Cervical spine movements during laryngoscopy and orotracheal intubation: a systematic review and meta-analysis

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ABSTRACT

Background Airway management is challenging in trauma patients because of the fear of worsening cervical spinal cord damage. Video-integrated and optic-integrated devices and intubation laryngeal mask airways have been proposed as alternatives to direct laryngoscopy with the Macintosh laryngoscope (MAC). We performed a meta-analysis to clarify which devices cause less cervical movement during airway management.

Methods We searched MEDLINE, Cochrane Central, Embase and LILACS from inception to January 2022. We selected randomised controlled trials comparing alternative devices with the MAC for cervical movement from C0 to C5 in adult patients, evaluated by radiological examination. Additionally, cervical spine immobilisation (CSI) techniques were evaluated. We used the Cochrane Risk of Bias Tool to evaluate the risk of bias, and the principles of the Grading of Recommendations, Assessment, Development, and Evaluations system to assess the quality of the body of evidence.

Results Twenty-one studies (530 patients) were included. Alternative devices caused statistically significantly less cervical movement than MAC during laryngoscopy with mean differences of −3.43 (95% CI −4.93 to −1.92) at C0–C1, −3.19 (−4.04 to −2.35) at C1–C2, −1.35 (−2.19 to −0.51) at C2–C3, and −2.61 (−3.62 to −1.60) at C3–C4; and during intubation: −3.60 (−5.08 to −2.12) at C0–C1, −2.38 (−3.17 to −1.58) at C1–C2, −1.20 (−2.09 to −0.31) at C2–C3. The Airtraq and the Intubation Laryngeal Mask Airway caused statistically significant less movement than MAC restricted to some cervical segments, as well as CSI. Heterogeneity was low to moderate in most results. The quality of the body of evidence was 'low' and 'very low'.

Conclusions Compared with the MAC, alternative devices caused less movement during laryngoscopy (C0–C4) and intubation (C0–C3). Due to the high risk of bias and the very low grade of evidence of the studies, further research is necessary to clarify the benefit of each device and to determine the efficacy of cervical immobilisation during airway management.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Patients with cervical diseases are at risk of worsening spinal cord damage during airway management.

⇒ The benefit of indirect laryngoscopy and intubation over the classic Macintosh laryngoscope in these patients is unclear.

WHAT THIS STUDY ADDS

⇒ This systematic review and meta-analysis of 21 randomised clinical trials (530 patients) found that, compared with the Macintosh, alternative devices as a group caused significantly less cervical movement in C0–C4 during laryngoscopy and in C0–C3 during intubation. Cervical immobilisation was used in a few trials and its benefit in reducing movement was observed at C0–C1 and C1–C2 only.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Video laryngoscopes and laryngeal mask airways promise to be of benefit in the trauma environment. Owing to the numerous available devices, more studies on this topic are required to determine the benefit of each device.

INTRODUCTION

Airway management poses challenges in treating trauma patients due to the fear of worsening any cervical spinal cord damage[1 2]; further, the cervical spine immobilisation (CSI) recommended for these patients can lead to complicated situations, such as hypoxaemia, hypotension and unsuccessful intubation.[3] Video-integrated and optic-integrated devices and intubation laryngeal mask airways operated by experienced technicians have been proposed as alternatives to direct laryngoscopy with the Macintosh laryngoscope (MAC) and as a rescue strategy in patients with difficult airways or trauma.[4 5] However, laryngeal exposure, time to intubation and number of attempts have been used as outcomes in most trials, instead of cervical spine (c-spine) movements evaluated by radiological examination. Typically, trials using X-ray and cine-fluoroscopy have a small number of patients due to ionising radiation. To date, there is no consensus on which device causes the least cervical movement during airway management.

Therefore, our objectives were to summarise the clinical evidence regarding the cervical movement caused by alternative devices used for laryngoscopy and endotracheal intubation (ETI) compared with MAC in adult patients based on radiological examinations; and to determine if there is an advantage in using these devices instead of MAC.

METHODS

This review adheres to the Preferred Reporting Items for Systematic Review and Meta-Analysis guidelines. We followed a pre-established protocol not registered on PROSPERO.

Eligibility criteria

Randomised controlled trials (RCTs) were eligible for inclusion if they involved an assessment of the angular movements of the c-spine by radiographic or cinefluoroscopy imaging in the sagittal plane during laryngoscopy and intubation with alternative devices in comparison with MAC. The outcome of interest was movement in each cervical segment measured in degrees (°). We excluded duplicates, trials on manikins, cadavers, and RCTs published in any other language apart from English, French, Spanish, or Portuguese.

Search strategy

Searches were performed using the electronic databases MEDLINE (via PubMed), Cochrane Central, Embase and LILACS. We also reviewed thesis banks (*Universidade de São Paulo* and *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* portal) and clinical trials registries (ClinicalTrials.gov and Brazilian Clinical Trials Registry) to search for non-published theses or ongoing trials. Bibliographies of the articles and book chapters were checked for references. The following search terms were used in combination with a list of synonyms: "intubation," "intratracheal intubation," "laryngoscope," "laryngoscopy" and "cervical vertebrae." No language restrictions were imposed at this stage (complete search strategies are provided as online supplemental appendix A). Searches were performed from inception to January 2022.

Study selection

Two reviewers (JBBC and VBF) screened the titles and abstracts yielded by the search strategy against the inclusion criteria independently and in duplicate, and independently screened the full-text reports and selected articles meeting the inclusion criteria. Disagreements were resolved by consensus. In case no agreement could be reached, a third author (GS) was consulted for arbitration.

Data extraction and statistical analysis

Data extraction is detailed in online supplemental appendix B. The following vertebral segments were analysed whenever available for laryngoscopy and intubation: C0–C1, C1–C2, C2–C3, C3–C4 and C4–C5. In original trials, the angles were measured from lines drawn by the authors on radiological images. The mean value, expressed as degree (°), and SD of the angles in each segment were extracted from the studies. As the lines drawn to obtain the angles were not identical across studies, we used the mean difference (MD) and its SD to compute the effect size with 95% CI. When a study did not report the SD, it was imputed through the formula suggested by the Cochrane Handbook, section 16.1.3.2. A correlation coefficient of 0.5 was arbitrarily chosen. Data expressed as median were assumed to be similar as mean, as the distribution of the cervical movement follows a normal distribution, and SD was calculated using the formula: SD=range/4. We conducted sensitivity analysis to assess the impact of excluding studies whose means were inferred from the medians. The analysis was performed using a random-effects model. An alpha value of 0.05 was considered statistically significant. The statistical heterogeneity of the treatment effect among the studies was assessed using the inconsistency test (I^2 statistic).

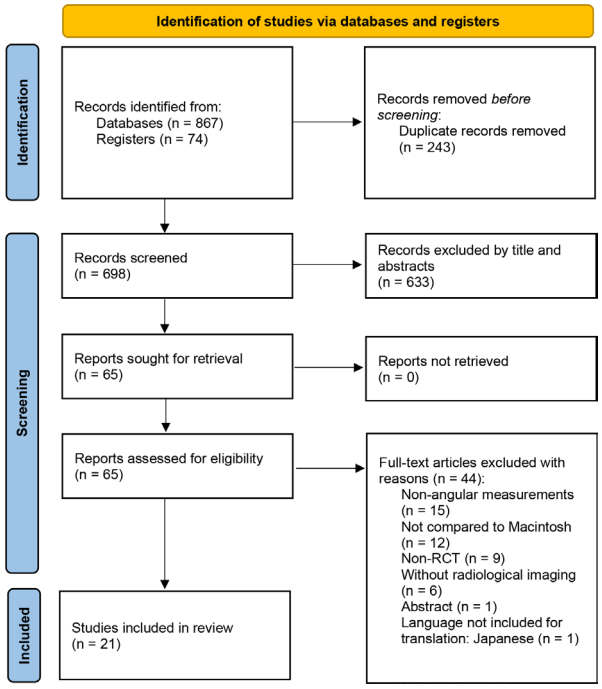

Figure 1 PRISMA study flow diagram. Page MJ, McKenzie JE, Bossuyt PM *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71. PRISMA, Preferred Reporting Items for Systematic Review and Meta-Analysis; RCT, randomised controlled trial.

All analyses were performed using the Review Manager V.5.3 program (The Cochrane Collaboration, Oxford, UK).

Risk of bias assessment

We performed a risk of bias assessment using the 'Cochrane Risk of Bias' tool.[6] The methodological quality of the included articles was independently assessed by two reviewers.

Subgroup analysis

The first comparison was between the groups 'alternative devices' versus MAC. If there were >2 RCTs for a specific device, a subgroup analysis was performed. Immobilisation techniques for the c-spine were also explored by a subgroup analysis as 'with CSI'. Trials involving a comparison among three devices were divided into two for analysis (each device vs MAC). The actual number of patients in each arm was recorded, not to overestimate the power of the study.

We used the principles of the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) system to assess the quality of the body of evidence. A summary table was constructed with the GRADEpro guideline development tool.

Patient and public involvement

There was no involvement of patients or the public at any phase of this research.

RESULTS

The search yielded 941 potentially relevant publications. We included 21 trials with the data of 530 patients (figure 1). MAC and 15 other devices were investigated (Airtraq; Airway Scope; Bullard; C-MAC D-blade; Fiberscope Karl Storz; Flexiblade; Fogarty catheter+MAC; Glidescope; Intubation Laryngeal Mask Airway (ILMA) Fastrach, ILMA CTrach; King Vision; McCoy;

