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REPORTS OF ORIGINAL INVESTIGATIONS

Indirect laryngoscopy is more effective than direct laryngoscopy when tracheal intubation is performed by novice operators: a systematic review, meta-analysis, and trial sequential analysis

La laryngoscopie indirecte plus efficace que la laryngoscopie directe lorsque l'intubation trachéale est réalisée par des opérateurs ou opératrices novices : revue systématique, méta-analyse, et analyse séquentielle des études

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Abstract

Purpose *We sought to perform a systematic review and meta-analysis to determine whether indirect laryngoscopy has an advantage over direct laryngoscopy in terms of the tracheal intubation rate, glottic visualization, and intubation time when used by novice operators.*

Methods *We extracted adult prospective randomized trials comparing tracheal intubation with indirect vs direct laryngoscopy in novice operators from electronic databases. We extracted the following data from the identified studies: success rate, glottic visualization, and intubation time. Data from each trial were combined via a random-effects model to calculate the pooled relative risk (RR) or weighted mean difference (WMD) with a 95% confidence interval (CI). We also performed a trial sequential analysis.*

Results *We included 15 articles (17 trials) comprising 2,290 patients in the systematic review. Compared with the direct laryngoscopy, indirect laryngoscopy improved success rate (RR, 1.15; 95% CI, 1.07 to 1.24; $P = 0.0002$; $I^2 = 88\%$), glottic visualization (RR, 1.76; 95% CI, 1.36 to 2.28; $P < 0.001$; $I^2 = 85\%$), and intubation time (WMD, −9.06 sec; 95% CI, −16.4 to −1.76; $P = 0.01$; $I^2 = 98\%$) in tracheal intubation. Trial sequential analysis showed that the total sample size was sufficient to analyze the success rate and intubation time.*

Conclusion *In this systematic review, we found that the tracheal intubation success rate, glottic visualization, and intubation time were improved when novice operators used indirect laryngoscopy rather than direct laryngoscopy. Trial sequential analysis results indicated that the sample size was sufficient for examining the success rate and intubation time.*

Study registration *PROSPERO (CRD42022309045); first registered 4 September 2022.*

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Résumé

Objectif *Nous avons cherché à réaliser une revue systématique et une méta-analyse pour déterminer si la laryngoscopie indirecte présente un avantage par rapport à la laryngoscopie directe en termes de taux de succès d'intubation trachéale, de visualisation glottique et de* *temps d'intubation lorsqu'elle est utilisée par des opératrices et opérateurs novices.*

Méthode *Nous avons extrait des études randomisées prospectives chez l'adulte comparant l'intubation trachéale avec une laryngoscopie indirecte vs directe réalisée par des opérateurs et opératrices novices à partir de bases de données électroniques. Nous avons extrait les données suivantes des études identifiées : taux de succès, visualisation glottique et temps d'intubation. Les données de chaque étude ont été combinées au moyen d'un modèle à effets aléatoires pour le calcul du risque relatif (RR) groupé ou de la différence moyenne pondérée (DMP) avec un intervalle de confiance (IC) de 95 %. Nous avons également réalisé une analyse séquentielle des études.*

Résultats *Nous avons inclus 15 articles (17 études) portant sur 2290 patient·es dans notre revue systématique. Par rapport à la laryngoscopie directe, la laryngoscopie indirecte a amélioré le taux de succès (RR, 1,15; IC 95 %, 1,07 à 1,24; P = 0,0002; I^2 = 88 %), la visualisation glottique (RR, 1,76; IC 95 %, 1,36 à 2,28; P < 0,001; I^2 = 85 %), et le temps d'intubation (DMP, −9,06 s; IC 95 %, −16,4 à −1,76; P = 0,01; I^2 = 98 %) pour l'intubation trachéale. L'analyse séquentielle des études a montré que la taille totale de l'échantillon était suffisante pour analyser le taux de succès et le temps d'intubation.*

Conclusion *Dans cette revue systématique, nous avons constaté que le taux de succès de l'intubation trachéale, la visualisation glottique et le temps d'intubation étaient améliorés lorsque les opératrices et opérateurs novices utilisaient la laryngoscopie indirecte plutôt que la laryngoscopie directe. L'analyse séquentielle des études a montré que la taille totale de l'échantillon était suffisante pour analyser le taux de succès et le temps d'intubation.*

Enregistrement de l'étude *PROSPERO (CRD42022309045); première inscription le 4 septembre 2022.*

Keywords indirect laryngoscopy · meta-analysis · novice · tracheal intubation

Indirect laryngoscopes, including videolaryngoscopes, are widely used for tracheal intubation in the clinical setting. They have a number of advantages for tracheal intubation in that they can be used successfully without needing to align the laryngeal, pharyngeal, and oral axes,[1,2] and the optical camera attached to the tip of the scope enables more accurate tracheal intubation by visualizing the glottis from a short distance.[3,4] Indeed, indirect laryngoscopy is reported to be superior to conventional direct laryngoscopy for tracheal intubation.[5,6]

