

# Alternative intubation techniques vs Macintosh laryngoscopy in patients with cervical spine immobilization: systematic review and meta-analysis of randomized controlled trials

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## Abstract

**Background:** Immobilization of the cervical spine worsens tracheal intubation conditions. Various intubation devices have been tested in this setting. Their relative usefulness remains unclear.

**Methods:** We searched MEDLINE, EMBASE, and the Cochrane Library for randomized controlled trials comparing any intubation device with the Macintosh laryngoscope in human subjects with cervical spine immobilization. The primary outcome was the risk of tracheal intubation failure at the first attempt. Secondary outcomes were quality of glottis visualization, time until successful intubation, and risk of oropharyngeal complications.

**Results:** Twenty-four trials (1866 patients) met inclusion criteria. With alternative intubation devices, the risk of intubation failure was lower compared with Macintosh laryngoscopy [risk ratio (RR) 0.53; 95% confidence interval (CI) 0.35–0.80]. Meta-analyses could be performed for five intubation devices (Airtraq, Airwayscope, C-Mac, Glidescope, and McGrath). The Airtraq was associated with a statistically significant reduction of the risk of intubation failure at the first attempt (RR 0.14; 95% CI 0.06–0.33), a higher rate of Cormack–Lehane grade 1 (RR 2.98; 95% CI 1.94–4.56), a reduction of time until successful intubation (weighted mean difference –10.1 s; 95% CI –3.2 to –17.0), and a reduction of oropharyngeal complications (RR 0.24; 95% CI 0.06–0.93). Other devices were associated with improved glottis visualization but no statistically significant differences in intubation failure or time to intubation compared with conventional laryngoscopy.

**Conclusions:** In situations where the spine is immobilized, the Airtraq device reduces the risk of intubation failure. There is a lack of evidence for the usefulness of other intubation devices.

**Key words:** airway; complications, spinal injury; intubation, tracheal tube; trauma

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**Editor's key points**

- Videolaryngoscopes enhance visualization of the laryngeal inlet but do not necessarily facilitate tracheal intubation.
- Cervical immobilization limits successful orotracheal intubation.
- This meta-analysis identifies improved success rates with at least one type of videolaryngoscope.
- Contemporary anaesthesia requires videolaryngoscopy training, experience, and skills.

Failure to perform adequate immobilization of the cervical spine during orotracheal intubation in patients with cervical spine injury or in patients at risk of cervical injury may result in a devastating neurological outcome.<sup>1</sup> International guidelines recommend manual or mechanical cervical immobilization in these patients.<sup>2,3</sup> Manual in-line stabilization (MILS) is the preferred technique to maintain the cervical spine immobile during tracheal intubation and has been shown to limit cervical spine displacements during orotracheal intubation compared with the use of a cervical collar.<sup>4,5</sup> While cervical immobilization may prevent injury of the cervical spine, it also worsens intubation conditions.<sup>6</sup> In particular, cervical spine immobilization may prevent adequate alignment of the oral, pharyngeal, and tracheal axes, jeopardizing visualization of the glottis when direct laryngoscopy is attempted.<sup>7</sup> Moreover, the use of a cervical collar reduces mouth opening, which may further complicate orotracheal intubation.<sup>8</sup> The most relevant outcome in this context is intubation failure. Various alternative intubation devices have been compared with the classic Macintosh blade in randomized controlled trials (RCTs), but it remains unclear whether these devices perform better compared with conventional laryngoscopy. The aim of our analysis was systematically to review the evidence from RCTs comparing alternative intubation devices with the standard Macintosh laryngoscope in subjects with cervical spine immobilization.