Table 1 Characteristics of included trials

Citation by author, year, in alphabetical order	Devices used (and number of patients)	Laryngoscopy and/or intubation	Cervical immobilisation and technique used	ASA*	Mallampati Class (1–4)	Limited to patients without signs of difficult intubation	BMI (kg/m^2) or weight (kg±SD or superior and inferior limits)	Level of experience of the laryngos-copist	General anaesthesia at the operating theatre
Bhardwaj *et al*,[16] 2013	MAC (25) and Truview (25)	Laryngoscopy	No	I	Not described	Yes	BMI ≤30	Not reported	Yes
El-Tahan *et al*,[18] 2017	MAC (29) and King Vision (29)	Laryngoscopy	No	I–II	1–2	Yes	BMI ≤35	Experienced anaesthetist	Yes
Erden *et al*,[24] 2010	MAC (16) and ATQ (17)	Laryngoscopy and intubation	No	I–II	1–2–3	Yes	Weight: 70.5±10.4	Not equally trained	Yes
Hindman *et al*,[17] 2014	MAC (14) and ATQ (14)	Laryngoscopy and intubation	No	I–II	1–2	Yes	BMI ≤30	Experienced anaesthetist	Yes
Hirabayashi *et al*,[10] 2007	MAC (20) and AWS (20)	Laryngoscopy	No	I–II	Not described	Yes	BMI ≤30	Not reported	Yes
Hirabayashi *et al*,[13] 2008	MAC (20) and ATQ (20)	Laryngoscopy	No	I–II	Not described	Yes	BMI ≤30	Not reported	Yes
Hirabayashi *et al*,[15] 2010	MAC (20) and Glidescope (20)	Laryngoscopy	No	I–II	Not described	Yes	BMI ≤30	Not reported	Yes
Inan *et al*,[22] 2019	MAC (20) ILMA Fastrach (20) ILMA CTrach (20)	Intubation	No	I–III	1–2–3	Yes	BMI ≤35	Experienced anaesthetist	Yes
Khedr *et al*,[27] 2016	MAC (20) and ILMA (20)	Laryngoscopy and intubation	Not described	I–II	Not described	Yes	BMI ≤30	Not reported	Yes
Laosuwan *et al*,[26] 2015	MAC (11) and McGrath S5 (11)	Laryngoscopy and intubation	Immobilisation with tapes	I–II	1–2	Yes	BMI ≤30	Experienced anaesthetist	Yes
LeGrand *et al*,[11] 2007	MAC (11) and Miller (11)	Intubation	No	I–II	Not described	Not described	BMI=26.1±5.2	Experienced anaesthetist	Yes
MacIntyre *et al*,[8] 1999	MAC (10) and McCoy (10)	Laryngoscopy	Rigid cervical collar	I–II	Not described	Yes	Not described	Experienced anaesthetist	Yes
Maruyama *et al*,[21] 2008†	MAC (12) and AWS (12) and McCoy (13)	Laryngoscopy and intubation	No	I–II	1–2	Yes	Weight MAC: 56.5±13.6 AWS: 58.0±6.5 McCoy: 56.8±7.4	Not reported	Yes
Maruyama *et al*,[12] 2008‡	MAC (11) and AWS (11)	Laryngoscopy and intubation	Universal head immobiliser (Velcro and bags)	I–II	1–2	Yes	Weight: 55.0 (41.0–75.0)	Not reported	Yes
Mentzelopoulos *et al*,[9] 2001	MAC (8) and MAC+Fogarty (8)	Intubation	No	'Healthy volunteers'	Not described	Yes	'Non-obese'	Experienced anaesthetist	Yes
Paik and Park,[19] 2020	MAC (20) and C-MAC D-blade (20)	Intubation	Philadelphia collar	–	1–2–3	Yes	BMI ≤30	Experienced anaesthetist	Yes
Sahin *et al*,[20] 2004	MAC (11) and ILMA (11) and FOB (9)	Laryngoscopy and intubation	No	I–II	1–2–3	Yes	Weight: MAC: 71.0±9.2 ILMA: 69.8±12.1 FOB: 67.8±15.9	Experienced anaesthetist	Yes
Turkstra *et al*,[14] 2009	MAC (24) and ATQ (24)	Laryngoscopy	MILS	I–III	1–2	Yes	BMI ≤28	Experienced anaesthetist	Yes
Uzun *et al*,[25] 2010	MAC (16) and Flexiblade (16)	Laryngoscopy and intubation	No	I–II	1–2–3	Yes	Weight: MAC: 75.0±13.0 Flexiblade: 75±15	Experienced anaesthetist	Yes
Waltl *et al*,[23] 2001	MAC (20) and ILMA (20)	Laryngoscopy and intubation	No	I–II	1–2	Yes	77.0±15.0	Trained anaesthesia residents	Yes
Watts *et al*,[7] 1997	MAC (12) and Bullard (12)	Laryngoscopy	With MILS and without MILS	I–III	1	Yes	79.0±11.0	Not reported	Yes

*ASA physical status class.
†Maruyama *et al*: *Br J Anaesth* 2008;100:120-4.
‡Maruyama *et al*: *Br J Anaesth* 2008;101:563-7.
ASA, American Society of Anesthesiologists; ATQ, Airtraq; AWS, airway scope; BMI, body mass index; FOB, Fiberscope Karl Storz; ILMA, intubation laryngeal mask airway; MAC, Macintosh laryngoscope; MILS, manual in-line stabilisation.

McGrath series 5; Miller and Truview). Patient and study characteristics are presented in table 1. Details regarding the trials that were read in full and excluded along with the reasons are presented as online supplemental appendix C.

Thirteen of 21 trials had a randomised crossover design.[7–19] One four-arm crossover trial involved a comparison between Bullard and MAC with and without manual in-line stabilisation (MILS),[7] and three trials involved a comparison of three devices.[20–22] Data were presented for laryngoscopy only in 8 trials,[7 8 10 13–16 18] laryngoscopy and ETI in 10[11 12 17 20 21 23–27] and ETI only in 3.[9 19 22] Regarding immobilisation techniques, MILS was used in two trials,[7 14] medical tapes and/or Velcro in two,[12 26] cervical collar in two[8 19] and not reported in one.[27] All patients were adults, with low risk of difficult airway, submitted to general anaesthesia in the operation theatre. Three trials included patients who underwent spine surgery, but all were free from myelopathic symptoms and instability.[20 22 27]

The results remained statistically significant after removing the studies whose means were inferred from the medians.

Risk of bias

Most studies were judged to have a 'low' risk of bias in 'random sequence generation', 'blinding of outcome assessment', 'incomplete outcome data' and 'selective reporting'. The method used to conceal the allocation sequence was not mentioned in most studies; these studies were judged to be at 'high' risk of bias. 'Other bias' included the analysis for the carryover effect,

performed in only 3 of the 13 trials with a randomised crossover design, judged to be at 'low' risk of bias; the other 10 trials were judged to be at 'high' risk. The anaesthesiologists' experience with the experimental devices was included as a 'new item' and judged to be at 'low risk' of bias in half of the studies. Risk of bias graph and summary are shown in figure 2.

The quality of the body of evidence evaluated by the GRADE system was 'low' and 'very low' in most of the analyses. The main results are presented in online supplemental appendix D.

Effects of interventions on angular movements

Laryngoscopy

C0–C1

This segment was studied in 10 trials.[7 8 10 12–18] 'Alternative devices' caused statistically significant less cervical movement than MAC (MD of −3.43 (95% CI −4.93 to –1.92), I^2=69%) (forest plot as online supplemental appendix E).

Three trials studied the Airtraq[13 14 17] and a subgroup analysis revealed that this device caused less movement than MAC (MD of −3.56 (95% CI −6.12 to –1.01), I^2=44%).

Four trials used CSI,[7 8 12 14] and these manoeuvres caused less cervical movement for 'alternative devices' compared with MAC (MD of −2.90 (95% CI −5.27 to –0.53), I^2=67%).

C1–C2

This segment was studied in 15 trials (figure 3 and online supplemental appendix F).[7 8 10 12–18 20 23–25 27] 'Alternative devices' caused less cervical movement than MAC (MD of −3.19 (95% CI −4.04 to –2.35), I^2=36%).

ILMA was studied in three trials,[20 23 27] and Airtraq in four trials.[13 14 17 24] Both devices caused less movement than MAC (MD of −6.48 (95% CI −8.60 to –4.35), I^2=0%, and −1.63 (95% CI −3.09 to –0.17), I^2=0%, respectively).

Three trials used CSI[7 8 12]; these manoeuvres caused less cervical movement for 'alternative devices' than with MAC (MD of −2.36 (95% CI −4.47 to –0.26), I^2=55%).

C2–C3

This segment was studied in 13 trials (figure 4 and online supplemental appendix G).[8 10 12 13 15–18 20 23–25 27] 'Alternative devices' caused less cervical movement than MAC (MD of −1.35 (95% CI −2.19 to –0.51), I^2=21%).

ILMA was studied in three trials[20 23 27] and caused less movement than MAC (MD of −4.48 (95% CI −6.37 to –2.58), I^2=0%); Airtraq was studied in three trials,[13 17 24] revealing no statistically significant differences relative to MAC (MD of −1.22 (95% CI −2.53 to 0.08), I^2=0%).

C3–C4

This segment was studied in eight trials[8 10 12 13 15–18] (forest plot as online supplemental appendix H); 'alternative devices' caused less cervical movement than MAC (MD of −2.61 (95% CI −3.62 to –1.60), I^2=33%).

Intubation

C0–C1

This segment was studied in six trials[9 11 12 17 19 26] (forest plot as online supplemental appendix I). 'Alternative devices' caused less cervical movement than MAC (MD of −3.60 (95% CI −5.08 to –2.12), I^2=0%).

Three trials[12 19 26] used CSI; less movement was observed for 'alternative devices' compared with the MAC (MD of −4.10 (95% CI −6.15 to –2.06), I^2=26%).

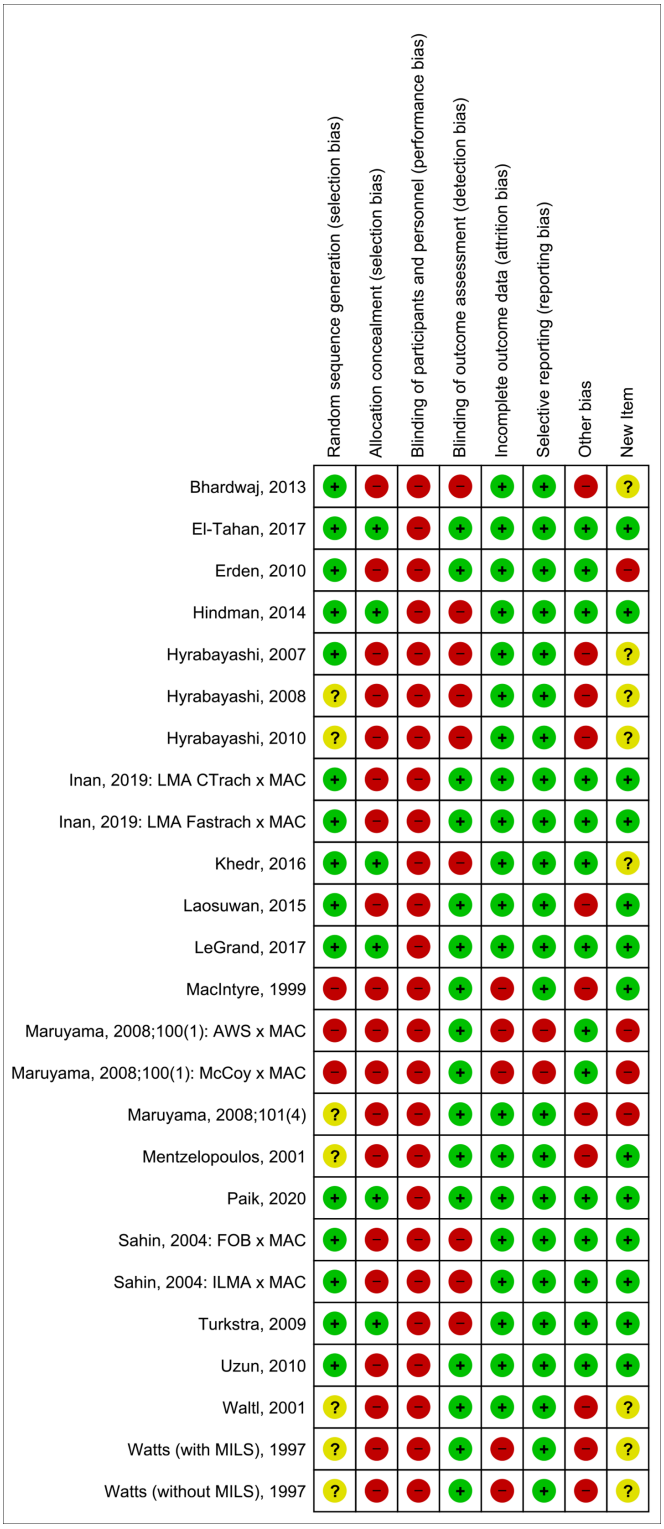

Figure 2 Risk of bias summary and graph: review authors' judgements about each risk of bias item for each included study. AWS, airway scope; FOB, Fiberscope Karl Storz; ILMA, intubation laryngeal mask airway; MAC, Macintosh laryngoscope; MILS, manual in-line stabilisation.