Previous meta-analyses have shown that indirect laryngoscopes are also useful in patients in whom intubation is difficult, such as those requiring manual in-line stabilization[7,8] and those with severe obesity.[9] In addition, indirect laryngoscopes are considered useful for tracheal intubation by novice operators. Studies in mannequins have shown that the intubation rate is higher and intubation time is shorter when novices use an indirect laryngoscope rather than a direct laryngoscope.[10,11] Nevertheless, an indirect laryngoscope may not be able to successfully guide the tracheal tube to the glottis, even if the glottis can be visualized,[12] and the video images do not visualize the pharynx and hypopharynx, which can lead to visual and cognitive blind spots.[13,14] These disadvantages suggest that indirect laryngoscopes may not always be effective in the hands of novice operators. Moreover, clinical studies in humans have not been able to determine whether indirect laryngoscopy is advantageous for tracheal intubation in inexperienced hands.[15–17]

We sought to undertake this systematic review and meta-analysis to determine whether indirect laryngoscopy has an advantage over direct laryngoscopy in terms of the tracheal intubation rate, glottic visualization, and intubation time when used by novice operators. We also aimed to compared the frequency of adverse events, including esophageal intubation, oropharyngeal injury, and desaturation, between indirect laryngoscopes and direct laryngoscopes.

Methods

The manuscript was prepared following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[18] The study protocol was registered at PROSPERO (registration number, CRD42022309045; registered 4 September 2022).

Search strategy

We conducted a comprehensive literature search using the PubMed, Embase, and Cochrane Central Register of Controlled Trials databases. The search strategy used is shown in Electronic Supplementary Material (ESM) eAppendix 1. We also manually searched the reference lists in the reports and reviews extracted to identify further potentially eligible articles. No restrictions were imposed on article type or language of the publication. The search was performed in October 2022.

Selection of included studies

Articles were extracted by each of the authors working independently and assessed for suitability for inclusion in the systematic review. Disagreements regarding interpretation or analysis of the data in the extracted articles were resolved through discussion. In the event of duplicate reporting, only the report that analyzed the most recent data were included. If necessary, the authors of potentially eligible articles were contacted directly to obtain missing data and resolve any inconsistencies. For each included study, we searched online to confirm if the research protocol had been published, and if so, whether its content matched the results subsequently reported. A risk of bias was recorded if the study protocol had not been published.

Studies were eligible for inclusion if they had a prospective randomized design and compared the outcomes of tracheal intubation for adult patients by novice operators using an indirect laryngoscope or a direct laryngoscope. Information on success rate (first attempt), glottic visualization (Cormack–Lehane classification 1 *vs* $\geq$ 2), and intubation time was extracted from the eligible articles. The definition of failure of tracheal intubation was recorded for each study. Adverse events during tracheal intubation were also compared between the two types of laryngoscopes.

The research question was framed using the Population, Intervention, Comparison, Outcomes framework as follows: population = patients requiring oral tracheal intubation when undergoing surgery under general anesthesia; intervention = tracheal intubation with an indirect laryngoscope attempted by a novice operator; comparison = tracheal intubation with a direct laryngoscope attempted by a novice operator; and outcomes = tracheal intubation success rate, glottic visualization, and intubation time.

Studies with mannequins; studies in which tracheal intubation was performed during cardiopulmonary resuscitation or nasal intubation, and in pediatric patients; and studies that used double-lumen tubes were excluded. We also divided the indirect laryngoscopy groups and direct laryngoscopy groups into subgroups to compare outcomes according to whether or not a tracheal tube guide was used.

Critical appraisal of study quality

Risk of bias and quality of evidence

We evaluated the risk of bias with reference to the Cochrane Handbook[19] (ESM eAppendix 2). The quality of evidence for the main outcomes was assessed using the Grading of Recommendations Assessment, Development and Evaluation approach[20] (ESM eAppendix 3).

Data synthesis and analysis

Statistical analysis was performed using the DerSimonian and Laird random effects model. Binary variable pool effect estimates (success rate, glottic visualization, and adverse events) are expressed as the relative risk (RR) with 95% confidence interval (CI). The pooled difference in intubation time between the indirect and direct laryngoscope groups is expressed as the weighted mean difference (WMD) of the 95% CI. The heterogeneity of effect size was examined using the Cochran Q test and the I^2 statistic.[21]

We also performed a trial sequential analysis (TSA) to assess sensitivity to prevent type I error arising from multiple tests of effect in the meta-analysis.[22,23] First, we calculated the required sample size (required information size [RIS]) and set the risk of type I error to 5% and the risk of type II error to 10%. We set the minimum clinically meaningful risk ratio in TSA to 1.33 and the mean difference to ten seconds. Trial Sequential Analysis version 0.9.5.5 beta (Copenhagen Trial Unit, Centre for Clinical Intervention Research, Copenhagen, Denmark) was used for this analysis.

Publication bias was assessed by testing the symmetry of a funnel plot[24] and by Begg's test.[25] A P value of < 0.1 from this test indicated publication bias.

