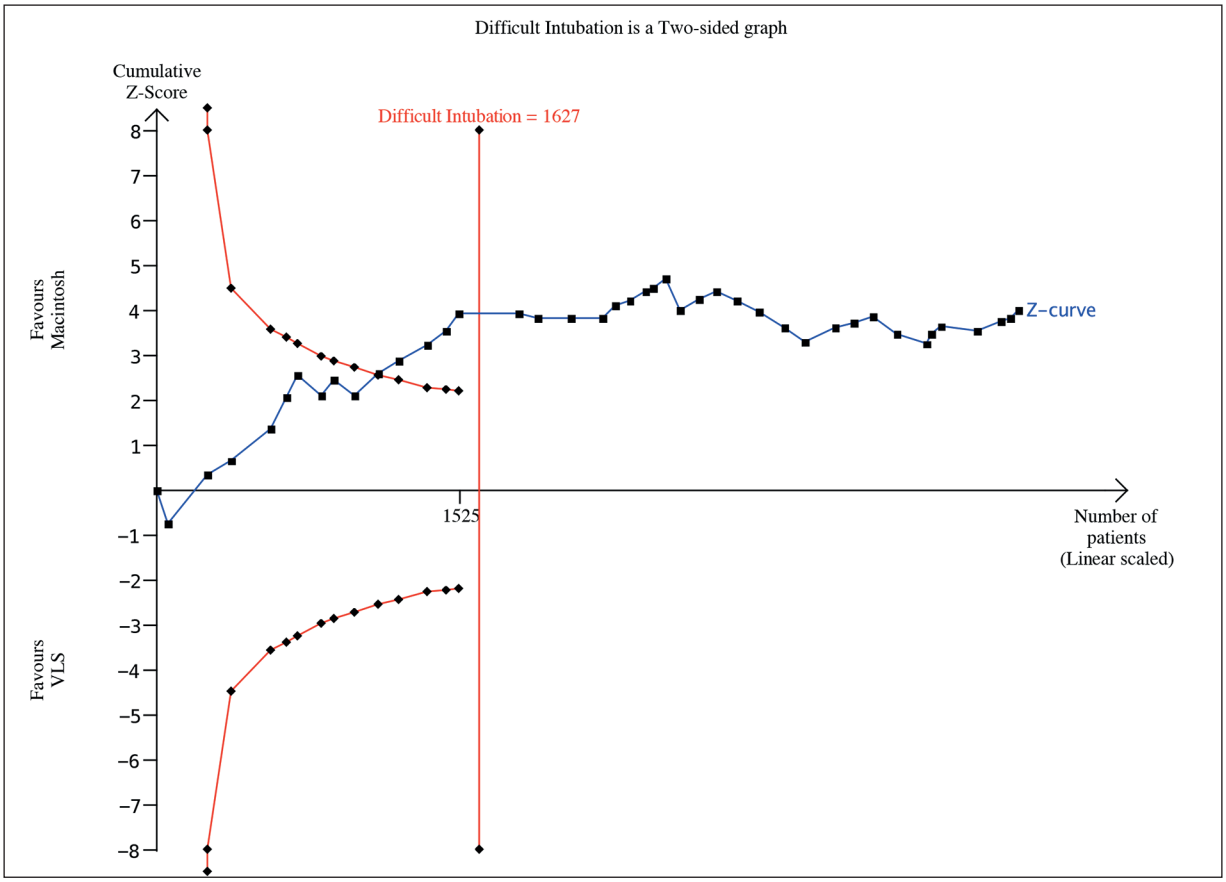

Figure 4. Trial sequential analysis for difficult intubation of VLSs *vs.* Macintosh. TSA was performed with Relative Risk and Random-effects (Der-Simonian and Laird). Zero-event Trials are not included. Pooled Effect: 0.41 (C.I: 0.26 to 0.63) based on conventional 95%. Inconsistency (I^2): 0.46; Diversity (D^2): 0.57. Boundaries: Type 1 Error: 5.0%, Alpha Spending: O'Brien-Fleming, Power: 80.0%.

Previous systematic reviews and meta-analysis investigating the use of VLSs *vs.* direct Macintosh laryngoscopy included cross-over studies[2,105]; were restricted to patients with predicted difficult airways[106], cervical immobilization[107], or receiving treatment in the ICU or emergency department[108-113]; were limited to procedures performed by trained anesthetists[114]; were limited to pediatric [115] and neonatal patients[116]; excluded particular VLSs types such as the Airtraq and Truview device[2,106]. Conversely, our meta-analysis included the most recent high-quality RCTs in adult patients; moreover, we performed subgroup analyses to investigate the different VLS types, including Airtraq and Truview devices.

Among the different VLS types, only the Airtraq, C-and V-Mac devices reduced the risk of difficult intubation. Compared to Macintosh laryngoscopy, the reduced risk of difficult intubation with the Airtraq has been reported in patients with cervical spine immobilization[114]. This benefit may be explained by the more pronounced curvature and the integral tube guidance channel of the Airtraq blade, which does not require alignment of oral, pharyngeal, and tracheal axes[115,116] and better positioning of optical components[100, 115,116]. The Pentax AWS device has a similar curvature and guides channel, but the tube may strike the epiglottis and may be challenging to advance, making intubation more difficult[117]. Reduced risk of difficult intubation observed with the C-and V-Mac devices using a classic Macintosh blade was unexpected. Physicians experienced with direct tracheal intubation, trying subconsciously to bring the axes in one line when intubating, may have fewer difficulties and do not need new skill requirements when using VLS devices with a classic shaped Macintosh blade like the C-and V-Mac[107] as compared to GlideScope, McGrath, and Truview devices[107]. VLSs reduced the risk of difficult intubations in patients with predicted or simulated difficult airways, in line with previous reports[2,105-107].