**Methods**

Search strategy, study selection, data extraction, and analysis were performed according to a predefined protocol (available from the authors). Data reporting followed the PRISMA statement (Supplementary material, Appendix SA).<sup>9</sup>

**Study selection**

To identify relevant articles, two authors (L.S. and C.M.) searched Medline, EMBASE, and the Cochrane Library (CENTRAL) using the keywords 'intubation', 'spine' or 'cervical' or 'axis', and 'immobilisation' or 'immobilization' or 'stabilisation' or 'stabilization', and combinations of those (Supplementary material, Appendix SB). Searches were performed to October 2014 and were restricted to RCTs. Bibliographies of retrieved articles were manually checked for additional references. Titles and abstracts were screened by two authors independently (L.S. and C.M.). All retrieved articles were reviewed by two authors (L.S. and C.M.). Any disagreement was resolved through consensus or, if necessary, by discussion with a third author (M.R.T.).

**Inclusion criteria**

We included RCTs comparing any alternative intubation device with the Macintosh laryngoscope in adult patients under cervical immobilization. Cervical immobilization had to be performed

using the MILS technique, head immobilization by fixation of at least two points, or a cervical collar. Crossover studies were included if the sequence of use of intubation devices was randomized. Manikin studies were not considered.

**Outcomes**

The primary end point was the risk of intubation failure at the first attempt. Secondary end points were the proportion of subjects with Cormack–Lehane grade 1,<sup>10</sup> time to successful intubation (duration of the first successful attempt), and the risk of immediate complications, such as tooth damage or oropharyngeal trauma.

**Data extraction**

One author (L.S.) extracted all relevant information from the original reports and entered the data into an electronic data sheet specifically designed for this study. Extracted data were cross-checked by a second author (C.M.). Discrepancies were resolved by consensus. Authors of original reports were contacted when data were missing or were reported in a format that did not allow statistical analysis.

**Quality of data reporting**

We assessed the quality of data reporting using a modified four-item Oxford scale, taking into account allocation concealment, sequence generation, blinding, and description of dropouts (Supplementary material, Appendix SC).<sup>11</sup> Additionally, we assessed outcomes and selective reporting.

**Data synthesis and analyses**

All analyses were performed according to the intention-to-treat principle. The Mantel–Haenszel method<sup>12</sup> was used to pool dichotomous data and to compute pooled risk ratios (RRs) with 95% confidence intervals (CIs). The inverse variance method was used to pool dichotomous data and to calculate weighted mean differences with 95% CIs.

The significance level was set at 0.05 for all analyses. Subgroup analyses for individual devices were performed when relevant data were reported in at least three studies or at least 100 patients.

Statistical heterogeneity was evaluated using the  $I^2$  statistic.<sup>13</sup> A random-effects model was used throughout. Potential factors explaining heterogeneity were explored by prespecified subgroup analyses, including immobilization technique, experience of the operators, and the use of a stylet in the control group.

Sensitivity analyses were conducted to check for the robustness of the data by removing each study one by one, excluding lower quality studies (Oxford score <4), excluding studies not using or not mentioning the use of a stylet in the control group, and excluding studies using immobilization techniques other than MILS. To evaluate the impact of the cervical immobilization technique and the use of a stylet on the incidence of intubation failure during Macintosh intubation, we compared the mean incidence of intubation failure in the control groups of studies using MILS vs other stabilization, and studies using a stylet in the control group vs studies not using or not mentioning the use of a stylet, and calculated the RR of failure using the  $\chi^2$  statistic. For statistically significant dichotomous results, we calculated numbers needed to treat (NNT) and numbers needed to harm (NNH) with 95% CIs using the inverse of the absolute risk reduction. When continuous data were not reported as means with standard deviations, we contacted the authors to obtain this information. If this request was unsuccessful, these data

were not analysed because a skewed distribution could not be ruled out. Publication bias was assessed using visual inspection of the funnel plot.

Analyses were performed using the Cochrane Review Manager software (RevMan 5.2.8; © The Nordic Cochrane Centre, The Cochrane Collaboration, 2013) and the Medcalc® online relative risk calculator ([www.medcalc.org/calc/relative\\_risk.php](http://www.medcalc.org/calc/relative_risk.php)).