Results

Characteristics of included studies

The literature search identified 332 potentially relevant articles. Eighty-six studies were immediately identified to be unrelated and excluded. The remaining 246 articles were carefully read to determine whether they met our eligibility criteria. A further 226 studies were excluded for the following reasons: trial performed in mannequins (n = 88); not a randomized controlled trial (n = 51);

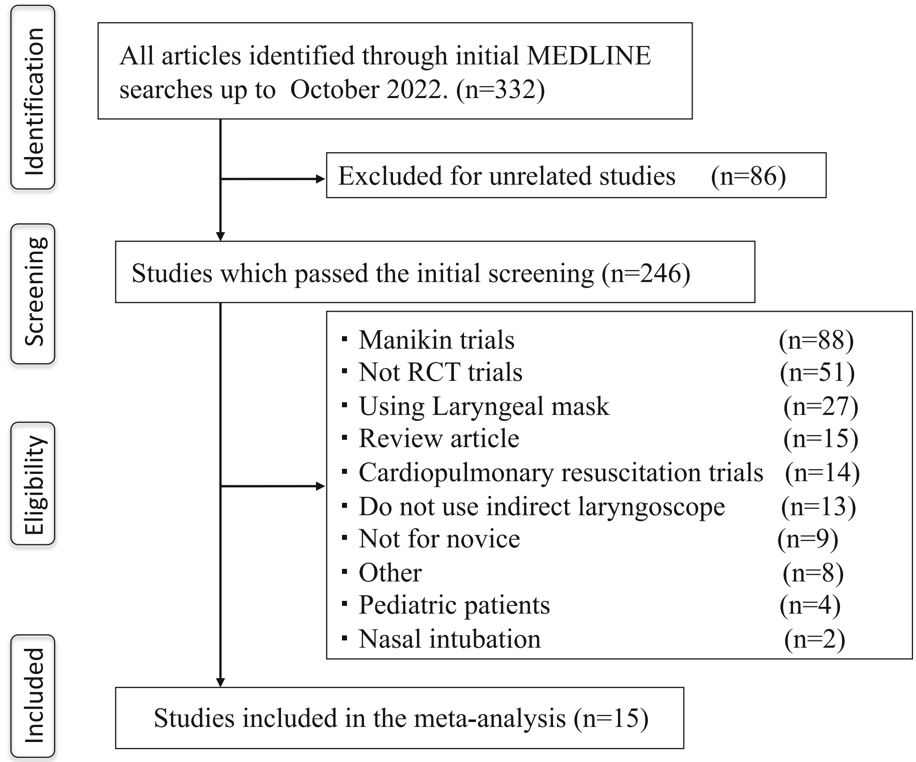

Fig. 1 Systematic review and meta-analysis flow chart
RCT = randomized controlled trial

laryngeal mask airway used (*n* = 27); a review article (*n* = 15); a cardiopulmonary resuscitation trial (*n* = 14); indirect laryngoscope not used (*n* = 13); not involving novice operators (*n* = 9); other reason (*n* = 8); involving pediatric patients (*n* = 4); and nasal intubation used (*n* = 2). The remaining 15 articles (17 trials) met our inclusion criterion and contained the data necessary for comparison (Fig. 1). These 15 articles are summarized in Table 1.[2,15–17,26–37]

The included studies were published between 2009 and 2018. The most common indirect laryngoscope used was the Airtraq™ (Mercury Medical®, Clearwater, FL, USA; six trials), followed by the GlideScope® (Verathon Inc., Bothell, WA, USA; four trials), the McGRATH™ (Medtronic PLC, Dublin, Ireland; three trials), the Pentax Airway Scope (Nihon Kohden Corp., Tokyo, Japan; two trials), the C-MAC® (Karl Storz SE & Co. KG, Tuttlingen, Germany; one trial), and the Truview EVO2 (Leica Geosystems AG, Heerbrugg, Switzerland; one trial). The definition of a novice operator was a resident in ten trials and a medical student in the remaining five trials. The preoperative condition of the airway was reported to be normal in all but one trial. All direct laryngoscopes used were Macintosh laryngoscopes (Table 1).

Meta-analysis results

In total, 1,169 patients were intubated using an indirect laryngoscope and 1,121 using a direct laryngoscope.

Intubation performance

In the 17 trials, the tracheal intubation success rate was significantly higher with an indirect laryngoscope than with a direct laryngoscope (RR, 1.15; 95% CI, 1.07 to 1.24; $P = 0.0002$; Cochrane's Q = 134.2; $I^2 = 88\%$; Fig. 2). Absolute risk reduction was 17.7% (indirect laryngoscopy, 89.1% *vs* direct laryngoscopy, 71.9%). For success rate, our TSA revealed that the Z-curve crossed the efficacy boundary, although the RIS was not reached (ESM eFig. 4).