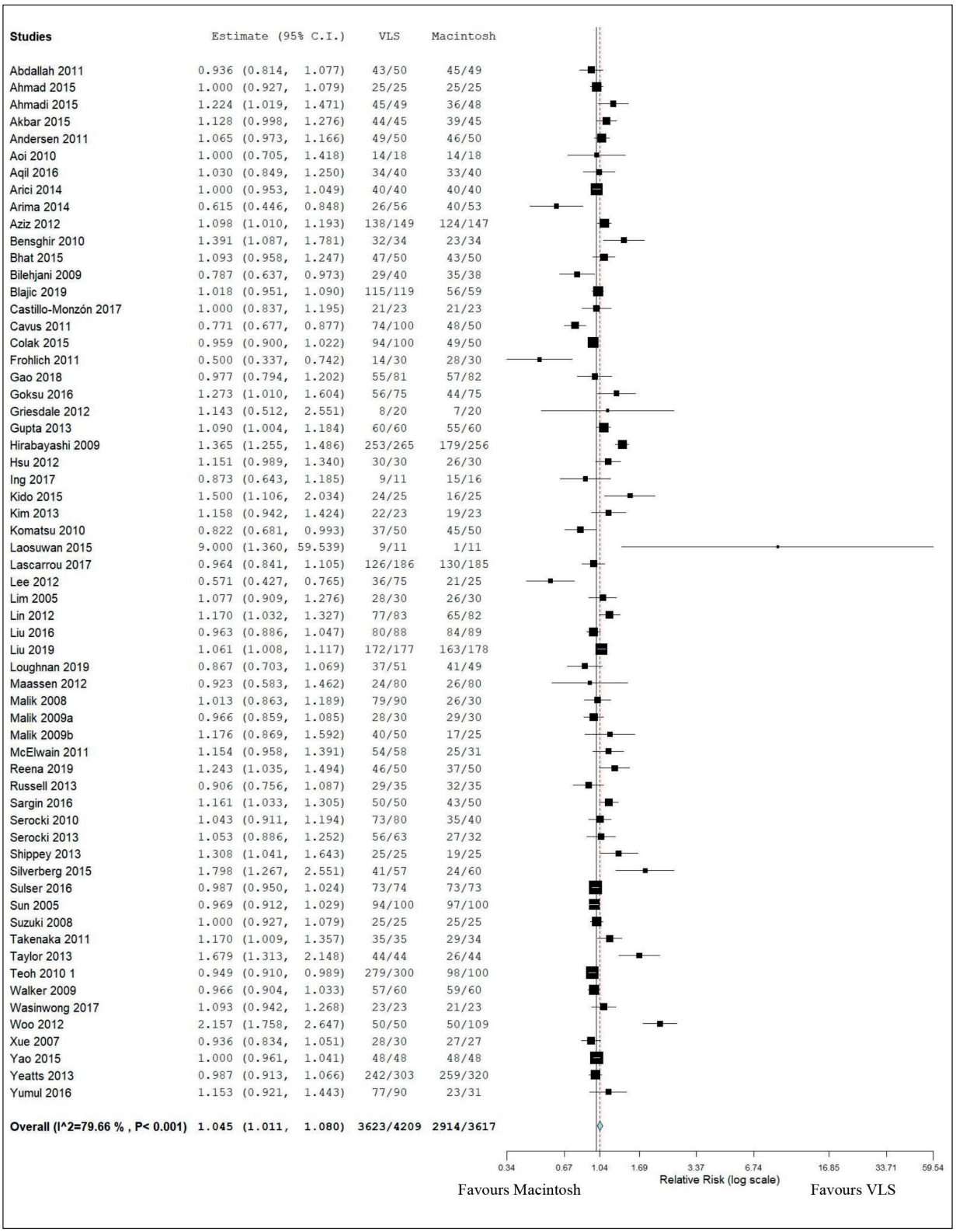

Figure 5. Forest plot for successful at first attempts of VLSs *vs.* Macintosh. VLS: videolaryngoscope. C.I.: confidence interval.

In contrast with Lewis et al[2], this meta-analysis found that VLSs increased the rate of successful intubation at the first attempt compared to direct Macintosh laryngoscopy. Several patients

Author(s):
Question: Videolaryngoscopy compared to Direct laryngoscopy for tracheal intubation
Setting: operation room
Bibliography:

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Videolaryngoscopy	Direct laryngoscopy	Relative (95% CI)	Absolute (95% CI)		
Difficult intubation												
60	randomised trials	serious [a]	not serious	not serious	not serious	strong association	83/3244 (2.6%)	243/2667 (9.1%)	**RR 0.47** (0.34 to 0.66)	**48 fewer per 1.000** (from 60 fewer to 31 fewer)	⨁⨁⨁⨁ HIGH	CRITICAL
Successful intubation at the first attempt												
80	randomised trials	serious [b]	not serious	not serious	not serious	strong association	3623/4209 (86.1%)	2914/3617 (80.6%)	**RR 1.04** (1.01 to 1.08)	**32 more per 1.000** (from 8 more to 64 more)	⨁⨁⨁⨁ HIGH	CRITICAL
Airway trauma												
51	randomised trials	serious [c]	not serious	not serious	not serious	strong association	181/3226 (5.6%)	214/2656 (8.1%)	**RR 0.69** (0.56 to 0.86)	**25 fewer per 1.000** (from 35 fewer to 11 fewer)	⨁⨁⨁⨁ HIGH	CRITICAL
Sore throat												
26	randomised trials	serious [d]	not serious	not serious	not serious	strong association	371/1527 (24.3%)	407/1268 (32.1%) 0.0%	**RR 0.87** (0.73 to 1.04)	**42 fewer per 1.000** (from 87 fewer to 13 more) **0 fewer per 1.000** (from 0 fewer to 0 fewer)	⨁⨁⨁⨁ HIGH	CRITICAL
Hoarseness												
13	randomised trials	serious [e]	not serious	not serious	not serious	none	105/668 (15.7%)	163/614 (26.5%)	**RR 0.67** (0.52 to 0.88)	**88 fewer per 1.000** (from 127 fewer to 32 fewer)	⨁⨁⨁◯ MODERATE	IMPORTANT

Figure 6. GRADE evidence profile for considered outcome.

and physician-related factors have been identified to be associated with first-attempt intubation failures, such as the anatomy of the supra-and infra-glottic airways, visibility of the glottis during laryngoscopy, device selection, pharmacologic choices, depth of anesthesia, adequate neuromuscular blockade, and experience [2,119,122]. In addition, increasing time to intubate may be associated with increased intubation-related complications, such as hypoxemia. Using VLS, superior views of the glottis are often obtained but may not consistently translate into easier tracheal intubation and a higher rate of first intubation success[19].