## Results

### Study selection and characteristics

We retrieved 767 references; 212 were double hits (Fig. 1). Of the 555 remaining articles, 416 were excluded based on title and abstract. Full texts were obtained for the 139 remaining articles. Of these, 38 were non-randomized trials, 23 did not use conventional laryngoscopy in the control group, 20 used an inadequate immobilization technique, 16 were performed on manikins, and 18 provided insufficient data. One additional study was identified during the peer review process.<sup>14</sup> We finally included 24 studies with data of 1866 patients,<sup>14–37</sup> evaluating 16 different alternative intubation devices. Intubations were performed exclusively by experienced anaesthetists in patients without cervical trauma undergoing elective surgery. For cervical immobilization, MILS was used in the majority of studies (Table 1). None of the studies included patients with expected difficult intubation, and conventional induction sequences using non-depolarizing neuromuscular blocking agents were performed throughout. In control groups, there were a total of 646 intubation attempts with the Macintosh blade; the failure risk ranged from 0<sup>19 35</sup> to 63%.<sup>18</sup>

### Intubation failure at first attempt

Eighteen studies (1500 patients) reported on intubation failure at first attempt.<sup>15–28 30 32 35 38</sup> On average, the risk of intubation

failure at first attempt was 9.9% with alternative devices and 24.5% with Macintosh laryngoscopy; RR 0.53 (95% CI 0.35–0.80), NNT 9.1 (95% CI 5.2–33; Fig. 2). Sufficient data to perform meta-analyses were available for the Airtraq, Airway scope, C-Mac, Glidescope, and McGrath devices (Supplementary material, Appendix SD). On average, the risk of intubation failure with Airtraq (five studies, 294 patients) was 3.4%, compared with 28.6% with Macintosh laryngoscopy; RR 0.14 (95% CI 0.06–0.33), NNT 5.0 (95% CI 3.9–8.1).<sup>15 23 26 30 35</sup> The risk of intubation failure was not significantly different with each of the four other devices (Airway scope, C-Mac, Glidescope, and McGrath) compared with Macintosh laryngoscopy (Fig. 3).

### Cormack–Lehane grade

Fifteen studies (1684 patients) reported on the Cormack–Lehane grade.<sup>15 16 18–22 24–28 30 32 38</sup> On average, 66% of patients had Cormack–Lehane grade 1 with alternative devices compared with 18% with Macintosh laryngoscopy; RR 3.44 (95% CI 2.78–4.26), NNT 4.1 (95% CI 3.6–4.8). Sufficient data to perform meta-analyses were available for all five devices, and all were associated with a significantly higher rate of Cormack–Lehane grade 1 compared with Macintosh laryngoscopy: Airtraq, RR 2.98 (95% CI 1.94–4.56); Airway scope, RR 5.16 (95% CI 3.19–8.33); C-Mac, RR 1.92 (95% CI 1.00–3.72); Glidescope, RR 4.33 (95% CI 2.43–7.70); and McGrath, RR 3.57 (95% CI 2.84–4.49; Fig. 4).

### Time to intubation

Seventeen studies (1441 patients) reported on the time to successful intubation.<sup>15–23 25–28 30 32 35 38</sup> It was generally reported as the time between the beginning of laryngoscopy and the confirmation of tracheal tube placement through direct visualization of the vocal cords or capnography. Sufficient data to perform