Glottic visualization was evaluated in nine trials and was better when an indirect laryngoscope was used (RR, 1.76; 95% CI, 1.36 to 2.28; $P < 0.001$; Cochrane's Q = 45.5; $I^2 = 85\%$; Fig. 3). Absolute risk reduction was 36.6% (indirect laryngoscope 83.3% *vs* direct laryngoscope 47.6%). The Z curve did not reach the TSA monitoring boundary for benefit, and the accrued sample size (*n* = 984)

Table 1 Characteristics of included studies

No.	Author	Year	Number of patients (indirect/direct)	Intubation devices	ASA Physical Status	Status of airway	Intubation route	Participants	Definition of novice laryngoscopists and preclinical practice of laryngoscope
1	Hirabayashi Y	2009	502 (264/256)	AirwayScope/ Macintosh	N/A	Normal	Oral	Adult patients	Nonanesthesia residents
2	Nouruzi-Sedeh P	2009	200 (100/100)	GlideScope®/ Macintosh	I–II	Normal	Oral	Adult patients	Twenty individuals participated in this study. Eight were in final training to become a paramedic, fourwere first-year residents, fourwere nurses, and fourwere medical students; all of them had not yet intubated a patient.
3	Walker L	2009	120 (60/60)	MacGrath™/ Macintosh	N/A	Normal	Oral	Adult patients	Novice anesthesiologist had received training in use of the McGrath laryngoscope. This followed a standard competency-based model, initially using a mannequin followed by 10 successful intubations in clinical practice.
4	Ayoub CM	2010	126 (63/63)	GlideScope/ Macintosh	I–II	Normal	Oral	Adult patients	After completion of the teaching phase during their first day of the anesthesia rotation, each medical student in each group performed three intubations spread over a one-week period using the Macintosh size −3 blade
5	Hirabayashi Y	2010	200 (100/100)	GlideScope/ Macintosh	N/A	Normal	Oral	Adult patients	The trainees received a short demonstration of the GlideScope videolaryngoscope device and were allowed 5–6 practice intubations using a mannequin before using the device clinically
6	Park SJ	2010	74 (37/37)	Airtraq™/ Macintosh	I–II	Normal	Oral	Adult patients	The medical students received orientation for endotracheal intubation using both the Macintosh direct laryngoscope and the Airtraq through audio-visual materials, and then performed 10 endotracheal intubations on intubation-training mannequins
7	Di Marco PD	2011	108 (54/54)	Airtraq/ Macintosh	I–III	Normal	Oral	Adult patients	All residents were in their first year of anesthesia training and had not had any prior experience using either laryngoscope. Residents had a standard two-hour demonstration by an experienced anesthesiologist on intubation techniques using the Macintosh and Airtraq blades.
8	de Oliveira GS	2011	30 (15/15)	Airtraq/ Macintosh	I–II	Normal	Oral	Adult patients	Medical students and intern trainees with no prior experience in tracheal intubation
9	Ferrando C	2011	120 (60/60)	Airtraq/ Macintosh	I–III	Normal	Oral	Adult patients	Anesthesiology unskillful residents of our department conducted the laryngoscopies. Previously to the beginning of the study, they had performed in patients less than two hundred intubations with the Macintosh laryngoscope and 10 intubations using the Airtraq.
10	Cattano D	2013	50 (25/25)	C-MAC®/ Macintosh	I–III	Normal	Oral	Adult patients	All the residents and the attending anesthesiologists were trained based on manufacturer's recommendations and performed a minimum of three intubations with the C-MAC videolaryngoscope prior to working on any patients in clinical conditions, as well as three laryngoscopy and intubations on a mannequin
11	Peirovifar A	2014	40 (20/20)	GlideScope/ Macintosh	I–II	Normal	Oral	Adult patients	Each medical student had to perform 50 intubations before entering the study
12	Zhao H	2014	149 (74/75)	Airtraq/ Macintosh	I–II	Normal	Oral	Adult patients	Medical students had no prior experience with either Macintosh or Airtraq laryngoscope
13	Bakshi SG	2015	28 (14/14)	MacGrath/ Truview EVO2/ Macintosh	I–II	Normal	Oral	Adult patients	Group novice to intubation, included residents who had recently commenced training in anesthesia and had no prior experience in tracheal intubation
14	Liu ZJ	2016	177 (88/89)	MacGrath/ Macintosh	I–II	Normal	Oral	Adult patients	The intubations were performed by nine first-year trainee anesthetists who had just graduated from medical college. Before this study, they had been trained with high strength for 1–2 months and finished 10 to 30 tracheal intubations with Macintosh blade.
15	Kim KN	2018	220 (110/110)	AirwayScope/ Macintosh	I–II	Normal	Oral	Adult patients	Intern doctors who had no intubation experience before the study

ASA = American Society of Anesthesiologists; N/A = not available was 22.7% of the required sample size (n = 4,328) (ESM eFig. 5).

Intubation time was significantly shorter with an indirect laryngoscope than with a direct laryngoscope (WMD, −9.06 sec; 95% CI, −16.4 to −1.76; P = 0.02; Cochrane's Q = 508.3; I^2 = 98%; Fig. 4). The Z curve crossed the futility boundary. Trial sequential analysis revealed that the accrued information size (n = 1,990) was 76.5% of the estimated RIS (n = 2,600) (ESM eFig. 6).

Subgroup analysis

In addition, the indirect and direct laryngoscopy groups were classified and analyzed according to whether a tracheal tube guide was used. The subgroup analysis according to whether or not a tracheal tube guide was used found that successful intubation and glottic visualization rates were significantly better with both indirect laryngoscopes than with a direct laryngoscope (with tracheal tube guide, success rate: RR, 1.24; 95% CI, 1.06 to 1.44; $P < 0.006$; Cochrane's Q = 68.7, I^2 = 90%; glottic visualization: RR, 2.38; 95% CI, 1.59 to 3.57; $P < 0.001$; Cochrane's Q = 14.7; I^2 = 80%, without tracheal tube guide, success rate: RR, 1.11; 95% CI, 1.01 to 1.23; $P = 0.03$; Cochrane's Q = 61.5, $I^2 = 88\%$; glottic visualization: RR, 1.76; 95% CI, 1.36 to 2.28; $P < 0.001$; Cochrane's Q = 45.5; $I^2 = 85\%$) (Figs 2 and 3). Nevertheless, intubation time using an indirect laryngoscope with or without a tracheal tube guide was comparable to that using a direct laryngoscope (Fig. 4).