Our data suggest that VLS should be immediately available and that all physicians in OR and ICU, especially non-experienced physicians, should be trained in its use[118,119]. With the high quality of evidence, our data demonstrated that the use of VLSs reduces the risk of airway trauma, probably because the use of VLSs may support the glottic view, allowing the application of less force during laryngoscopy[120-122].

This meta-analysis has several strengths. TSA was conclusive for the primary outcome in favor of VLS. According to the GRADE approach, we found a high quality of evidence for 4 out of 7 outcomes.

Our findings should be interpreted regarding several limitations. First, large-scale RCTs, comparing VLSs with direct Macintosh laryngoscopy, are missing, and all RCTs included in this meta-analysis enrolled only a small number of patients. Second, the generalizability of our results may be limited since particular clinical scenarios, such as emergency or out-of-hospital settings, have not been sufficiently explored in the included RCT. Third, in the included RTCs, different criteria were used to define the physician's intubation expertise. Similar to previous meta-analyses[2,105], we considered a physician experienced after 20 successful intubations using both VLSs and direct laryngoscopy, while a systematic review, analyzing learning curves, suggested 50 successful intubations[123-125]. We were able to distinguish performance differences between VLS types. Fourth, although only high-quality RCTs, the first-attempt intubation success rate showed substantial heterogeneity, not allowing conclusions at an acceptable evidence level. Fifth, definitions of complications (e.g., airway trauma, sore throat, and hypoxia) were

not standardized and varied from center to center. Sixth, reported time for tracheal intubation was frequently not reported in the studies included or not normally distributed, prohibiting any statistical analysis. The remaining RCTs showed substantial heterogeneity for tracheal intubation time, not allowing data pooling. Sixth, the protocol for this meta-analysis was registered at PROSPERO after the commencement of the systematic review process. Finally, formal statistical tests did not support the presence of publication bias for any considered outcome, which could have impacted the estimated pooled effect.

Conclusions

Our results suggest that VLSs reduced the risk of difficult intubation and airway trauma while slightly increasing successful intubation at the first attempt among adult patients with a high quality of evidence.

Ethical Approval and Consent to Participate

Not required.

Conflicts of Interest

The authors declare that they have no conflict of interests.

Availability of Data and Materials

Further data and material can be accessed by contacting the corresponding author.

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Authors' Contributions

MV, GS, PB, CI, PP, CP: study design, data collection, data analysis, writing up the draft of the paper, approved the final version GPH, SE, LB, NP: data collection, data analysis, writing up the draft of the paper, approved the final version. MA: language editing, grammar check, approval of final version.
All authors have read and approved the manuscript.

References

1) Woodall NM, Cook TM. National census of airway management techniques used for anaesthesia in the UK: first phase of the Fourth National Audit Project at the Royal College of Anaesthetists. Br J Anaesth 2011; 106: 266-271.
2) Lewis SR, Butler A, Parker J, Cook TM, Smith AF. Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation. Cochrane Database Syst Rev 2016; 11: CD011136.
3) Vargas M, Pastore A, Aloj F, Laffey JG, Servillo G. A comparison of videolaryngoscopes for tracheal intubation in predicted difficult airway: a feasibility study. BMC Anesthesiol 2017; 25: 1-6.
4) Zaouter C, Calderon J, Hemmerling TM. Videolaryngoscopy as a new standard of care. Br J Anaesth 2015; 114: 181-183.
5) Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, Savovic J, Schulz KF, Weeks L, Sterne JA; Cochrane Bias Methods Group; Cochrane Statistical Methods Group. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 2011; 343: d5928.
6) Peters JL, Sutton AJ, Jones DR, Abrams KR, Rushton L. Comparison of two methods to detect publication bias in meta-analysis. JAMA 2006; 295: 676-680.
7) Watterslev J, Jakobsen JC, Gluud C. Trial sequential analysis in systematic reviews with meta-analysis. BMC Med Res Methodol 2017; 17: 39.
8) Abdallah R, Galway U, You J, Kurz A, Sessler DI, Doyle DJ. A randomized comparison between the Pentax AWS video laryngoscope and the Macintosh laryngoscope in morbidly obese patients. Anesth Analg 2011; 113: 1082-1087.
9) Ahmad N, Zahoor A, Motowa SA, Riad W. Influence of GlideScope assisted intubation on intraocular pressure. Can J Anesth 2013; 1: S24.
10) Ahmad N, Zahoor A, Riad W, Al Motowa S. Influence of GlideScope assisted endotracheal intubation on intraocular pressure in ophthalmic patients. Saudi J Anaesth 2015; 9: 195-198.
11) Ahmadi K, Ebrahimi M, Hashemian AM, Sarshar S, Rahimi-Movaghar V. GlideScope Video laryngoscope for difficult intubation in emergency patients: a quasi-randomized controlled trial. Acta Med Iran 2015; 53: 738-742.
12) Akbar SH, Ooi JS. Comparison between C-MAC video-laryngoscope and Macintosh direct laryngoscope during cervical spine immobilization. Middle East J Anaesthesiol 2015; 23: 43-50.
13) Amini S, Shakib M. Hemodynamic changes following endotracheal intubation in patients undergoing cesarean section with general anesthesia: application of glidescope® videolaryngoscope versus direct laryngoscope. Anesth Pain Med 2015; 5: e21836.
14) Andersen LH, Rovsing L, Olsen K. GlideScope videolaryngoscope vs. Macintosh direct laryngoscope for intubation of morbidly obese patients: a randomized trial. Acta Anaesthesiol Scand 2011; 55: 1090-1097.
15) Aoi Y, Inagawa G, Nakamura K, Sato H, Kariya T, Goto T. Airway scope versus Macintosh laryngoscope in patients with simulated limitation of neck movements. J Trauma 2010; 69: 838-842.
16) Aqil M, Khan MU, Hussain A, Khokhar RS, Mansoor S, Alzahrani T. Routine use of glidescope and