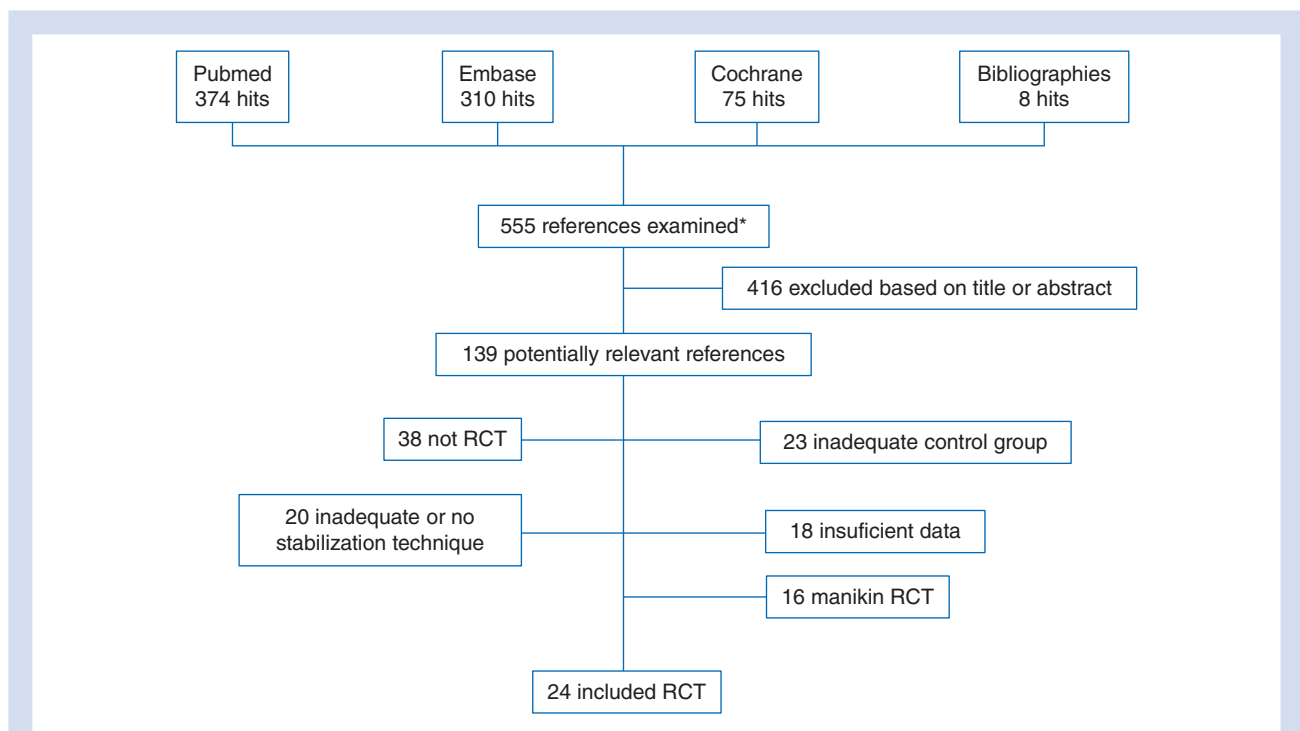


Fig 1 Study flow chart. RCT, randomized controlled trial.

**Table 1** Characteristics of included trials. \*Crossover study. ILMA, intubating laryngeal mask airway; MILS, manual in-line stabilization