Adverse events

Adverse events during tracheal intubation were compared according to whether an indirect laryngoscope or direct laryngoscope was used. The incidence of all adverse events during tracheal intubation was significantly lower with an indirect laryngoscope (esophageal intubation: RR, 0.16; 95% CI, 0.04 to 0.61; P = 0.007; Cochrane's Q = 2.18; I^2 = 8%; oropharyngeal injury: RR, 0.42; 95% CI, 0.23 to 0.76; P = 0.004; Cochrane's Q = 2.50; I^2 = 0.0%; oxygen desaturation; RR, 0.51; 95% CI, 0.27 to 0.97; P = 0.04; Cochrane's Q = 0.08; I^2 = 0.0%; Table 2).

Quality of evidence

The quality of evidence for success rate, glottic visualization, and intubation time according to type of laryngoscope used by a novice operator was graded as "very low." All of the included studies were found to have a moderate risk of bias because the operator could not be blinded to the type of laryngoscope used. Heterogeneity was high for all parameters, and there was publication bias in terms of the success rate and glottic visualization rate. Accordingly, the quality of evidence was downgraded to "very low" (Fig. 5).

Results of publication bias

The Begg's test identified publication bias for success rate (Kendall's statistic = 50.0; Z = 1.85; P = 0.02) and glottic visualization (Kendall's statistic = 20.0; Z = 2.09; P = 0.06). No publication bias was found for intubation time (Kendall's statistic = −12.0; Z = 0.59; P = 0.4). Figure 6 summarizes the risks of bias.

Discussion

This systematic review and meta-analysis found that tracheal intubation success rate, glottic visualization, and intubation time were improved when a novice operator used an indirect laryngoscope rather than a direct laryngoscope. Use of an indirect laryngoscope by a novice also reduced the risk of adverse events, including esophageal intubation, oropharyngeal injury, and desaturation.

In general, direct laryngoscopy enables tracheal intubation by aligning the oral, pharyngeal, and laryngeal axes.[1,2] Nevertheless, indirect laryngoscopy can visualize the glottis without aligning them. Furthermore, use of an indirect laryngoscope allows the glottis to be confirmed in closer proximity by displaying the image obtained by the camera attached to the tip of the laryngoscope blade on an external monitor.[3,4] These advantageous features of indirect laryngoscopes are considered to make tracheal intubation easier, thereby contributing to successful tracheal intubation by novice operators.[27,38,39]

Another advantage of using indirect laryngoscopes for novice operators is that information on the condition of the upper respiratory tract and the area near the glottis can be shared with supervisors during tracheal intubation.[27,38,39] By sharing these images, the novice operator can receive appropriate advice and is thus more likely perform tracheal intubation successfully.

Novice operators can also learn to perform tracheal intubation more quickly using an indirect laryngoscope. Previous studies have also shown that the learning curve is less steep for an indirect laryngoscope than for a direct laryngoscope.[15,31,40,41] Most of the randomized controlled trials included in the present systematic review and meta-analysis incorporated practicing tracheal intubation using both indirect and direct laryngoscopes on mannequins before use in patients. It may be easier for novices to master tracheal intubation with fewer preclinical exercises when using an indirect laryngoscope.