macintosh laryngoscope by trainee anesthetists. J Coll Physicians Surg Pak 2016; 26: 245-249.
17) Arici S, Karaman S, Doğru S, Karaman T, Tapar H, Özsoy AZ, Kaya Z, Süren' M. The McGrath Series 5 video laryngoscope versus the Macintosh laryngoscope: a randomized trial in obstetric patients. Turk J Med Sci 2014; 44: 387-392.
18) Arima T, Nagata O, Miura T, Ikeda K, Mizushima T, Takahashi A. Comparative analysis of airway scope and Macintosh laryngoscope for intubation primarily for cardiac arrest in prehospital setting. Am J Emerg Med 2014; 32: 40-43.
19) Aziz MF, Dillman D, Fu R, Ansgar MB. Comparative effectiveness of the C-MAC video laryngoscope versus direct laryngoscopy in the setting of the predicted difficult airway. Anesthesiology 2012; 116: 629-636.
20) Bakshi SG, Vanjari VS, Divatia JV. A prospective, randomised, clinical study to compare the use of McGrath(®), Truview(®) and Macintosh laryngoscopes for endotracheal intubation by novice and experienced Anaesthesiologists. Indian J Anaesth 2015; 59: 421-427.
21) Bensghir M, Alaoui H, Azendour H, Drissi M, Elwali A, Meziane M, Lalaoui JS, Akhaddar A, Kamili ND. Faster double-lumen tube intubation with the videolaryngoscope than with a standard laryngoscope. Can J Anaesth 2010; 57: 980-984.
22) Bensghir M, Chouikh C, Bouhabba N, Fjjouji S, Kasouati J, Azendour H. Comparison between the Airtraq, X-Lite, and direct laryngoscopes for thyroid surgery: a randomized clinical trial. Can J Anaesth 2013; 60: 377-384.
23) Bhandari G, Shahi KS, Asad M, Bhakuni R. Airtraq(®) versus Macintosh laryngoscope: a comparative study in tracheal intubation. Anesth Essays Res 2013; 7: 232-236.
24) Bhat R, Sanickop CS, Patil MC, Umrani VS, Dhorigol MG. Comparison of macintosh laryngoscope and C-MAC video laryngoscope for intubation in lateral position. J Anaesthesiol Clin Pharmacol. 2015; 31: 226-229.
25) Bilehjani E, Fakhari S. Hemodynamic response to laryngoscopy in ischemic heart disease: Macintosh blade versus GlideScope videolaryngoscope. Rawal Med J 2009; 34: 151-154.
26) Carassiti M, Biselli V, Cecchini S, Zanzonico R, Schena E, Silvestri S. Force and pressure distribution using Macintosh and GlideScope laryngoscopes in normal airway: an in vivo study. Minerva Anestesiol 2013; 79: 515-524.
27) Castillo-Monzón CG, Marroquín-Valz HA, Fernández-Villacañas-Marín M, Moreno-Cascales M, García-Rojo B, Candia-Arana CA. Comparison of the macintosh and airtraq laryngoscopes in morbidly obese patients: a randomized and prospective study. J Clin Anesth 2017; 36: 136-141.
28) Cavus E, Thee C, Moeller T, Kieckhaefer J, Doerges V, Wagner K. A randomised, controlled crossover comparison of the C-MAC videolaryngoscope with direct laryngoscopy in 150 patients during routine induction of anaesthesia. BMC Anesthesiol 2011; 11: 6.
29) Choi GS, Lee E, Lim CS, Yoon SH. A comparative study on the usefulness of the Glidescope or Macintosh laryngoscope Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation when intubating normal airways. Korean J Anesthesiol 2011; 60: 339-343.
30) Çolak A, Çopuroğlu E, Yılmaz A, Şahin SH, Turan N. A comparison of the effects of different types of laryngoscope on the cervical motions: randomized clinical trial. Balkan Med J 2015; 32: 176-182.
31) Cordovani D, Russell T, Wee W, Suen A, Katznelson R, Cooper R. Measurement of forces applied using a Macintosh direct laryngoscope compared with the GlideScope video laryngoscope in patients with at least one difficult intubation risk. J Clin Anesthesia 2013; 25: 250-251.
32) Dashti M, Amini S, Azarfarin R, Totonchi Z, Hatami M. Hemodynamic changes following endotracheal intubation with GlideScope(®) video-laryngoscope in patients with untreated hypertension. Res Cardiovasc Med 2014; 3: e17598.
33) Enomoto Y, Asai T, Arai T, Kamishima K, Okuda Y. Pentax-AWS, a new videolaryngoscope, is more effective than the Macintosh laryngoscope for tracheal intubation in patients with restricted neck movements: a randomized comparative study. Br J Anaesthesia 2008; 100: 544-548.
34) Foulds LT, McGuire BE, Shippey BJ. A randomised cross-over trial comparing the McGrath(®) Series 5 videolaryngoscope with the Macintosh laryngoscope in patients with cervical spine immobilisation. Anaesthesia. 2016; 71: 437-442.
35) Frohlich S, Borovickova L, Foley E, O'Sullivan E. A comparison of tracheal intubation using the McGrath or the Macintosh laryngoscopes in routine airway management. Eur J Anaesthesiol 2011; 28: 465-467.
36) Griesdale DE, Chau A, Isac G, Ayas N, Foster D, Irwin C, Choi P; Canadian Critical Care Trials Group. Video-laryngoscopy versus direct laryngoscopy in critically ill patients: a pilot randomized trial. Can J Anaesth 2012; 59: 1032-1039.
37) Gupta N, Rath GP, Prabhakar H. Clinical evaluation of C-MAC videolaryngoscope with or without use of stylet for endotracheal intubation in patients with cervical spine immobilization. J Anesth 2013; 27: 663-670.
38) Hindman BJ, Santoni BG, Puttlitz CM, From RP, Todd MM. Intubation biomechanics: laryngoscope force and cervical spine motion during intubation with Macintosh and Airtraq laryngoscopes. Anesthesiology 2014; 121: 260-271.
39) Hirabayashi Y, Seo N. Tracheal intubation by non anaesthetist physicians using the Airway Scope. Emerg Med J 2007; 24: 572-573.
40) Hirabayashi Y, Seo N. Tracheal intubation by nonanesthesia residents using the Pentax-AWS airway scope and Macintosh laryngoscope. J Clin Anesth 2009; 21: 268-271.
41) Hsu HT, Chou SH, Wu PJ, Tseng KY, Kuo YW, Chou CY, Cheng KI. Comparison of the GlideScope® videolaryngoscope and the Macintosh laryngoscope for double-lumen tube intubation. Anaesthesia 2012; 67: 411-415.
42) Ilyas S, Symons J, Bradley WP, Segal R, Taylor H, Lee K, Balkin M, Bain C, Ng I. A prospective randomised controlled trial comparing tracheal