Citation	Intubation techniques used (number of patients)	Use of a stylet in the control group	Patients with difficult intubation criteria excluded	Level of experience of the operators	Cervical immobilization technique used	Randomization (0–2)	Concealment (0–1)	Blinding (0–1)	Follow-up (0–2)
Amor and colleagues <sup>15</sup>	Macintosh (60) Airtraq (60)	Not specified	Yes	Experienced anaesthetists	MILS	2	1	1	2
Aoi and colleagues <sup>16</sup>	Macintosh (18) Airway Scope (18)	Not specified	Yes	Experienced anaesthetists	Cervical collar	1	0	0	2
Bharti and colleagues <sup>17</sup>	Macintosh (19) McCoy (21) Truview EVO2 (20)	Not systematic	Yes	One experienced anaesthetist	MILS	2	1	0	2
Byhahn and colleagues <sup>18</sup>	Macintosh (38) Bonfils Fiberscope (38)	Not specified	Yes	Experienced anaesthetists	Cervical collar	1	1	0	2
Gercek and colleagues <sup>19</sup>	Macintosh (12) Flexible fibre-optic (oral) (12) Flexible fibre-optic (nasal) (12) ILMA (12)	Not specified	Yes	Experienced anaesthetists	MILS	2	0	0	2
Gupta and Thukral <sup>20</sup>	Macintosh (30) C-MAC, without stylet (30) C-MAC, with stylet (30)	Yes	Yes	Experienced anaesthetists	MILS	2	0	0	2
Ilyas and colleagues <sup>21</sup>	Macintosh (64) McGrath (64)	Yes	Yes	Experienced anaesthetists	MILS	2	1	0	2
Kihara and colleagues <sup>22</sup>	Macintosh (96) StyletScope (97)	Yes	Yes	Experienced anaesthetists	MILS	1	1	1	2
Koh and colleagues <sup>23</sup>	Macintosh (25) Airtraq (25)	Not at first attempt	Yes	Experienced anaesthetists	Cervical collar	2	1	1	2
Kok and colleagues <sup>24*</sup>	Macintosh (94) Levitan FPS (91)	Yes	Yes	Experienced anaesthetists	MILS	2	1	0	2
Lim and Yeo <sup>25</sup>	Macintosh (30) GlideScope (30)	Yes	Yes	Experienced anaesthetists	MILS	1	1	0	2
Maharaj and colleagues <sup>26</sup>	Macintosh (20) Airtraq (20)	Not specified	Yes	Experienced anaesthetists	MILS	1	1	0	2
Malik and colleagues <sup>27</sup>	Macintosh (30) Truview EVO2 with stylet (30) Glidescope with stylet (30) Airway Scope (30)	Not specified	Yes	Experienced anaesthetists	MILS	2	1	0	2
Malik and colleagues <sup>28</sup>	Macintosh (30) Aiway Scope (30) LMA Ctrach (30)	Not specified	Yes	Experienced anaesthetists	MILS	2	1	0	2
Maruyama and colleagues <sup>29*</sup>	Macintosh (11) Airway Scope (11)	Not specified	Yes	Experienced anaesthetists	Head immobilizer	1	0	0	2
McElwain and Laffey <sup>30</sup>	Macintosh (31) Airtraq (29) C-MAC, with stylet (29)	No	Yes	Experienced anaesthetists	MILS	2	1	0	2

Robitaille and colleagues <sup>31*</sup>	Macintosh (10)	Yes	No	Experienced anaesthetists	MILS	2	0	0	2
Smith and colleagues <sup>32</sup>	Glidescope (10) Macintosh (44)	Yes	Yes	Experienced anaesthetists	MILS	1	0	0	2
Taylor and colleagues <sup>14*</sup>	WuScope (43) Macintosh (44)	Yes	Yes	Experienced anaesthetists	MILS	1	2	0	2
Tolon and colleagues <sup>33</sup>	McGrath (44) Macintosh (20)	Not specified	Yes	Not specified	MILS	1	0	0	2
Turkstra and colleagues <sup>34*</sup>	Airtraq (20) Macintosh (36) Glidescope (18) LightWand (18)	Not specified	Yes	Experienced anaesthetists	Head taping	2	1	0	2
Turkstra and colleagues <sup>36*</sup>	Macintosh (23) Shikami Optical Stylet (23)	Not specified	Yes	Experienced anaesthetists	MILS	2	1	0	2
Turkstra and colleagues <sup>35*</sup>	Macintosh (24) Airtraq (24)	Not specified	Yes	Experienced anaesthetists	MILS	2	1	0	2
Watts and colleagues <sup>37*</sup>	Macintosh (29) Bullard (29)	Not specified	Yes	Experienced anaesthetists	MILS	1	0	0	2

meta-analyses were available for Airtraq, Airway scope, Glidescope, and MacGrath devices.