C1–C2

This segment was studied in 13 trials[9 11 12 17 19–27] (figure 3 and online supplemental appendix J). 'Alternative devices' caused less cervical movement than MAC (MD of −2.38 (95% CI −3.17 to –1.58), I^2=0%).

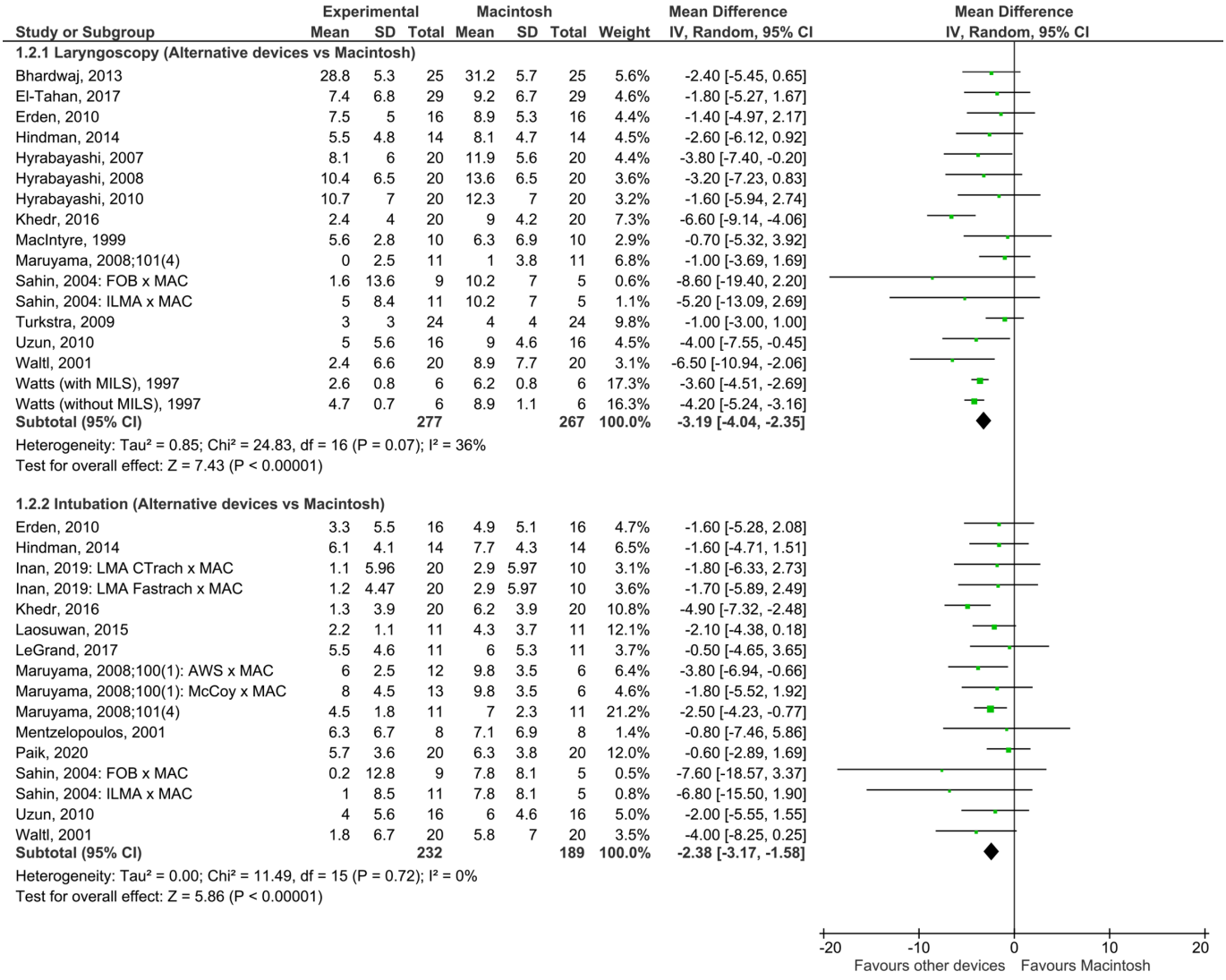

Figure 3 Forest plot for cervical movement at C1–C2 during laryngoscopy and intubation: alternative devices versus Macintosh. Mean difference in degrees (°) and 95% CI. AWS, airway scope; FOB, Fiberscope Karl Storz; ILMA, intubation laryngeal mask airway; MAC, Macintosh laryngoscope; MILS, manual in-line stabilisation.

ILMA was studied in four trials[20 22 23 27] causing less movement than MAC (MD of −4.20 (95% CI −6.04 to –2.37), I^2=0%).

Three trials[12 19 26] involved CSI; a statistically significant difference was observed between 'alternative devices' and MAC (MD of −1.86 (95% CI −3.07 to –0.71), I^2=0%).

C2–C3

This segment was studied in 11 trials[9 11 12 17 20 22–27] (figure 4 and online supplemental appendix K); less cervical movement was observed with 'alternative devices' compared with MAC (MD of −1.20 (95% CI −2.09 to –0.31), I^2=0%).

A subgroup analysis of ILMA (four trials)[20 22 23 27] revealed no statistically significant differences compared with MAC (MD of −1.19 (95% CI −3.07 to 0.68), I^2=0%).

C3–C4

This segment was studied in six trials[9 11 12 17 21 26] (forest plot as online supplemental appendix L); no statistically significant difference was observed between 'alternative devices' and MAC (MD of −1.09 (95% CI −2.84 to 0.66), I^2=59%).

C4–C5

This segment was studied in three trials[9 11 17] (forest plot as online supplemental appendix M); no statistically significant difference was observed between 'alternative devices' and MAC (MD of −1.00 (95% CI −2.83 to 0.84), I^2=0%).

'Alternative devices without CSI' was analysed as a subgroup for laryngoscopy and intubation to exclude the effect of the immobilisation techniques on the main group. As only a minority of the trials used CSI, the results were similar to those of 'alternative devices' main group and are presented in table 2.

DISCUSSION

The main finding of the present systematic review and meta-analysis is that during laryngoscopy, the 'alternative devices' group caused less cervical movement than the MAC group from C0 to C4. During intubation, the benefits in terms of reduced cervical movement were limited to segments C0–C3. Cervical immobilisation was used in some trials and its benefit in reducing movement was observed at C0–C1 and C1–C2 during laryngoscopy and during intubation.

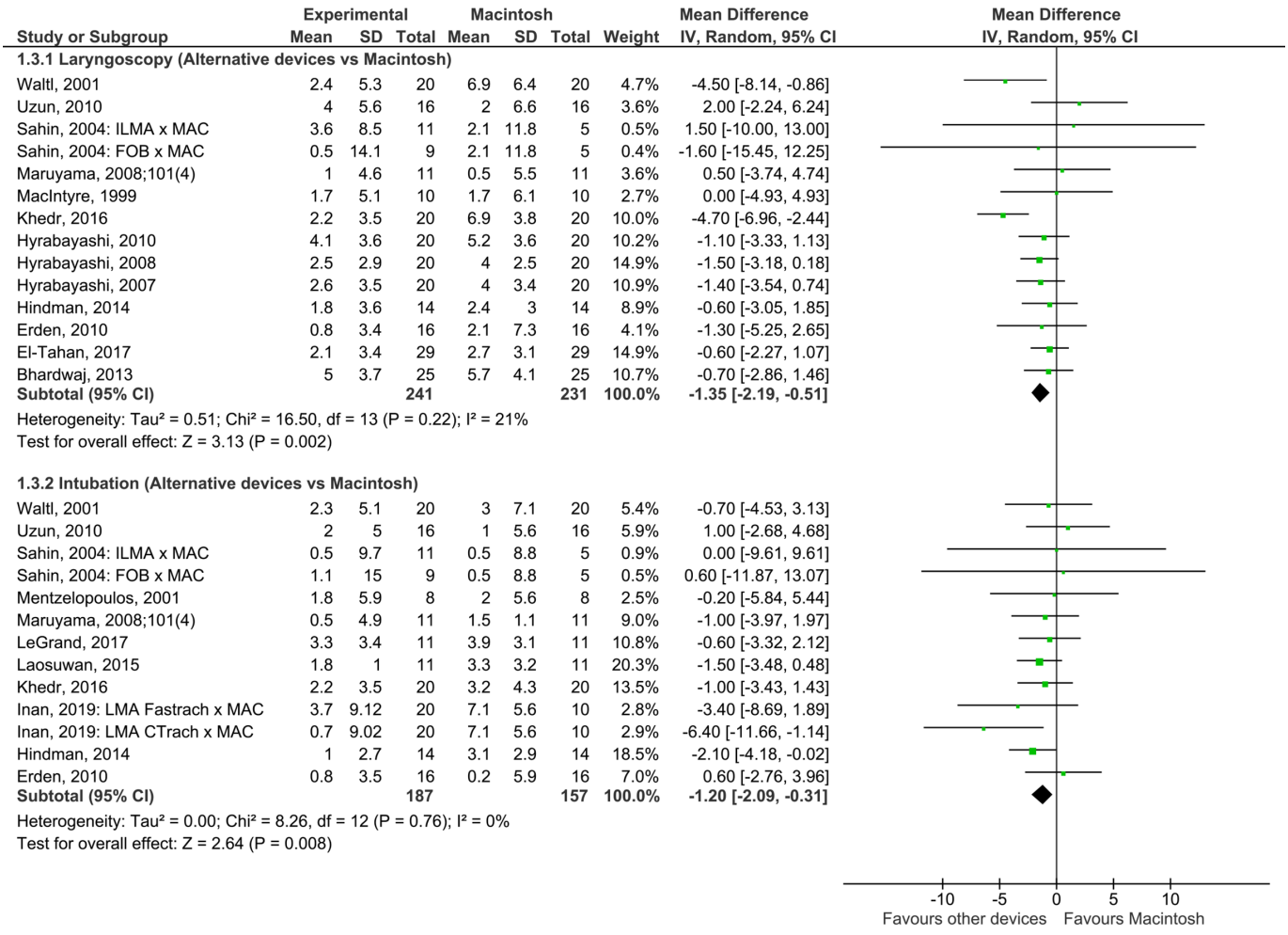

Figure 4 Forest plot for cervical movement at C2–C3 during laryngoscopy and intubation: alternative devices versus Macintosh. Mean difference in degrees (°) and 95% CI. FOB, Fiberscope Karl Storz; ILMA, intubation laryngeal mask airway; MAC, Macintosh laryngoscope.