intubation plus manual in-line stabilisation of the cervical spine using the Macintosh laryngoscope vs the McGrath Series 5 videolaryngoscope. Anaesthesia 2014; 69: 1345-1350.
43) Ing R, Liu N, Chazot T, Fessler J, Dreyfus JF, Fischler M, Le Guen M. Nociceptive stimulation during Macintosh direct laryngoscopy compared with McGrath Mac videolaryngoscopy: A randomized trial using indirect evaluation using an automated administration of propofol and remifentanil. Medicine 2017; 96: e8087.
44) Ithnin F, Lim Y, Shah M, Shen L, Sia AT. Tracheal intubating conditions using propofol and remifentanil target-controlled infusion: a comparison of remifentanil EC50 for Glidescope and Macintosh. Eur J Anaesthesiol 2009; 26: 223-228.
45) Jungbauer A, Schumann M, Brunkhorst V, Borgers A, Groeben H. Expected difficult tracheal intubation: a prospective comparison of direct laryngoscopy and video laryngoscopy in 200 patients. Br J Anaesth 2009; 102: 546-550.
46) Kanchi M, Nair H, Banakal S, Murthy K, Murugesan C. Haemodynamic response to endotracheal intubation in coronary artery disease: direct versus video laryngoscopy. Indian J Anaesth 2011; 55: 260-265.
47) Kido H, Komasawa N, Matsunami S, Kusaka Y, Minami T. Comparison of McGRATH MAC and Macintosh laryngoscopes for double-lumen endotracheal tube intubation by anesthesia residents: a prospective randomized clinical trial. J Clin Anesth. 2015; 27: 476-480.
48) Kill C, Risse J, Wallot P, Seidl P, Steinfeldt T, Wulf H. Videolaryngoscopy with glidescope reduces cervical spine movement in patients with unsecured cervical spine. J Emerg Med 2013; 44: 750-756.
49) Kim MK, Park SW, Lee JW. Randomized comparison of the Pentax AirWay Scope and Macintosh laryngoscope for tracheal intubation in patients with obstructive sleep apnoea. Br J Anaesth 2013; 111: 662-666.
50) Komatsu R, Kamata K, Sessler DI, Ozaki M. Airway scope and Macintosh laryngoscope for tracheal intubation in patients lying on the ground. Anesth Analg 2010; 111: 427-431.
51) Laosuwan P, Earsakul A, Numkarunarunrote N, Khamjaisai J, Charuluxananan S. Randomized cinefluoroscopic comparison of cervical spine motion using McGrath series 5 and Macintosh laryngoscope for intubation with manual in-line stabilization. J Med Assoc Thai 2015; 98: S63-69.
52) Lascarrou JB, Boisrame-Helms J, Bailly A, Le Thuaut A, Kamel T, Mercier E, Ricard JD, Lemiale V, Colin G, Mira JP, Meziani F, Messika J, Dequin PF, Boulain T, Azoulay E, Champigneulle B, Reignier J; Clinical Research in Intensive Care and Sepsis (CRICS) Group. Video laryngoscopy vs direct laryngoscopy on successful first-pass orotracheal intubation among ICU patients: a randomized clinical trial. JAMA 2017; 317: 483-493.
53) Lee RA, van Zundert AA, Maassen RL, Willems RJ, Beeke LP, Schaaper JN, van Dobbelsteen J, Wieringa PA. Forces applied to the maxillary incisors during video-assisted intubation. Anesth Analg 2009; 108: 187-191.
54) Lee RA, van Zundert AAJ, Maassen RLJG, Wieringa PA. Forces applied to the maxillary incisors by video laryngoscopes and the Macintosh laryngoscope. Acta Anaesthesiol Scand 2012; 56: 224-229.
55) Lee H. The Pentax airway scope versus the Macintosh laryngoscope: comparison of hemodynamic responses and concentrations of plasma norepinephrine to tracheal intubation. Korean J Anesthesiol 2013; 64: 315-320.
56) Lim Y, Yeo SW. Comparison of the GlideScope (R) with the Macintosh laryngoscope for tracheal intubation in patients with simulated difficult airway. Anaesth Intensive Care 2005; 33: 243-247.
57) Lin W, Li H, Liu W, Cao L, Tan H, Zhong Z. A randomised trial comparing the CEL-100 videolaryngoscope (TM) with the Macintosh laryngoscope blade for insertion of double lumen tubes. Anaesthesia 2012; 67: 771-776.
58) Liu ZJ, Yi J, Guo WJ, Ma C, Huang YG. Comparison of Mcgrath series 3 and Macintosh laryngoscopes for tracheal intubation in patients with normal airway by inexperienced anesthetists: a randomized study. Medicine 2016; 95: e2514.
59) Maassen RL, Pieters BM, Maathuis B, Serroyen J, Marcus MA, Wouters P, van Zundert AA. Endotracheal intubation using videolaryngoscopy causes less cardiovascular response compared to classic direct laryngoscopy, in cardiac patients according a standard hospital protocol. Acta Anaesthesiol Belg 2012; 63: 181-186.
60) Malik MA, Maharaj CH, Harte BH, Laffey JG. Comparison of Macintosh, Truview EVO2, Glidescope, and Airwayscope laryngoscope use in patients with cervical spine immobilization. Br J Anaesth 2008; 101: 723-730.
61) Malik MA, Subramaniam R, Churasia S, Maharaj CH, Harte BH, Laffey JG. Tracheal intubation in patients with cervical spine immobilization: a comparison of the Airwayscope, LMA CTrach, and the Macintosh laryngoscopes. Br J Anaesth 2009; 102: 654-661.
62) Malik MA, Subramaniam R, Maharaj CH, Harte BH, Laffey JG. Randomized controlled trial of the Pentax AWS, Glidescope, and Macintosh laryngoscopes in predicted difficult intubation. Br J Anaesth 2009; 103: 761-768.
63) Maruyama K, Yamada T, Kawakami R, Hara K. Randomized cross-over comparison of cervical-spine motion with the AirWay Scope or Macintosh laryngoscope with inline stabilization: a video-fluoroscopic study. Br J Anaesth 2008; 101: 563-567.
64) Maruyama K, Yamada T, Kawakami R, Kamata T, Yokochi M, Hara K. Upper cervical spine movement during intubation: fluoroscopic comparison of the AirWay Scope, McCoy laryngoscope, and Macintosh laryngoscope. Br J Anaesth 2008; 100: 120-124.
65) McElwain J, Laffey JG. Comparison of the C-MAC, Airtraq, and Macintosh laryngoscopes in patients undergoing tracheal intubation with cervical spine immobilization. Br J Anaesth 2011; 107: 258-264.
66) Najafi A, Imani F, Makarem J, Khajavi MR, Eteza-