Study or Subgroup	Indirect laryngoscope Events	Indirect laryngoscope Total	Direct laryngoscope Events	Direct laryngoscope Total	Weight	Risk Ratio IV, Random, 95% CI
1.1.1 With tracheal tube guide						
Ferrando C 2011	60	60	60	60	9.4%	1.00 [0.97, 1.03]
Di Marco P 2011	47	54	43	54	6.3%	1.09 [0.92, 1.30]
Zhao H 2014	54	74	50	75	5.3%	1.09 [0.89, 1.35]
Kim K.N 2018	104	110	89	110	8.1%	1.17 [1.06, 1.29]
Hirabayashi Y 2009	253	264	179	256	8.5%	1.37 [1.26, 1.49]
Park SJ 2010	32	37	19	37	3.2%	1.68 [1.20, 2.36]
de Oliveira GS 2011	12	15	6	15	1.1%	2.00 [1.02, 3.91]
de Oliveira GS 2011	11	15	2	15	0.3%	5.50 [1.46, 20.71]
Subtotal (95% CI)		**629**		**622**	**42.1%**	**1.24 [1.06, 1.44]**
Total events	573		448			
Heterogeneity: $Tau^2 = 0.03$; $Chi^2 = 68.65$, df = 7 (P < 0.00001); $I^2 = 90\%$						
Test for overall effect: Z = 2.74 (P = 0.006)						
1.1.2 Without tracheal tube guide						
Bakshi SG 2015	36	42	20	21	6.7%	0.90 [0.77, 1.05]
Liu ZJ 2016	80	88	84	89	8.5%	0.96 [0.89, 1.05]
Walker L 2009	60	60	60	60	9.4%	1.00 [0.97, 1.03]
Cattano D 2013	25	25	25	25	8.7%	1.00 [0.93, 1.08]
Bakshi SG 2015	41	42	20	21	7.9%	1.02 [0.92, 1.14]
Hirabayashi Y 2010	94	100	77	100	7.7%	1.22 [1.08, 1.37]
Peirovifar A 2014	16	20	12	20	2.3%	1.33 [0.88, 2.03]
Nouruzi-Sedeh 2009	93	100	51	100	5.6%	1.82 [1.49, 2.23]
Ayoub CM 2010	30	63	9	63	1.1%	3.33 [1.73, 6.44]
Subtotal (95% CI)		**540**		**499**	**57.9%**	**1.11 [1.01, 1.23]**
Total events	475		358			
Heterogeneity: $Tau^2 = 0.02$; $Chi^2 = 61.46$, df = 8 (P < 0.00001); $I^2 = 87\%$						
Test for overall effect: Z = 2.11 (P = 0.03)						
Total (95% CI)		**1169**		**1121**	**100.0%**	**1.15 [1.07, 1.24]**
Total events	1048		806			
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 134.19$, df = 16 (P < 0.00001); $I^2 = 88\%$						
Test for overall effect: Z = 3.72 (P = 0.0002)						
Test for subgroup differences: $Chi^2 = 1.26$, df = 1 (P = 0.26), $I^2 = 20.5\%$						

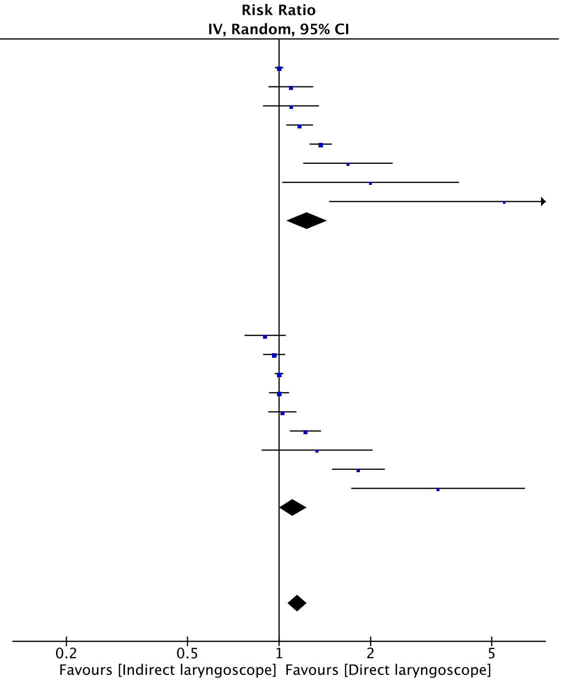

Fig. 2 Forest plot of the success rate of tracheal intubation using indirect laryngoscopy *versus* direct laryngoscopy

Study or Subgroup	Direct laryngoscope Events	Direct laryngoscope Total	Indirect laryngoscope Events	Indirect laryngoscope Total	Weight	Risk Ratio IV, Random, 95% CI
1.1.1 With tracheal tube guide						
Ferrando C 2011	56	60	34	60	14.4%	1.65 [1.31, 2.08]
Di Marco P 2011	47	54	25	54	13.3%	1.88 [1.39, 2.55]
Zhao H 2014	70	74	24	75	12.8%	2.96 [2.12, 4.13]
de Oliveira GS 2011	25	30	3	30	4.2%	8.33 [2.81, 24.67]
Subtotal (95% CI)		**218**		**219**	**44.6%**	**2.38 [1.59, 3.57]**
Total events	198		86			
Heterogeneity: $Tau^2 = 0.12$; $Chi^2 = 14.73$, df = 3 (P = 0.002); $I^2 = 80\%$						
Test for overall effect: Z = 4.19 (P < 0.0001)						
1.1.2 Without tracheal tube guide						
Cattano D 2013	18	25	17	25	12.3%	1.06 [0.74, 1.52]
Walker L 2009	55	60	47	60	15.4%	1.17 [1.00, 1.36]
Liu ZJ 2016	71	88	48	89	14.6%	1.50 [1.20, 1.86]
Nouruzi-Sedeh 2009	66	100	32	100	13.0%	2.06 [1.50, 2.84]
Subtotal (95% CI)		**273**		**274**	**55.4%**	**1.39 [1.08, 1.79]**
Total events	210		144			
Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 12.59$, df = 3 (P = 0.006); $I^2 = 76\%$						
Test for overall effect: Z = 2.56 (P = 0.01)						
Total (95% CI)		**491**		**493**	**100.0%**	**1.76 [1.36, 2.28]**
Total events	408		230			
Heterogeneity: $Tau^2 = 0.10$; $Chi^2 = 45.49$, df = 7 (P < 0.00001); $I^2 = 85\%$						
Test for overall effect: Z = 4.34 (P < 0.0001)						
Test for subgroup differences: $Chi^2 = 4.86$, df = 1 (P = 0.03), $I^2 = 79.4\%$						