Only Airtraq and ILMA were investigated in >2 trials. Airtraq caused less cervical movement than MAC at C0–C1, C1–C2, and C3–C4 during laryngoscopy and only at C1–C2 during intubation. ILMA was studied only at C1–C2–C3 and caused less cervical movement than MAC at C1–C2 and C2–C3 during insertion, the period equivalent to laryngoscopy. During the

Table 2 Meta-analyses results for 'alternative devices without CSI' subgroups during laryngoscopy and intubation, from C0 to C5

Moment of airway management	Cervical segment	Number of studies, comparisons and references	Number of patients	Mean difference IV, random, 95% CI
Laryngoscopy				
	C0–C1	7 studies[7 10 13 15–18]	268	−3.73 (−5.61 to 1.85); I^2=64%
	C1–C2	13 studies; 14 comparisons[7 10 13–18 20 23–25 27]	490	−3.39 (−4.44 to 2.33); I^2=35%
	C2–C3	11 studies; 12 comparisons[10 13 15–18 20 23–25 27]	430	−1.46 (−2.38 to 0.55); I^2=29%
	C3–C4	6 studies[10 13 15–18]	256	−2.75 (−3.89 to 1.61); I^2=46%
Intubation				
	C0–C1	3 studies[9 11 17]	66	−2.34 (−5.13 to 0.45); I^2=0%
	C1–C2	10 studies; 13 comparisons[9 11 17 20 22–27]	337	−2.78 (−3.85 to 1.70); I^2=0%
	C2–C3	10 studies; 12 comparisons[9 11 17 20 22–27]	322	−1.22 (−2.16 to 0.29); I^2=0%
	C3–C4	5 studies; 6 comparisons[9 11 17 21 26]	125	−0.86 (−2.85 to 1.13); I^2=65%
	C4–C5	3 studies[9 11 17]	66	−1.00 (−2.83 to 0.84); I^2=0%

The outcomes are presented as mean difference and 95% CI.
CSI, cervical spine immobilisation; I^2, heterogeneity.

tube passage through its lumen, the intubation phase, there was less cervical movement only at C1–C2. We expected to find a more robust difference between video laryngoscopes and MAC. The indirect visualisation of the glottis while applying less force leads to the expectation of less cervical movement. However, as shown by Hindman *et al*,[26] less force does not necessarily imply less movement. It is possible that cervical movement results from the tube passage itself, as demonstrated by Sawin *et al*,[28] and differences in efficacy between devices may reflect differences in their geometry and usage. Unfortunately, the limited number of trials with each device greatly limits the relevance of each device for the analysis.

Historically, investigation of cervical movement using cine-fluoroscopy or X-ray is limited by ethical constraints and all evidence has been generated by studies in uninjured volunteers, cadaveric models, case series and years of cumulative experience. We believe that, except for the trials not compared with the MAC, all others were included in our meta-analysis. To date, there are no similar meta-analyses on cervical motion assessed by radiological examination for comparison. Suppan *et al*[4] used successful first-time intubation as outcome during cervical immobilisation and found superiority for Airtraq, and Singleton *et al*[29] found that McGrath, C-MAC D-blade, Airtraq, King Vision and C-MAC significantly improved first-pass success for subjects with cervical immobilisation and increased the probability of a Cormack-Lehane grade 1 of laryngeal view.

Although the term 'spinal motion restriction' has gained favour over 'spinal immobilisation', both refer to the same concept. As all studies in this systematic review and meta-analysis used c-spine immobilisation, we maintained consistency by using this term to avoid confusion. This standard of care for trauma patients has no solid scientific basis, as demonstrated by a systematic review by Cochrane Collaboration.[30] However, the lack of advantages identified in our meta-analysis regarding CSI in most cervical segments could be due to the small number of trials in which protective manoeuvres were performed, considerably limiting the scope of the present results.

All trials involved patients free of myelopathic symptoms; therefore, the results must be interpreted with caution in patients with cervical instability, and it is difficult to extrapolate these data to injured patients with potential spinal cord damage.

There are other limitations to our meta-analysis. Moderate and high heterogeneity was observed in some analyses. As the devices themselves and the use of CSI manoeuvres were supposed to be the main sources of the heterogeneity, subgroup analyses were planned whenever possible. Other potential reasons for the heterogeneity may involve differences in anaesthesiologists' experience. This may have skewed the results in favour of the most extensively used equipment, the MAC laryngoscope.

All trials involved controlled scenarios with the patients under general anaesthesia at the operating theatre. Prehospital attendance, ED and intensive care unit admittance were not explored, and extrapolating the results to these patients may not be possible.

The quality of the body of evidence evaluated by the GRADE system was 'low' and 'very low' in most analyses. Our results highlight the general low quality of evidence and the necessity for larger trials to evaluate the cervical movement during laryngoscopy and intubation.

CONCLUSIONS

In this meta-analysis of randomised studies with anaesthetised patients without myelopathic symptoms and no history of recent trauma, laryngoscopy with 'alternative devices' resulted in less cervical angular movement than the MAC group from C0 to C4. During intubation, the benefits in terms of reduced cervical angular movement were limited to C0–C3. Cervical immobilisation techniques were used in some trials and their benefit in reducing movement was observed at C0–C1 and C1–C2 during laryngoscopy and during intubation. Airtraq and ILMA also determined less cervical angular movement in a few cervical segments. The grade of recommendation for using these devices to minimise movement of the c-spine during airway management is 'low' to 'very low'.

Owing to the number of available devices, more studies are required on this topic, preferably with patients in the neutral position and with the use of immobilisation manoeuvres, as recommended by trauma care guidelines.

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Patient consent for publication Not required.

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Provenance and peer review Not commissioned; externally peer reviewed.

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Supplemental material, Appendix A: Complete search strategy applied to MEDLINE and other databases.

MEDLINE (via PubMed).

#1	"Intubation" [MeSH] OR "Intubations" OR "Intubation, Intratracheal" [MeSH] OR "Intratracheal Intubation" OR "Intratracheal Intubations" OR "Intubations, Intratracheal", OR "Intubation, Endotracheal" OR "Intubations, Endotracheal" OR "Endotracheal Intubations" OR "Tracheal Intubation"
#2	"Laryngoscopy" [MeSH] OR "Laryngoscopes" [MeSH] OR "Laryngoscope" OR "Laryngoscopies" OR "Videolaryngoscopy" OR "Videolaryngoscope"
#3	"Cervical Vertebrae" [MeSH] OR "Upper Cervical spine movement" OR "Upper cervical Spine" OR "Cervical Spine" OR "Cervical Spine Motion" OR "Cervical Spine Movement" OR "Cervical Spine Movements" OR "Cervical Movements"
#4	#1 AND #2 AND #3

EMBASE	'intubation'/exp OR 'intubation' OR 'endotracheal intubation'/exp OR 'endotracheal intubation' OR 'intratracheal intubation' OR 'intubation, endotracheal' OR 'intubation, intratracheal' OR 'intubation, orotracheal' OR 'intubation, trachea' OR 'orotracheal intubation' OR 'trachea intubation' OR 'tracheal intubation' AND ('laryngoscopy'/exp OR 'fiberoptic laryngoscopy' OR 'indirect laryngoscopy' OR 'laryngoscopy' OR 'laryngoscopy, fiberoptic' OR 'laryngoscope' OR 'laryngoscope'/exp OR

	'laryngoscope' OR 'laryngoscope, device (physical object)' OR 'laryngoscope, endoscope' OR 'laryngoscope, nasopharyngoscope' OR 'laryngoscopes') AND ('cervical vertebra'/exp OR 'c vertebra' OR 'c vertebrae' OR 'cervical lower vertebra' OR 'cervical vertebra' OR 'cervical vertebrae' OR 'upper cervical spine movement' OR 'upper cervical spine' OR 'cervical spine'/exp OR 'cervical spine motion' OR 'cervical spine movement' OR 'cervical spine movements' OR 'cervical movements')
LILACS	"Intubação" AND "Laringoscópio"
Cochrane Library/Central	MeSH descriptor: [Intubation] explode all trees; MeSH descriptor: [Intubation, Intratracheal] explode all trees; MeSH descriptor: [Laryngoscopy] explode all trees; MeSH descriptor: [Laryngoscopes] explode all trees; MeSH descriptor: [Cervical Vertebrae] explode all trees
Digital library of theses and dissertations of São Paulo University (USP)	Simple search applied to all documents, without date of publication restrictions: "Laringoscópio" AND "intubação"
Catalog of theses and dissertations of CAPES Portal	Intuba* AND laringoscop* AND (cervical OR vertebr* OR angul*)

ClinicalTrials.gov	Filter applied for adult patients, laryngoscopy AND intubation AND cervical spine.
Brazilian Clinical Trials Registry	Simple search applied to all documents: “Laringoscópio” AND “intubação”

Data extraction

Data were extracted independently using a standardised data protocol. One author (JC) extracted all relevant information from the reports and entered it into an electronic data sheet. Extracted data were cross-checked by a second author (VF). Disagreements were resolved by consensus. In case no agreement could be reached, a third author (GS) was consulted for arbitration.

According to the inclusion criteria for study selection, only those providing the data in angles were included. Raw angular data, provided in degrees (°), were extracted from studies corresponding to tree different moments of airway management, whenever available: T1 = image captured immediately before airway management; T2 = image captured during laryngoscopy; and T3 = image captured in the intubation or post-intubation phase. Studies that evaluated laryngoscopy only provided data for T1 and T2, studies that evaluated intubation only provided data for T1 and T3, and those that evaluated laryngoscopy and intubation provided data for the three times, T1, T2 and T3. Whenever available, data was collected for five cervical segments (C0-C1, C1-C2, C2-C3, C3-C4 and C4-C5). Information on grouped segments like C2-C5 or C5-Th, was not collected, as there were only a few trials that used them and the c-spine movement analysis for each individual level provides more valuable information.

Supplemental material, Appendix C: Studies excluded at the full text review process (by author, in alphabetical order, with references).