di F, Habibi S, Shariat Moharari R. Postoperative sore throat after laryngoscopy with Macintosh or Glide scope video laryngoscope blade in normal airway patients. Anesth Pain Med 2014; 4: e15136.
67) Nishikawa K, Matsuoka H, Saito S. Tracheal intubation with the PENTAX-AWS (airway scope) reduces changes of hemodynamic responses and bispectral index scores compared with the Macintosh laryngoscope. J Neurosurg Anesthesiol 2009; 21: 292-296.
68) Peck MJ, Novikova O, Hung O, Launcelott S, Law J.A, Macquarrie K. Laryngoscopy and tracheal intubation using the McGrath laryngoscope in patients with cervical spine in-line immobilization. Can J Anesth 2009; 56: S85.
69) Pournajafian AR, Ghodraty MR, Faiz SH, Rahimzadeh P, Goodarzynejad H, Dogmehchi E. Comparing GlideScope video laryngoscope and Macintosh laryngoscope regarding hemodynamic responses during orotracheal intubation: a randomized controlled trial. Iranian Red Crescent Med J 2014; 16: e12334.
70) Robitaille A, Williams SR, Tremblay MH, Guilbert F, Theriault M, Drolet P. Cervical spine motion during tracheal intubation with manual in-line stabilization: direct laryngoscopy versus GlideScope videolaryngoscopy. Anesth Analg 2008; 106: 935-941.
71) Russell T, Khan S, Elman J, Katznelson R, Cooper RM. Measurement of forces applied during Macintosh direct laryngoscopy compared with GlideScope videolaryngoscopy. Anaesthesia 2012; 67: 626-631.
72) Russell T, Slinger P, Roscoe A, McRae K, Rensburg A. A randomised controlled trial comparing the GlideScope and the Macintosh laryngoscope for double-lumen endobronchial intubation. Anaesthesia 2013; 68: 1253-1258.
73) Sandhu H, Gombar S, Kapoor D. A comparative evaluation of glide scope and Macintosh laryngoscope for endotracheal intubation. Indian J Crit Care Med 2014; 18: S9.
74) Sargin M, Uluer MS. Comparison of McGrath(®) Series 5 video laryngoscope with Macintosh laryngoscope: a prospective, randomised trial in patients with normal airways. Pak J Med Sci 2016; 32: 869-874.
75) Serocki G, Bein B, Scholz J, Dorges V. Management of the predicted difficult airway: a comparison of conventional blade laryngoscopy with video-assisted blade laryngoscopy and the GlideScope. Eur J Anaesthesiol 2010; 27: 24-30.
76) Serocki G, Neumann T, Scharf E, Dorges V, Cavus E. Indirect videolaryngoscopy with C-MAC D-Blade and GlideScope: a randomized, controlled comparison in patients with suspected difficult airways. Minerva Anestesiol 2013; 79: 121-129.
77) Shippey B, McGuire B, Dalton A. A comparison of the McGrath videolaryngoscope and the Macintosh laryngoscope in patients with cervical spine immobilisation. Anaesthesia 2013; 68: 883.
78) Siddiqui N, Katznelson R, Friedman Z. Heart rate/blood pressure response and airway morbidity following tracheal intubation with direct laryngoscopy, GlideScope and Trachlight: a randomized control trial. Eur J Anaesthesiol 2009; 26: 740-745.
79) Silverberg MJ, LiN, Acquah SO, Kory PD. Comparison of video laryngoscopy versus direct laryngoscopy during urgent endotracheal intubation: a randomized controlled trial. Crit Care Med 2015; 4: 336-341.
80) Sulser S, Ubmann D, Schlaepfer M, Brueesch M, Goliasch G, Seifert B, Spahn DR, Ruetzler K. C-MAC videolaryngoscope compared with direct laryngoscopy for rapid sequence intubation in an emergency department: a randomised clinical trial. Eur J Anaesthesiol 2016; 33: 943-948.
81) Sun DA, Warriner CB, Parsons DG, Klein R, Umedaly HS, Moult M. The GlideScope Video Laryngoscope: randomized clinical trial in 200 patients. Br J Anaesth 2005; 94: 381-384.
82) Suzuki A, Toyama Y, Katsumi N, Kunisawa T,Henderson JJ, Iwasaki H. Cardiovascular responses to tracheal intubation with the Airway Scope (Pentax-AWS). J Anesth 2008; 22: 100-101.
83) Takenaka I, Aoyama K, Iwagaki T, Kadoya T. Efficacy of the Airway Scope on tracheal intubation in the lateral position: comparison with the Macintosh laryngoscope. Eur J Anaesthesiol 2011; 28: 164-168.
84) Taylor AM, Peck M, Launcelott S, Hung OR, Law JA, MacQuarrie K, McKeen D, George RB, Ngan J. The McGrath (R) Series 5 videolaryngoscope vs the Macintosh laryngoscope: a randomised, controlled trial in patients with a simulated difficult airway. Anaesthesia 2013; 68: 142-147.
85) Teoh WH, Saxena S, Shah MK, Sia AT. Comparison of three videolaryngoscopes: Pentax Airway Scope, C-MAC, GlideScope vs the Macintosh laryngoscope for tracheal intubation. Anaesthesia 2010; 65: 1126-1132.
86) Turkstra TP, Craen RA, Pelz DM, Gelb AW. Cervical spine motion: a fluoroscopic comparison during intubation with lighted stylet, GlideScope, and Macintosh laryngoscope. Anesth Analg 2005; 101: 910-915.
87) Turkstra TP, Pelz DM, Jones PM. Cervical spine motion: a fluoroscopic comparison of the AirTraq Laryngoscope versus the Macintosh laryngoscope. Anesthesiology 2009; 111: 97-101.
88) Walker L, Brampton W, Halai M, Hoy C, Lee E, Scott I, McLernon DJ. Randomized controlled trial of intubation with the McGrath Series 5 videolaryngoscope by inexperienced anaesthetists. Br J Anaesth 2009; 103: 440-445.
89) Wasinwong W, Pukdeetanakul V, Kanchanawanitkul O, Sriyannaluk B. Comparison of intubation time with glidescope® and mcintosh laryngoscope in obese patients. J Med Assoc Thai 2017; 100: 306-312.
90) Woo CH, Kim SH, Park JY, Bae JY, Kwak IS, Mun SH, Kim KM. Macintosh laryngoscope vs. Pentax-AWS video laryngoscope: comparison of efficacy and cardiovascular responses to tracheal intubation in major burn patients. Korean J Anesthesiol 2012; 62: 119-124.
91) Xue FS, Zhang GH, Li XY, Sun HT, Li P, Li CW, Liu KP. Comparison of hemodynamic responses