The Airtraq device was associated with a statistically significant reduction in the time to successful intubation; weighted mean difference 10.1 s (95% CI 3.2–17.0; Supplementary material, Appendix SE). With Airway scope and Glidescope, the time to successful intubation was not significantly different compared with Macintosh laryngoscopy. The McGrath device was associated with an increased time to successful intubation; weighted mean difference 20.6 s (95% CI 3.2–38.0).

### Complications

Fourteen studies (1325 patients) reported on local complications (supraglottic or lip trauma, minor bleeding).<sup>15–18 20–28 30 38</sup> Sufficient data to perform meta-analysis were available on Airtraq, Airway scope, C-Mac, and Glidescope and MacGrath devices.

The Airtraq device was associated with a significant reduction in the incidence of local complications compared with conventional laryngoscopy; RR 0.24 (95% CI 0.06–0.93). The incidence of local complications was not different compared with Macintosh laryngoscopy with Airway scope (RR 1.21; 95% CI 0.49–2.94), C-Mac (RR 1.07; 95% CI 0.37–3.12), Glidescope (RR 0.40; 95% CI 0.13–1.21), and MacGrath (RR 0.63; 95% CI 0.32–1.23; Supplementary material, Appendix SF).

### Sensitivity analyses and sources of heterogeneity

The outcome of intubation failure at the first attempt was not sensitive to a single study, and pooled RR remained statistically significant and of similar magnitude after exclusion of individual studies. Likewise, exclusion of studies using immobilization techniques other than MILS (RR 0.56, 95% CI 0.35–0.91 for the overall comparison; RR 0.17, 95% CI 0.06–0.44 for the Airtraq device) or exclusion of studies of lower quality did not significantly alter the estimates. The pooled RR of the primary outcome was slightly increased and lost statistical significance (RR 0.57; 95% CI 0.29–1.11) after exclusion of studies not using or not mentioning the use of a stylet in the control group. The comparison between the Airtraq device and Macintosh laryngoscopy was no longer possible because the five studies evaluating the Airtraq device did not explicitly use a stylet in the control group. Regarding the quality of glottis visualization, studies using immobilization techniques other than MILS were associated with a higher estimate of treatment effect (RR 15.99, 95% CI 5.29–48.3 vs RR 3.28, 95% CI 2.76–3.89). The rate of intubation failure in control groups was significantly higher in studies using a cervical collar than in those using MILS (RR 2.05, 95% CI 1.53–2.75), but no statistically significant difference was observed between studies using or not using, or not mentioning, the use of a stylet (RR 1.13, 95% CI 0.86–1.50). Moderate heterogeneity ( $I^2=37%$ ) was detected for the overall comparison of the primary outcome but appeared to result mainly from the diversity of devices; no or low heterogeneity was detected in the per device subgroup analyses except for the McGrath device. The main sensitivity analyses are provided in the Supplementary material, Appendix SG, SH and SI.

### Publication bias

On visual inspection of the funnel plots, there was no evidence of publication bias for the primary and secondary outcomes (Supplementary material, Appendix S).