Author and date	Reason for exclusion	Details
Agrawal, 2018 [1]	Intervention	Not compared to MAC
Agrawal, 2021 [2]	Intervention	Not compared to MAC
Aoi YG, 2011 [3]	Intervention	Type of immobilization
Aziz M, 2013 [4]	Design	Review study
Bharadwaj A, 2016 [5]	Intervention	Not compared to MAC
Bilgin H, 2006 [6]	Outcome	Data in non-angular measurements
Brück S, 2015 [7]	Outcome	Data in non-angular measurements
Carley S, 2000 [8]	Design	Case report
Chou HC, 1993 [9]	Outcome	Data in non-angular measurements
Cohn AI, 1995 [10]	Outcome	Data in non-angular measurements
Eldeyasty BK, 2017 [11]	Abstract	Only as abstract
Fan H, 2017 [12]	Intervention	Not compared to MAC
Fitzgerald RD, 1994 [13]	Design	Non-randomized
Gajraj NM, 1994 [14]	Outcome	Data in non-angular measurements
Gercek EBM, 2008 [15]	Methodology	Without radiological imaging (ultrasound)
Gotou M, 2007 [16]	Design	Case report
Hastings RH, 1994 [17]	Methodology	Without radiological imaging
Hastings RH,1995 [18]	Outcome	Data in non-angular measurements
Horton WA, 1990 [19]	Outcome	Data in non-angular measurements
Hyuga S, 2012 [20]	Design	Case report

Author and date	Reason for exclusion	Details
Ilyas S, 2014 [21]	Outcome	Data in non-angular measurements
Kill C, 2013 [22]	Methodology	Without radiological imaging (video)
Kim TK, 2011 [23]	Outcome	Data in non-angular measurements
Kim TK, 2017 [24]	Intervention	Not compared to MAC
Komatsu R, 2008 [25]	Methodology	Without radiological imaging
Konishi AT, 1997 [26]	Language	Japanese
Kovitwanawong N, 2016 [27]	Intervention	Not compared to MAC
Langeron O, 1992 [28]	Methodology	Without radiological imaging
Mahmoudpour, 2007 [29]	Intervention	Not compared to MAC
Majernick TG, 1986 [30]	Outcome	Data in non-angular measurements
Nam K, 2018 [31]	Intervention	Not compared to MAC
Robitaille A, 2008 [32]	Outcome	Data in non-angular measurements
Rudolph C, 2005 [33]	Design	Not randomised
Sahin T, 2018 [34]	Design	Not randomised
Shippey B, 2013 [35]	Outcome	No spine movement
Sawin PD, 1996 [36]	Design	Cohort study
Swain A, 2015 [37]	Intervention	Not compared to MAC
Takenaka I, 2009 [38]	Intervention	Not compared to MAC
Tamu DP, 2021 [39]	Design	Congress abstract (no data available)
Turkstra TP, 2005 [40]	Outcome	Data in non-angular measurements
Turkstra TP, 2007 [41]	Outcome	Data in non-angular measurements

Author and date	Reason for exclusion	Details
Wahlen BM, 2004 [42]	Methodology	Without radiological imaging
Wong DM, 2009 [43]	Intervention	Not compared to MAC
Wu C-N, 2015 [44]	Outcome	Data in non-angular measurements

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Author(s):
Question: Alternative devices compared to Macintosh for laryngoscopy and intubation of patients at risk for spinal cord damage during airway management
Setting: cervical disease or trauma
Bibliography: . [Intervention] for [health problem]. Cochrane Database of Systematic Reviews [Year], Issue [Issue].

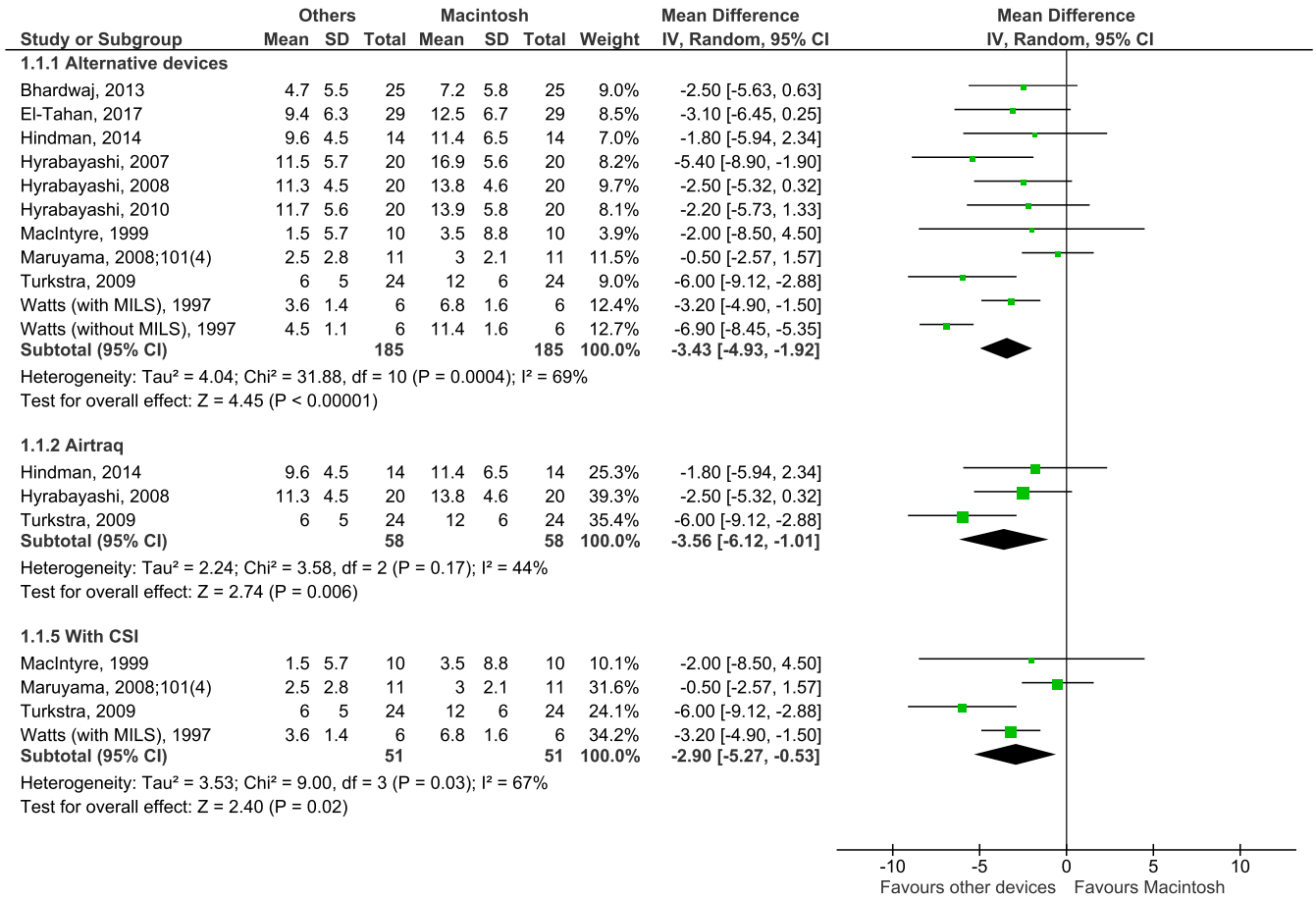
Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Alternative devices	Macintosh	Relative (95% CI)	Absolute (95% CI)		
C0-C1 (Laryngoscopy) - Alternative devices												
11	randomised trials	very serious[a,b,c,d,e,f]	very serious[g,h]	serious[i]	serious[j]	none	185	185	-	MD **3.39 lower** (4.87 lower to 1.9 lower)	⨁◯◯◯ Very low	CRITICAL
C0-C1 (Laryngoscopy) - Airtraq												
3	randomised trials	very serious[b,c]	serious[g]	serious[i]	not serious	none	58	58	-	MD **3.56 lower** (6.12 lower to 1.01 lower)	⨁◯◯◯ Very low	CRITICAL
C0-C1 (Laryngoscopy) - With CSI												
4	randomised trials	very serious[a,b,c,d,e,f,k]	serious[g]	serious[i]	not serious	none	51	51	-	MD **2.67 lower** (5.31 lower to 0.03 lower)	⨁◯◯◯ Very low	CRITICAL
C1-C2 (Laryngoscopy) - Alternative devices												
17	randomised trials	very serious[a,b,c,d,e,f]	serious[g]	serious[i]	serious[j]	none	277	267	-	MD **3.14 lower** (4 lower to 2.28 lower)	⨁◯◯◯ Very low	CRITICAL
C1-C2 (Laryngoscopy) - Intubation Laryngeal Mask												
3	randomised trials	very serious[a,b,c,e]	not serious	serious[i]	not serious	none	51	45	-	MD **6.48 lower** (8.6 lower to 4.35 lower)	⨁◯◯◯ Very low	CRITICAL
C1-C2 (Laryngoscopy) - Airtraq												
4	randomised trials	very serious[a,b,c,e]	not serious	serious[i]	not serious	none	74	74	-	MD **1.63 lower** (3.09 lower to 0.17 lower)	⨁◯◯◯ Very low	CRITICAL
C2-C3 (Laryngoscopy) - Alternative devices												
14	randomised trials	very serious[a,b,c,d,e]	serious[g]	serious[i]	serious[j]	publication bias strongly suspected[l]	241	231	-	MD **1.26 lower** (2.11 lower to 0.4 lower)	⨁◯◯◯ Very low	CRITICAL
C2-C3 (Laryngoscopy) - Intubation Laryngeal Mask												
3	randomised trials	very serious[a,b,c,e]	not serious	serious[i]	serious[j]	none	51	45	-	MD **4.48 lower** (6.37 lower to 2.58 lower)	⨁◯◯◯ Very low	CRITICAL
C2-C3 (Laryngoscopy) - Airtraq												
3	randomised trials	very serious[a,b,c,e]	not serious	serious[i]	not serious	none	50	50	-	MD **1.22 lower** (2.53 lower to 0.08 higher)	⨁◯◯◯ Very low	CRITICAL
C3-C4 (Laryngoscopy) - Alternative devices												
8	randomised trials	very serious[a,b,c,d,e,f]	serious[g]	serious[i]	not serious	none	149	149	-	MD **2.67 lower** (3.68 lower to 1.67 lower)	⨁◯◯◯ Very low	CRITICAL
C0-C1 (Intubation) - Alternative devices												
6	randomised trials	very serious[a,b,d]	not serious	serious[i]	not serious	none	75	75	-	MD **3.3 lower** (4.94 lower to 1.67 lower)	⨁◯◯◯ Very low	CRITICAL
C0-C1 (Intubation) - With CSI												
3	randomised trials	very serious[a,b,d]	not serious	serious[i]	serious[j]	none	42	42	-	MD **3.81 lower** (6.12 lower to 1.49 lower)	⨁◯◯◯ Very low	CRITICAL
C1-C2 (Intubation) - Alternative devices												