to orotracheal intubation with the GlideScope videolaryngoscope and the Macintosh direct laryngoscope. J Clin Anesth 2007; 19: 245-250.
92) Yeatts DJ, Dutton RP, Hu PF, Chang YW, Brown CH, Chen H, Grissom TE, Kufera JA, Scalea TM. Effect of video laryngoscopy on trauma patient survival: a randomized controlled trial. J Trauma Acute Care Surg 2013; 75: 212-219.
93) Yao WL, Wan L, Xu H, Qian W, Wang XR, Tian YK, Zhang CH. A comparison of the McGrath® Series 5 videolaryngoscope and Macintosh laryngoscope for double-lumen tracheal tube placement in patients with a good glottic view at direct laryngoscopy. Anaesthesia 2015; 70: 810-817.
94) Yoo JY, Park SY, Kim JY, Kim M, Haam SJ, Kim DH. Comparison of the McGrath videolaryngoscope and the Macintosh laryngoscope for double lumen endobronchial tube intubation in patients with manual in-line stabilization: A randomized controlled trial. Medicine 2018; 97: e0081
95) Yousef GT, Abdalgalil DA, Ibrahim TH. Orotracheal intubation of morbidly obese patients, comparison of GlideScope(®) video laryngoscope and the LMA CTrach™ with direct laryngoscopy. Anesth Essays Res 2012; 6: 174-179.
96) Yumul R, Elvir-Lazo OL, White PF, Sloninsky A, Kaplan M, Kariger R, Naruse R, Parker N, Pham C, Zhang X, Wender RH. Comparison of three video laryngoscopy devices to direct laryngoscopy for intubating obese patients: a randomized controlled trial. J Clin Anesth 2016; 31: 71-77.
97) Zhao H, Feng Y, Zhou Y. Teaching tracheal intubation: Airtraq is superior to Macintosh laryngoscope. BMC Med Educ 2014; 14: 144.
98) Aggarwal H, Kaur S1, Baghla N, Kaur S. Hemodynamic Response to Orotracheal Intubation: Comparison between Macintosh, McCoy, and C-MAC Video Laryngoscope. Anesth Essays Res 2019; 13: 308-312.
99) Blajic I, Hodzovic I, Lucovnik M, Mekis D, Novak-Jankovic V, Stopar Pintaric T. A randomised comparison of C-MAC™ and King Vision® videolaryngoscopes with direct laryngoscopy in 180 obstetric patients. Int J Obstet Anesth 2019; 39: 35-41.
100) Gao YX, Song YB, Gu ZJ, Zhang JS, Chen XF, Sun H, Lu Z. Video versus direct laryngoscopy on successful first-pass endotracheal intubation in ICU patients. World J Emerg Med 2018; 9: 99-104
101) Goksu E, Kilic T, Yildiz G, Unal A, Kartal M. Comparison of the C-MAC video laryngoscope to the Macintosh laryngoscope for intubation of blunt trauma patients in the ED. Turk J Emerg Med 2016; 16: 53-56.
102) Liu DX, Ye Y, Zhu YH, Li J, He HY, Dong L, Zhu ZQ. Intubation of non-difficult airways using video laryngoscope versus direct laryngoscope: a randomized, parallel-group study. BMC Anesthesiol 2019; 19: 75.
103) Loughnan A, Deng C, Dominick F, Pencheva L, Campbell D. A single-centre, randomised controlled feasibility pilot trial comparing performance of direct laryngoscopy versus videolaryngoscopy for endotracheal intubation in surgical patients. Pilot Feasibility Stud 2019; 5: 50
104) Reena. Comparison of King Vision video laryngoscope (channeled blade) with Macintosh laryngoscope for tracheal intubation using armored endotracheal tubes. J Anaesthesiol Clin Pharmacol 2019; 35: 359-362.
105) Lewis SR, Butler AR Parwker J, Cook TM, Schofield-Robinson OJ, Smith AF. Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation: a Cochrane Systematic Review. Br J Anaesth 2017; 119: 369-383.
106) Pieters BMA, Maes EHA, Knape JTA, van Zundert AAJ. Videolaryngoscopy vs. direct laryngoscopy use by experienced anaesthetists in patients with known difficult airways: a systematic review and meta-analysis. Anaesthesia 2017; 72: 1532-1541.
107) Suppan L, Tramer MR, Niquille M, Grosggurin O, Marti C. Alternative intubation techniques vs Macintosh laryngoscopy in patients with cervical spine immobilization: systematic review and meta-analysis of randomized controlled trials. Br J Anaesth 2016; 116: 27-36.
108) De Jong A, Molinari N, Conseil M, Coisel Y, Pouzeratte Y, Belafia F, Jung B, Chanques G, Jaber S. Video laryngoscopy versus direct laryngoscopy for orotracheal intubation in the intensive care unit: a systematic review and meta-analysis. Intensive Care Med 2014; 40: 629-639.
109) Jiang J, Ma D, Li B, Yue Y, Xue F. Video laryngoscopy does not improve the intubation outcomes in emergency and critical patients - a systematic review and meta-analysis of randomized controlled trials. Crit Care 2017; 24: 288.
110) Huang HB, Peng JM, Xu B, Liu GY, Du B. Video Laryngoscopy for Endotracheal Intubation of Critically Ill Adults: A Systemic Review and Meta-Analysis. Chest 2017; 152: 510-517.
111) Savino PB, Reicheldefer S, Mercer MP, Wang RC, Sporer KA. Direct versus video laryngoscopy for prehospital intubation: a systematic review and meta-analysis. Acad Emerg Med 2017; 24: 1018-1026.
112) Zhao BC, Huang TY, Liu KX. Video laryngoscopy for ICU intubation: a meta-analysis of randomised trials. Intensive Care Med 2017; 43: 947-948.
113) 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. Br J Anaesth 2018; 120: 712-724.
114) Pieters BMA, Maas EHA, Knape JTA, van Zundert AAJ. Videolaryngoscopy vs. direct laryngoscopy use by experienced anaesthetists in patients with known difficult airways: a systematic review and meta-analysis. Anaesthesia 2017; 72: 1532-1541.
115) Koh JC, Lee JS, Lee YW, Chang CH. Comparison of the laryngeal view during intubation using Airtraq and Macintosh laryngoscopes in patients with cervical spine immobilization and mouth opening limitation. Korean J Anesthesiol 2010; 59: 314-318.
116) Schulz KF, Chalmers I, Hayes RJ, Altman DG. Empirical evidence of bias. Dimensions of methodological quality associated with estimates of