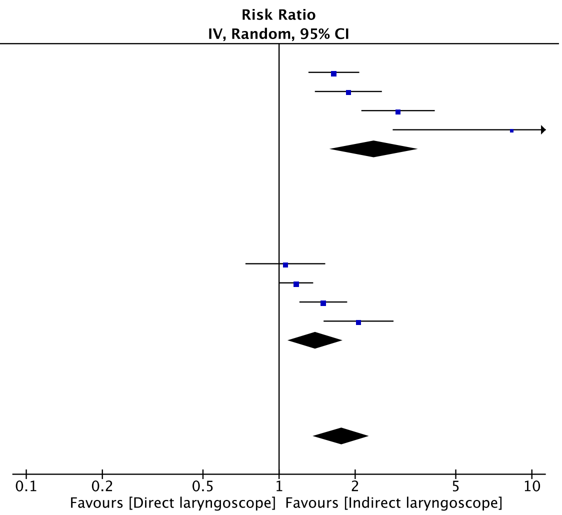

Fig. 3 Forest plot of glottic visualization with indirect laryngoscopy *versus* direct laryngoscopy (Cormack–Lehane grade 1 and 2 *vs* other grades)

The subgroup analysis showed that the success rate and glottis visualization were significantly better for both indirect laryngoscopes regardless of whether a tracheal tube guide was used, compared with direct laryngoscope. Furthermore, intubation time was not significantly different between indirect and direct laryngoscopes, regardless of whether a tracheal tube guide was used. This finding suggests that tracheal intubation can be performed successfully using an indirect laryngoscope with or without a tracheal tube guide. Nevertheless, intubation time also varies depending on whether an intubation aid such as a stylet or gum-elastic bougie was used during tracheal intubation.[42] In this systematic review and meta-analysis, we were unable to investigate the use of intubation aids, so we were unable to remove these biases. Further studies are warranted, as each study defined intubation time differently and the sample size was insufficient for analysis.

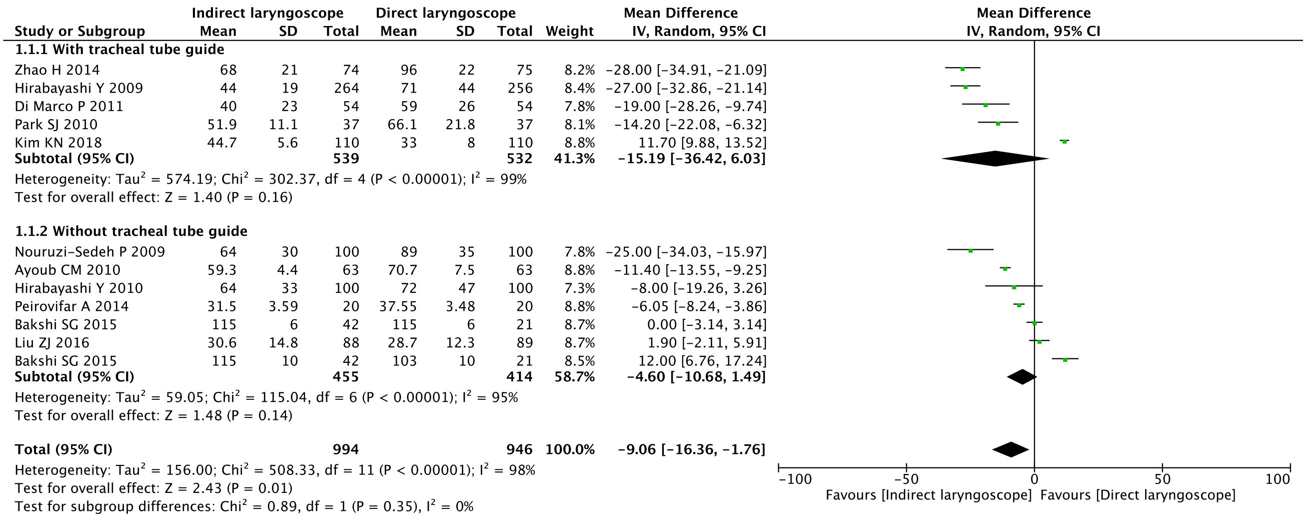

Fig. 4 Forest plot of intubation time for tracheal intubation using indirect laryngoscopy *versus* direct laryngoscopy

Table 2 Comparison of adverse events during tracheal intubation using indirect laryngoscopy *versus* direct laryngoscopy

	Number of trials	RR or WMD (95% CI)	*P* value	Cochrane's Q	I^2 statistic, %
Esophageal intubation	3	0.16 (0.04 to 0.61)	0.0007*	2.18	8
Oropharyngeal injury	5	0.42 (0.23 to 0.76)	0.004*	2.50	0.0
Desaturation	2	0.51 (0.27 to 0.97)	0.04*	0.08	0.0

*Significant difference

CI = confidence interval; N/A = not applicable; RR = relative risk; WMD = weighted mean difference

The incidence of adverse events was significantly lower when an indirect laryngoscope was used. The main reason for the reduced incidence of esophageal intubation with an indirect laryngoscope is that novice operators can share accurate information with their supervisor on a video screen and receive better guidance.[27,38,39]