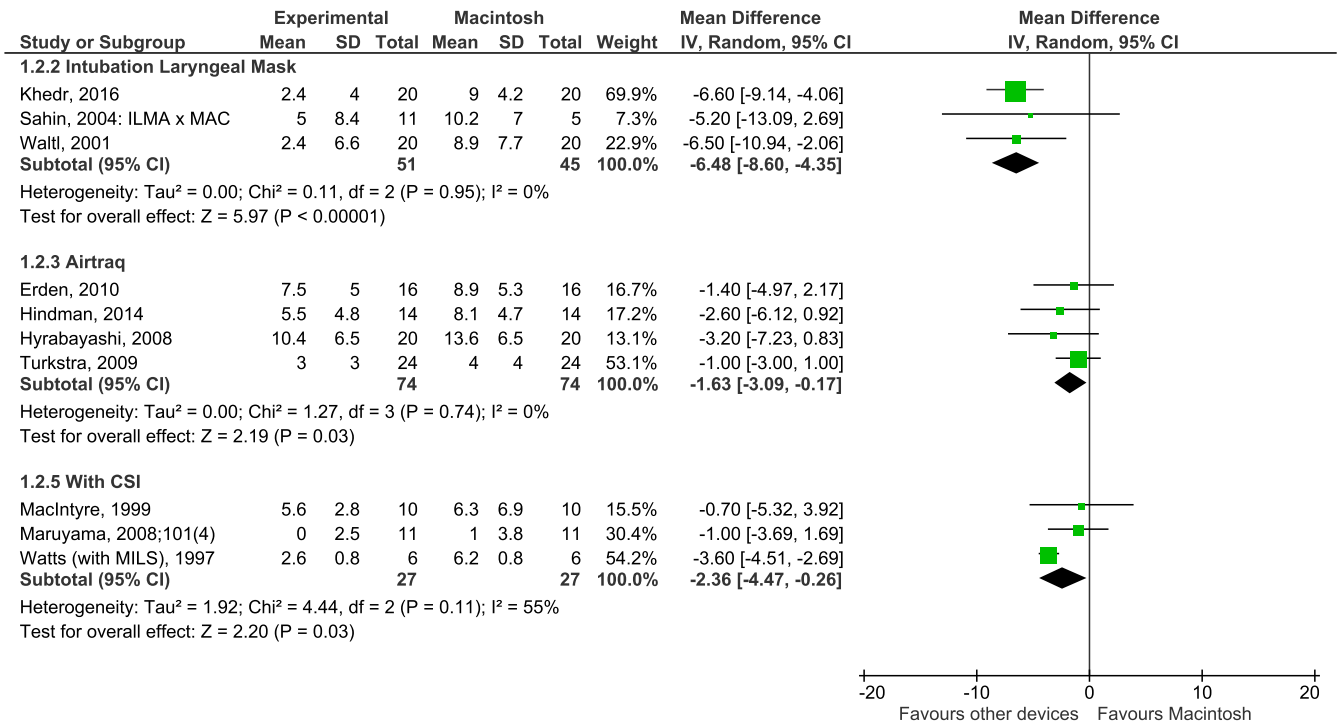
16	randomised trials	very serious[a,b]	not serious	serious[i]	serious[j]	none	232	189	-	MD **2.26 lower** (3.2 lower to 1.32 lower)	⨁◯◯◯ Very low	CRITICAL
C1-C2 (Intubation) - Intubation Laryngeal Mask												
4	randomised trials	very serious[a,b,c,e]	not serious	serious[i]	not serious	none	71	55	-	MD **4.2 lower** (6.04 lower to 2.37 lower)	⨁◯◯◯ Very low	CRITICAL
C1-C2 (Intubation) - With CSI												
3	randomised trials	very serious[a,b,d]	not serious	serious[i]	not serious	none	42	42	-	MD **1.46 lower** (3 lower to 0.08 higher)	⨁◯◯◯ Very low	CRITICAL
C2-C3 (Intubation) - Alternative devices												
13	randomised trials	very serious[a,b]	not serious	serious[i]	not serious	none	187	157	-	MD **1.13 lower** (2.02 lower to 0.23 lower)	⨁◯◯◯ Very low	CRITICAL
C2-C3 (Intubation) - Intubation Laryngeal Mask												
4	randomised trials	very serious[a,b,c,e]	not serious	serious[i]	not serious	none	71	55	-	MD **1.19 lower** (3.07 lower to 0.68 higher)	⨁◯◯◯ Very low	CRITICAL
C3-C4 (Intubation) - Alternative devices												
7	randomised trials	very serious[a,b,d]	not serious	serious[i]	not serious	none	80	67	-	MD **1.29 lower** (2.92 lower to 0.34 higher)	⨁◯◯◯ Very low	CRITICAL
C4-C5 (Intbation) - Alternative devices												
3	randomised trials	serious[b]	not serious	serious[i]	not serious	none	33	33	-	MD **1 lower** (2.83 lower to 0.84 higher)	⨁⨁◯◯ Low	CRITICAL

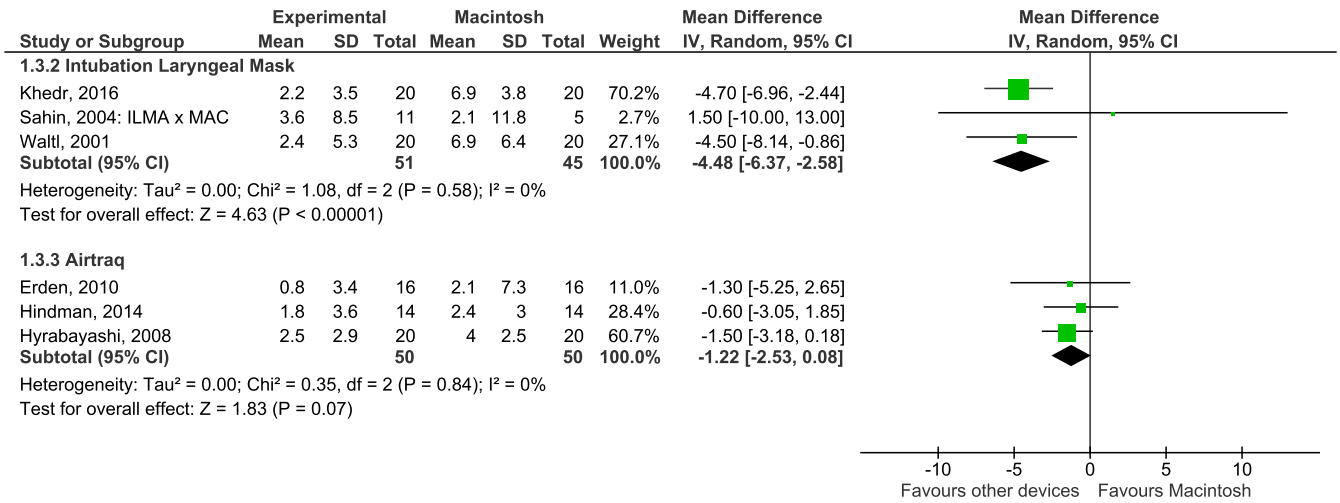
CI: confidence interval; **MD:** mean difference

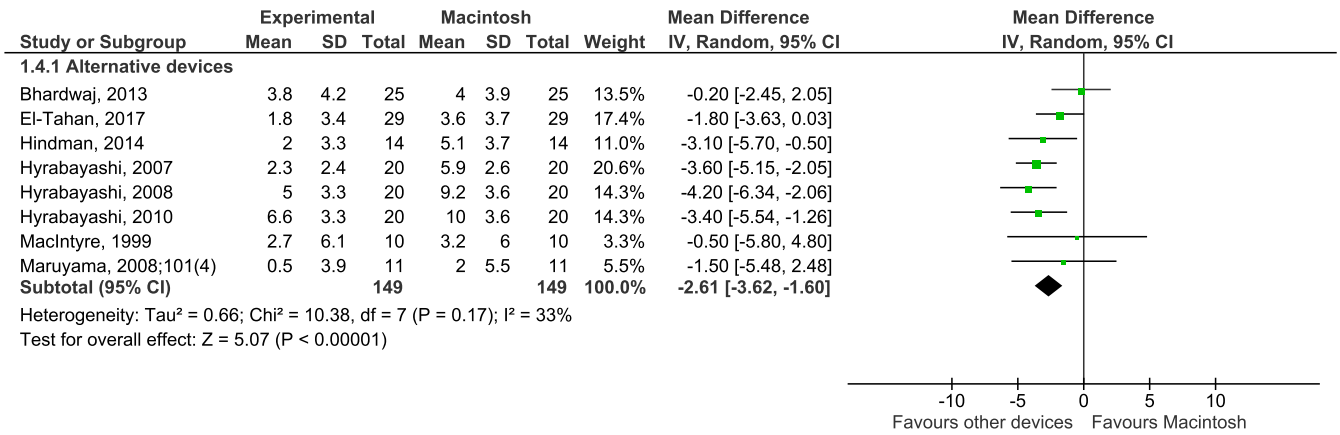
Explanations

a. No allocation concealment in most trials
b. Impossible to blind the anaesthetist to the device being used
c. Inadequate blinding of outcome evaluators in most trials
d. Cross-over effect not evaluated in most trials
e. Experience with the alternative device not described or unequal to control in most trials
f. Random sequence generation not described precisely or ina ppropriately
g. Inconsistency test (I2) = 25-50%
h. Inconsistency test (I2) >= 50%
i. Patients free from myelopathic symptoms
j. Confidence interval very large in some trials
k. Missing data
l. Based on funnel plot


Others
Macintosh
Mean Difference
Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
1.1.1 Alternative devices
Bhardwaj, 2013 4.7 5.5 25 7.2 5.8 25 9.0% -2.50 [-5.63, 0.63]
El-Tahan, 2017 9.4 6.3 29 12.5 6.7 29 8.5% -3.10 [-6.45, 0.25]
Hindman, 2014 9.6 4.5 14 11.4 6.5 14 7.0% -1.80 [-5.94, 2.34]
Hyrabayashi, 2007 11.5 5.7 20 16.9 5.6 20 8.2% -5.40 [-8.90, -1.90]
Hyrabayashi, 2008 11.3 4.5 20 13.8 4.6 20 9.7% -2.50 [-5.32, 0.32]
Hyrabayashi, 2010 11.7 5.6 20 13.9 5.8 20 8.1% -2.20 [-5.73, 1.33]
MacIntyre, 1999 1.5 5.7 10 3.5 8.8 10 3.9% -2.00 [-8.50, 4.50]
Maruyama, 2008;101(4) 2.5 2.8 11 3 2.1 11 11.5% -0.50 [-2.57, 1.57]
Turkstra, 2009 6 5 24 12 6 24 9.0% -6.00 [-9.12, -2.88]
Watts (with MILS), 1997 3.6 1.4 6 6.8 1.6 6 12.4% -3.20 [-4.90, -1.50]
Watts (without MILS), 1997 4.5 1.1 6 11.4 1.6 6 12.7% -6.90 [-8.45, -5.35]
Subtotal (95% CI) 185 185 100.0% -3.43 [-4.93, -1.92]
Heterogeneity: Tau² = 4.04; Chi² = 31.88, df = 10 (P = 0.0004); I² = 69%
Test for overall effect: Z = 4.45 (P < 0.00001)
1.1.2 Airtraq
Hindman, 2014 9.6 4.5 14 11.4 6.5 14 25.3% -1.80 [-5.94, 2.34]
Hyrabayashi, 2008 11.3 4.5 20 13.8 4.6 20 39.3% -2.50 [-5.32, 0.32]
Turkstra, 2009 6 5 24 12 6 24 35.4% -6.00 [-9.12, -2.88]
Subtotal (95% CI) 58 58 100.0% -3.56 [-6.12, -1.01]
Heterogeneity: Tau² = 2.24; Chi² = 3.58, df = 2 (P = 0.17); I² = 44%
Test for overall effect: Z = 2.74 (P = 0.006)
1.1.5 With CSI
MacIntyre, 1999 1.5 5.7 10 3.5 8.8 10 10.1% -2.00 [-8.50, 4.50]
Maruyama, 2008;101(4) 2.5 2.8 11 3 2.1 11 31.6% -0.50 [-2.57, 1.57]
Turkstra, 2009 6 5 24 12 6 24 24.1% -6.00 [-9.12, -2.88]
Watts (with MILS), 1997 3.6 1.4 6 6.8 1.6 6 34.2% -3.20 [-4.90, -1.50]
Subtotal (95% CI) 51 51 100.0% -2.90 [-5.27, -0.53]
Heterogeneity: Tau² = 3.53; Chi² = 9.00, df = 3 (P = 0.03); I² = 67%
Test for overall effect: Z = 2.40 (P = 0.02)
-10
-5
0
5
10
Favours other devices
Favours Macintosh