treatment effects in controlled trials. JAMA 1995; 273: 408-412.
117) Asai T, Liu EH, Matsumoto S, Hirabayashi Y, Seo N, Suzuki A, Toi T, Yasumoto K, Okuda Y. Use of the Pentax-AWS in 293 patients with difficult airways. Anesthesiology 2009; 110: 898-904
118) American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology 2003; 98: 1269-1277.
119) Frerk C, Mitchell VS, McNarry AF, Bhagrath R, Patel A, O'Sullivan EP, Woodall NM. Difficult airway society guidelines 2015 for management of unticipated diffciult intubation in adults. Br J Anesth 2015; 115: 827-848.
120) Domino KB, Posner KL, Caplan RA, Cheney FW. Airway injury during anesthesia: a closed claims analysis. Anesthesiology 1999; 91: 1703-1711.
121) Hua M, Brady J, Li G. The epidemiology of upper airway injury in patients undergoing major surgical procedures. Anesth Analg 2012; 114: 148-151.
122) Pieters B, Maassen R, Van Eig E, Maathuis B, Van Den Dobbelsteen J, Van Zundert A. Indirect videolaryngoscopy using Macintosh blades in patients with non-anticipated difficult airways results in significantly lower forces exerted on teeth relative to classic direct laryngoscopy: a randomized crossover trial. Minerva Anestesiol 2015; 81: 846-854.
123) Buis ML, Maissan IM, Hoeks SE, Klimek M, Stolker RJ. Defining the learning curve for endotracheal intubation using direct laryngoscopy: A systematic review. Resuscitation 2016; 99: 63-71.
124) Vargas M, Servillo G, Tessitore G, Aloj F, Brunetti I, Arditi E, Salami D, Kacmarek RM, Pelosi P. Double lumen endotracheal tube for percutaneous tracheostomy. Respir Care 2014; 59: 1652-1659.
125) De Robertis E, Zito Marinosci G, Romano GM, Piazza O, Iannuzzi M, Cirillo F, De Simone S, Servillo G. The use of sugammadex for bariatric surgery: analysis of recovery time from neuromuscular blockade and possible economic impact. Clinicoecon Outcomes Res 2016; 8: 317-322.