A previous study found a higher incidence of adverse events, including soft tissue bleeding, oropharyngeal injury, and dental trauma, when video laryngoscopes were used.[13] Indirect laryngoscopes create visual and cognitive blind spots that can increase the risk of oropharyngeal injury.[14] Nevertheless, in our meta-analysis, the incidence of oropharyngeal injury was significantly lower when an indirect laryngoscope was used. Use of an indirect laryngoscope achieved successful tracheal intubation even if the pharyngeal lifting force of the laryngeal deployment was low.[43,44] This low pharyngeal lifting force helps to protect against oropharyngeal injury. Also, indirect laryngoscope blades made of polyethylene are softer and less sharp than a stainless steel blade of an direct laryngoscope. This indirect laryngoscope blade configuration also helps to reduce incidence of oropharyngeal injury. When intubated without a stylet with a videolaryngoscope and an angled blade (GlideScope, McGRATH, C-MAC), it may be difficult to pass the tube through the vocal cords despite a good glottic view.[42] On the other hand, the use of stylets contributes to oropharyngeal injury. This systematic review did not include studies that described the use of stylets, so we were unable to establish a clear relationship between stylet use and oropharyngeal injury. The shorter intubation time associated with use of an indirect laryngoscope may also decrease the risk of desaturation.

The results of our study show that indirect laryngoscopes are useful for tracheal intubation in novice operators. This result suggests the possibility of making tracheal intubation safer for residents and nonexperienced anesthesiologists, as well as making tracheal intubation safer for novice operators outside of operating rooms such as hospital wards and emergency departments.

Limitations

This systematic review and meta-analysis has several limitations. First, the type of laryngoscope used could not be blinded, which increased the risk of bias. Second, moderate to high heterogeneity was found in our results, which affected the study quality; however, subgroup

Summary of findings:

Indirect compared to Direct in Novice

Patient or population: Novice
Setting:
Intervention: Indirect
Comparison: Direct

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with Direct	Risk with Indirect				
Success rate	719 per 1,000	**827 per 1,000** (769 to 892)	**RR 1.15** (1.07 to 1.24)	2290 (18 RCTs)	⊕◯◯◯ Very low[a,b,c]	
Glottis visualisation	467 per 1,000	**821 per 1,000** (634 to 1,000)	**RR 1.76** (1.36 to 2.28)	984 (8 RCTs)	⊕◯◯◯ Very low[a,b,c,d]	
Intubation time		MD **9.06 second lower** (16.4 lower to 1.76 lower)	-	1940 (12 RCTs)	⊕◯◯◯ Very low[a,b]	

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **MD:** mean difference; **RR:** risk ratio

GRADE Working Group grades of evidence
High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.
Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.
Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

Explanations

a. There was no study with low risk of bias in the overall domain.
b. There was high heterogeneity in the over all effect.
c. Existence of a publication bias.
d. Number of samples included in this analysis is less than 2000.

Fig. 5 The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach

analyses were performed. Third, the definition of a novice operator was not consistent between the included trials. Most operators were residents, but were medical students in four trials. Fourth, RIS was not reached for some results in the TSA analysis. Therefore, analysis of the glottis visualization was underpowered. Also, a separate per geometry analysis of individual indirect laryngoscopes was not possible, and detailed data on the preoperative airway status of individual patients were not available. Furthermore, patient age and height, anesthesia method, and definition of intubation time varied across the trials, and these differences also affected the study quality.

Conclusion

In this systematic review and meta-analysis, we found that the tracheal intubation success rate, glottic visualization, and intubation time were improved when novice operators used an indirect laryngoscope rather than a direct laryngoscope. Moreover, the risk of adverse events, including esophageal intubation, oropharyngeal injury, and desaturation, was lower when novices used an indirect laryngoscope. Trial sequential analysis indicated that the sample size was sufficient for examining the success rate and intubation time.

Fig. 6 Green circles, red circles, and yellow circles indicate "low risk of bias," "high risk of bias," and "unclear risk of bias," respectively

Author	Year	Random sequence generation	Allocation concealment	Blind of participants and personnel	Blind of outcome assessmant	Incomplete outcome data	Selective reporting	Other potential threats to validity
Hirabayashi Y	2009	+	?	−	?	+	?	+
Nouruzi-Sedeh P	2009	+	+	−	?	+	?	+
Walker L	2009	+	+	−	+	+	?	+
Ayoub CM	2010	+	+	−	?	+	?	+
Hirabayashi Y	2010	+	?	−	?	+	?	+
Park SJ	2010	+	?	−	?	+	?	+
Di Marco PD	2011	+	?	−	?	+	?	+
de Oliveira GS	2011	+	?	−	?	+	+	+
Ferrando C	2011	+	?	−	?	+	?	+
Cattano D	2013	+	+	−	?	+	+	+
Peirovifar A	2014	+	+	−	?	+	?	+
Zhao H	2014	+	+	−	?	+	?	+
Bakshi SG	2015	+	+	−	?	+	+	+
Liu ZJ	2016	+	+	−	?	+	?	+
Kim KN	2018	+	+	−	?	+	+	+

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