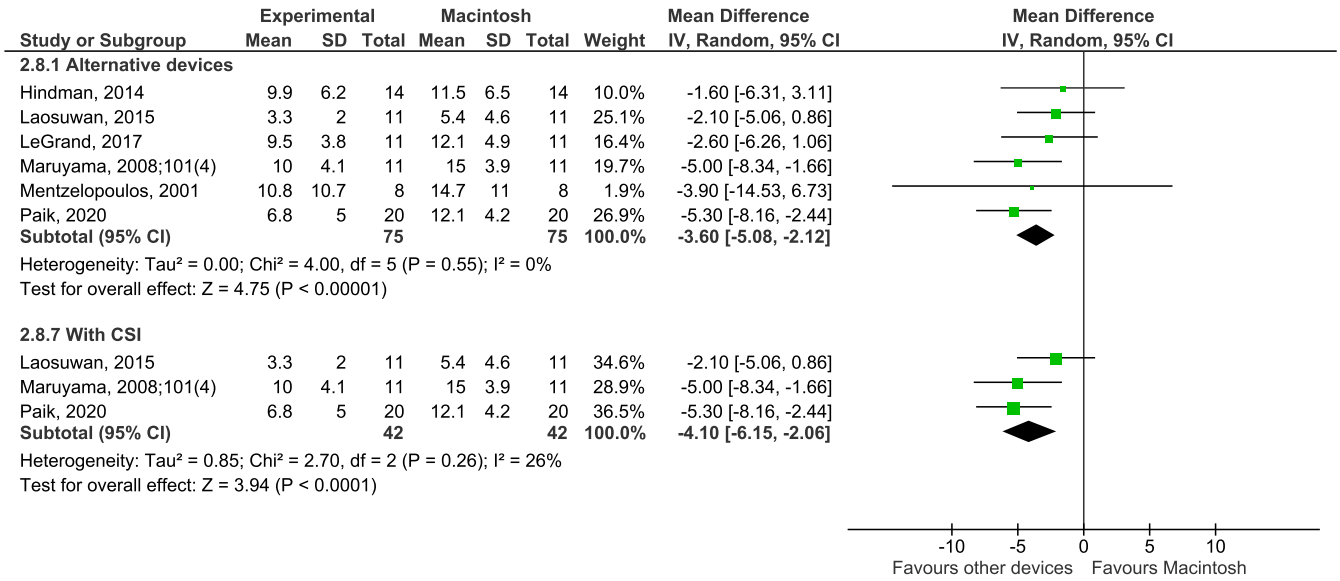

Experimental
Macintosh
Mean Difference
Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
1.2.2 Intubation Laryngeal Mask
Khedr, 2016 2.4 4 20 9 4.2 20 69.9% -6.60 [-9.14, -4.06]
Sahin, 2004: ILMA x MAC 5 8.4 11 10.2 7 5 7.3% -5.20 [-13.09, 2.69]
Waltl, 2001 2.4 6.6 20 8.9 7.7 20 22.9% -6.50 [-10.94, -2.06]
Subtotal (95% CI) 51 45 100.0% -6.48 [-8.60, -4.35]
Heterogeneity: Tau² = 0.00; Chi² = 0.11, df = 2 (P = 0.95); I² = 0%
Test for overall effect: Z = 5.97 (P < 0.00001)
1.2.3 Airtraq
Erden, 2010 7.5 5 16 8.9 5.3 16 16.7% -1.40 [-4.97, 2.17]
Hindman, 2014 5.5 4.8 14 8.1 4.7 14 17.2% -2.60 [-6.12, 0.92]
Hyrabayashi, 2008 10.4 6.5 20 13.6 6.5 20 13.1% -3.20 [-7.23, 0.83]
Turkstra, 2009 3 3 24 4 4 24 53.1% -1.00 [-3.00, 1.00]
Subtotal (95% CI) 74 74 100.0% -1.63 [-3.09, -0.17]
Heterogeneity: Tau² = 0.00; Chi² = 1.27, df = 3 (P = 0.74); I² = 0%
Test for overall effect: Z = 2.19 (P = 0.03)
1.2.5 With CSI
MacIntyre, 1999 5.6 2.8 10 6.3 6.9 10 15.5% -0.70 [-5.32, 3.92]
Maruyama, 2008;101(4) 0 2.5 11 1 3.8 11 30.4% -1.00 [-3.69, 1.69]
Watts (with MILS), 1997 2.6 0.8 6 6.2 0.8 6 54.2% -3.60 [-4.51, -2.69]
Subtotal (95% CI) 27 27 100.0% -2.36 [-4.47, -0.26]
Heterogeneity: Tau² = 1.92; Chi² = 4.44, df = 2 (P = 0.11); I² = 55%
Test for overall effect: Z = 2.20 (P = 0.03)
-20
-10
0
10
20
Favours other devices
Favours Macintosh

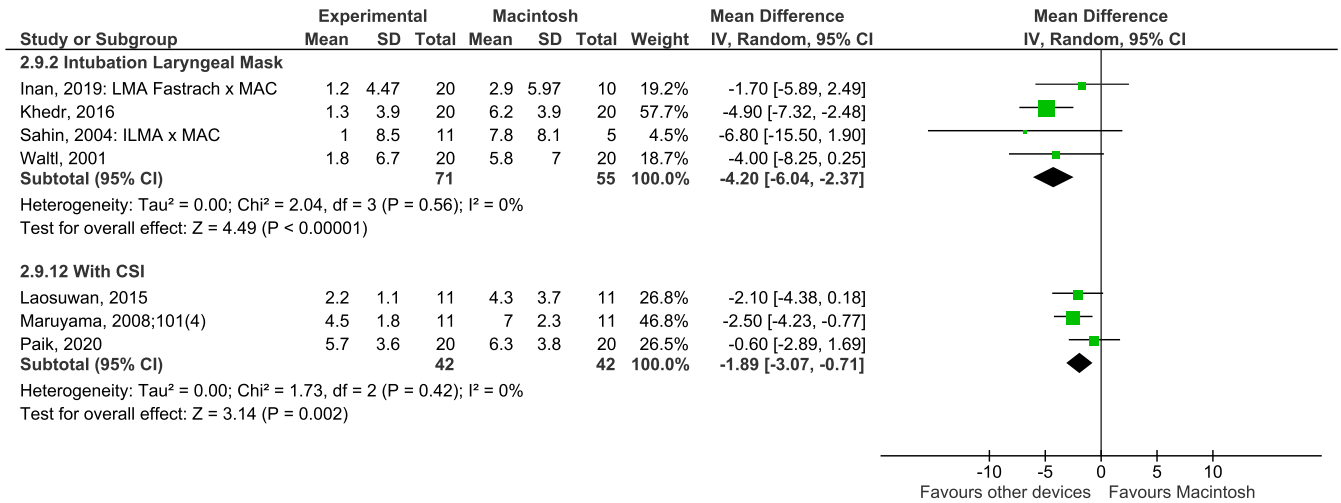

Experimental
Macintosh
Mean Difference
Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
1.3.2 Intubation Laryngeal Mask
Khedr, 2016 2.2 3.5 20 6.9 3.8 20 70.2% -4.70 [-6.96, -2.44]
Sahin, 2004: ILMA x MAC 3.6 8.5 11 2.1 11.8 5 2.7% 1.50 [-10.00, 13.00]
Waltl, 2001 2.4 5.3 20 6.9 6.4 20 27.1% -4.50 [-8.14, -0.86]
Subtotal (95% CI) 51 45 100.0% -4.48 [-6.37, -2.58]
Heterogeneity: Tau² = 0.00; Chi² = 1.08, df = 2 (P = 0.58); I² = 0%
Test for overall effect: Z = 4.63 (P < 0.00001)
1.3.3 Airtraq
Erden, 2010 0.8 3.4 16 2.1 7.3 16 11.0% -1.30 [-5.25, 2.65]
Hindman, 2014 1.8 3.6 14 2.4 3 14 28.4% -0.60 [-3.05, 1.85]
Hyrabayashi, 2008 2.5 2.9 20 4 2.5 20 60.7% -1.50 [-3.18, 0.18]
Subtotal (95% CI) 50 50 100.0% -1.22 [-2.53, 0.08]
Heterogeneity: Tau² = 0.00; Chi² = 0.35, df = 2 (P = 0.84); I² = 0%
Test for overall effect: Z = 1.83 (P = 0.07)
-10
-5
0
5
10
Favours other devices
Favours Macintosh

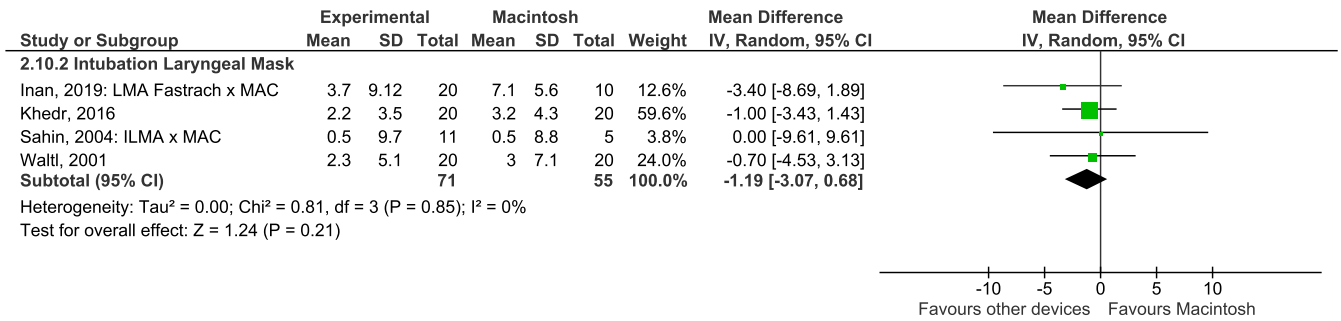


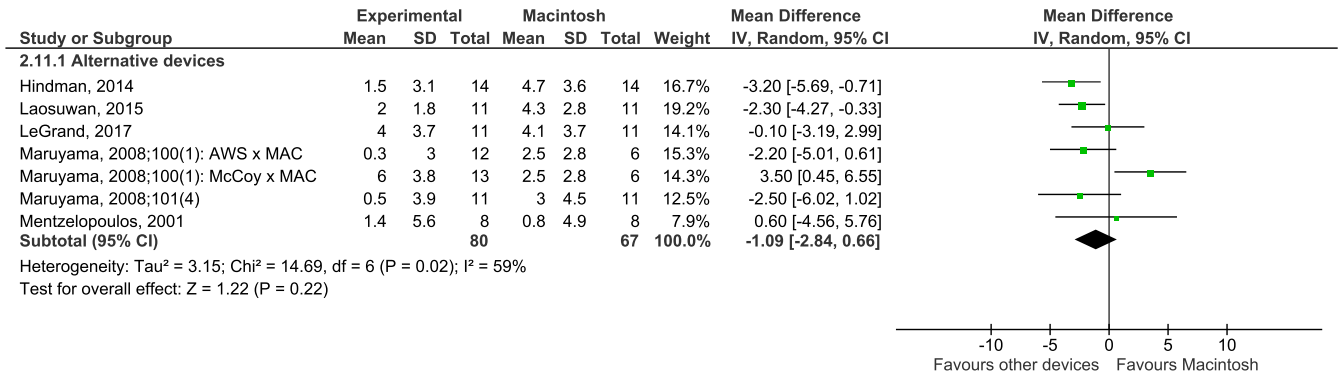
Study or Subgroup	Experimental Mean	SD	Total	Macintosh Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
1.4.1 Alternative devices								
Bhardwaj, 2013	3.8	4.2	25	4	3.9	25	13.5%	-0.20 [-2.45, 2.05]
El-Tahan, 2017	1.8	3.4	29	3.6	3.7	29	17.4%	-1.80 [-3.63, 0.03]
Hindman, 2014	2	3.3	14	5.1	3.7	14	11.0%	-3.10 [-5.70, -0.50]
Hyrabayashi, 2007	2.3	2.4	20	5.9	2.6	20	20.6%	-3.60 [-5.15, -2.05]
Hyrabayashi, 2008	5	3.3	20	9.2	3.6	20	14.3%	-4.20 [-6.34, -2.06]
Hyrabayashi, 2010	6.6	3.3	20	10	3.6	20	14.3%	-3.40 [-5.54, -1.26]
MacIntyre, 1999	2.7	6.1	10	3.2	6	10	3.3%	-0.50 [-5.80, 4.80]
Maruyama, 2008;101(4)	0.5	3.9	11	2	5.5	11	5.5%	-1.50 [-5.48, 2.48]
Subtotal (95% CI)			**149**			**149**	**100.0%**	**-2.61 [-3.62, -1.60]**

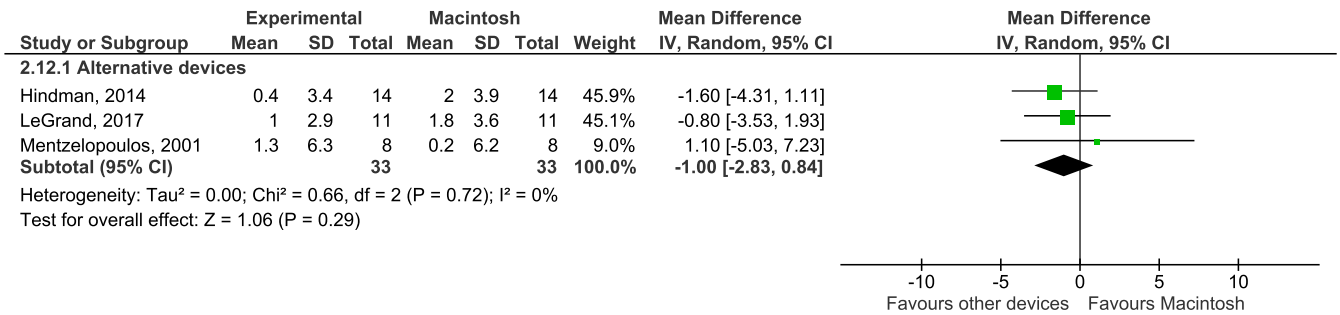
Heterogeneity: Tau² = 0.66; Chi² = 10.38, df = 7 (P = 0.17); I² = 33%
Test for overall effect: Z = 5.07 (P < 0.00001)


Experimental
Macintosh
Mean Difference
Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
2.8.1 Alternative devices
Hindman, 2014 9.9 6.2 14 11.5 6.5 14 10.0% -1.60 [-6.31, 3.11]
Laosuwan, 2015 3.3 2 11 5.4 4.6 11 25.1% -2.10 [-5.06, 0.86]
LeGrand, 2017 9.5 3.8 11 12.1 4.9 11 16.4% -2.60 [-6.26, 1.06]
Maruyama, 2008;101(4) 10 4.1 11 15 3.9 11 19.7% -5.00 [-8.34, -1.66]
Mentzelopoulos, 2001 10.8 10.7 8 14.7 11 8 1.9% -3.90 [-14.53, 6.73]
Paik, 2020 6.8 5 20 12.1 4.2 20 26.9% -5.30 [-8.16, -2.44]
Subtotal (95% CI) 75 75 100.0% -3.60 [-5.08, -2.12]
Heterogeneity: Tau² = 0.00; Chi² = 4.00, df = 5 (P = 0.55); I² = 0%
Test for overall effect: Z = 4.75 (P < 0.00001)
2.8.7 With CSI
Laosuwan, 2015 3.3 2 11 5.4 4.6 11 34.6% -2.10 [-5.06, 0.86]
Maruyama, 2008;101(4) 10 4.1 11 15 3.9 11 28.9% -5.00 [-8.34, -1.66]
Paik, 2020 6.8 5 20 12.1 4.2 20 36.5% -5.30 [-8.16, -2.44]
Subtotal (95% CI) 42 42 100.0% -4.10 [-6.15, -2.06]
Heterogeneity: Tau² = 0.85; Chi² = 2.70, df = 2 (P = 0.26); I² = 26%
Test for overall effect: Z = 3.94 (P < 0.0001)
-10
-5
0
5
10
Favours other devices
Favours Macintosh


Experimental
Macintosh
Mean Difference
Mean Difference
Study or Subgroup
Mean SD Total Mean SD Total Weight
IV, Random, 95% CI
IV, Random, 95% CI
2.9.2 Intubation Laryngeal Mask
Inan, 2019: LMA Fastrach x MAC 1.2 4.47 20 2.9 5.97 10 19.2% -1.70 [-5.89, 2.49]
Khedr, 2016 1.3 3.9 20 6.2 3.9 20 57.7% -4.90 [-7.32, -2.48]
Sahin, 2004: ILMA x MAC 1 8.5 11 7.8 8.1 5 4.5% -6.80 [-15.50, 1.90]
Waltl, 2001 1.8 6.7 20 5.8 7 20 18.7% -4.00 [-8.25, 0.25]
Subtotal (95% CI) 71 55 100.0% -4.20 [-6.04, -2.37]
Heterogeneity: Tau² = 0.00; Chi² = 2.04, df = 3 (P = 0.56); I² = 0%
Test for overall effect: Z = 4.49 (P < 0.00001)
2.9.12 With CSI
Laosuwan, 2015 2.2 1.1 11 4.3 3.7 11 26.8% -2.10 [-4.38, 0.18]
Maruyama, 2008;101(4) 4.5 1.8 11 7 2.3 11 46.8% -2.50 [-4.23, -0.77]
Paik, 2020 5.7 3.6 20 6.3 3.8 20 26.5% -0.60 [-2.89, 1.69]
Subtotal (95% CI) 42 42 100.0% -1.89 [-3.07, -0.71]
Heterogeneity: Tau² = 0.00; Chi² = 1.73, df = 2 (P = 0.42); I² = 0%
Test for overall effect: Z = 3.14 (P = 0.002)
-10 -5 0 5 10
Favours other devices
Favours Macintosh


Experimental
Macintosh
Mean Difference
Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
2.10.2 Intubation Laryngeal Mask
Inan, 2019: LMA Fastrach x MAC 3.7 9.12 20 7.1 5.6 10 12.6% -3.40 [-8.69, 1.89]
Khedr, 2016 2.2 3.5 20 3.2 4.3 20 59.6% -1.00 [-3.43, 1.43]
Sahin, 2004: ILMA x MAC 0.5 9.7 11 0.5 8.8 5 3.8% 0.00 [-9.61, 9.61]
Waltl, 2001 2.3 5.1 20 3 7.1 20 24.0% -0.70 [-4.53, 3.13]
Subtotal (95% CI) 71 55 100.0% -1.19 [-3.07, 0.68]
Heterogeneity: Tau² = 0.00; Chi² = 0.81, df = 3 (P = 0.85); I² = 0%
Test for overall effect: Z = 1.24 (P = 0.21)
-10
-5
0
5
10
Favours other devices
Favours Macintosh


Experimental
Macintosh
Mean Difference
Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
2.11.1 Alternative devices
Hindman, 2014 1.5 3.1 14 4.7 3.6 14 16.7% -3.20 [-5.69, -0.71]
Laosuwan, 2015 2 1.8 11 4.3 2.8 11 19.2% -2.30 [-4.27, -0.33]
LeGrand, 2017 4 3.7 11 4.1 3.7 11 14.1% -0.10 [-3.19, 2.99]
Maruyama, 2008;100(1): AWS x MAC 0.3 3 12 2.5 2.8 6 15.3% -2.20 [-5.01, 0.61]
Maruyama, 2008;100(1): McCoy x MAC 6 3.8 13 2.5 2.8 6 14.3% 3.50 [0.45, 6.55]
Maruyama, 2008;101(4) 0.5 3.9 11 3 4.5 11 12.5% -2.50 [-6.02, 1.02]
Mentzelopoulos, 2001 1.4 5.6 8 0.8 4.9 8 7.9% 0.60 [-4.56, 5.76]
Subtotal (95% CI) 80 67 100.0% -1.09 [-2.84, 0.66]
Heterogeneity: Tau² = 3.15; Chi² = 14.69, df = 6 (P = 0.02); I² = 59%
Test for overall effect: Z = 1.22 (P = 0.22)
-10
-5
0
5
10
Favours other devices
Favours Macintosh


Experimental
Macintosh
Mean Difference
Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI
IV, Random, 95% CI
2.12.1 Alternative devices
Hindman, 2014 0.4 3.4 14 2 3.9 14 45.9% -1.60 [-4.31, 1.11]
LeGrand, 2017 1 2.9 11 1.8 3.6 11 45.1% -0.80 [-3.53, 1.93]
Mentzelopoulos, 2001 1.3 6.3 8 0.2 6.2 8 9.0% 1.10 [-5.03, 7.23]
Subtotal (95% CI) 33 33 100.0% -1.00 [-2.83, 0.84]
Heterogeneity: Tau² = 0.00; Chi² = 0.66, df = 2 (P = 0.72); I² = 0%
Test for overall effect: Z = 1.06 (P = 0.29)
-10
-5
0
5
10
Favours other devices
Favours Macintosh