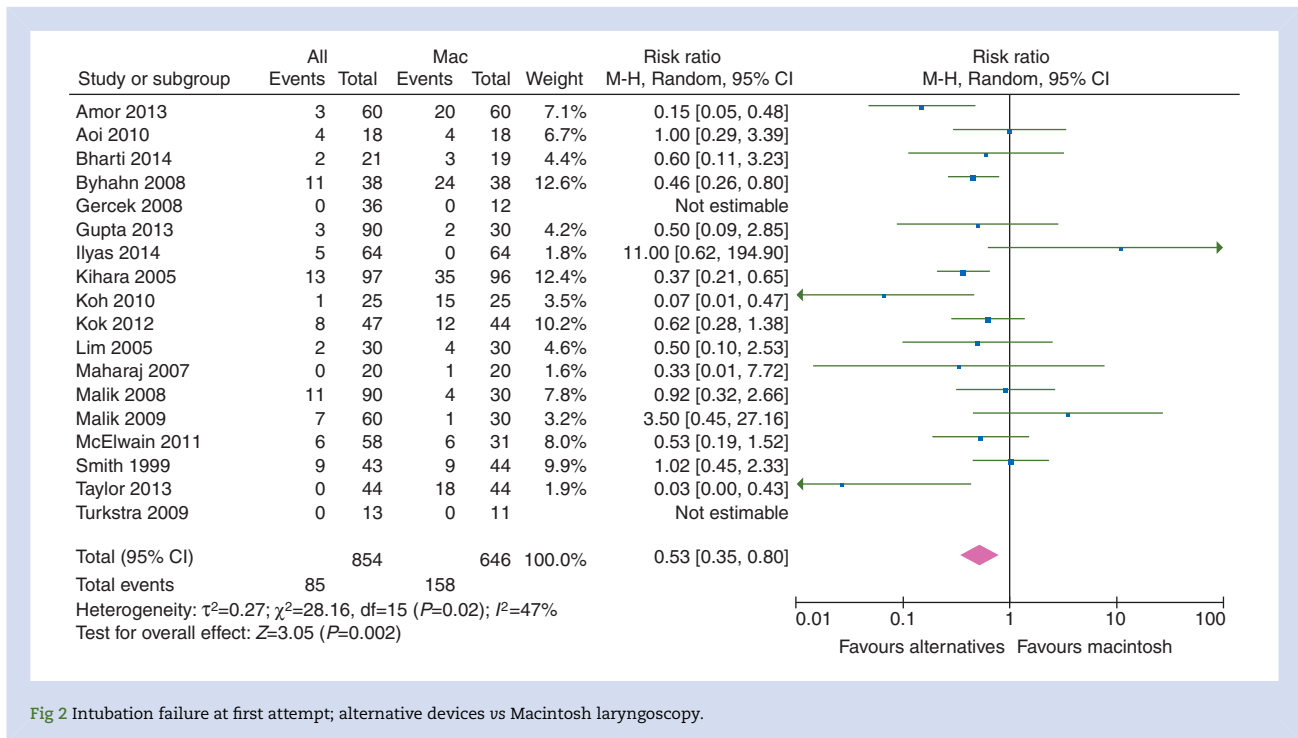


Fig 2 Intubation failure at first attempt; alternative devices vs Macintosh laryngoscopy.

## Discussion

Our analysis aimed to evaluate efficacy and risks of alternative intubation devices compared with the Macintosh laryngoscope in subjects with cervical spine immobilization. The average failure rate at first attempt of more than 20% when using conventional laryngoscopy confirms the difficulty in performing tracheal intubation when the cervical spine is immobilized. Our analyses suggest that this failure rate may be decreased by about one-half when using alternative devices. The magnitude of the estimated treatment effect appears clinically relevant. Also, the outcome failure rate was not sensitive to an individual study or to the cervical spine immobilization technique. While the benefit of alternative devices appears convincing, the main question for the clinician is the choice of the intubation technique, because numerous intubation devices have been commercialized, and the present review included 16 different devices.

To avoid giving undue weight to devices that have been tested in a very limited number of subjects only and to limit measurement error (background noise), we arbitrarily decided to limit meta-analyses to devices that were tested in at least three studies or studies including a total of at least 100 subjects.

Among the five devices with a sufficient amount of data, only the Airtraq was associated with a statistically significant reduction in both the rate of intubation failures at first attempt and in the time to successful intubation. Nevertheless, for the four other devices, confidence intervals around the point estimates were wide, suggesting that the absence of statistical significance was probably attributable to a lack of relevant data. These results are in accordance with a previous meta-analysis comparing the Airtraq with conventional laryngoscopy, which showed a reduction of intubation failure at first attempt when used by novices, a reduction of the incidence of oesophageal intubation, and a reduction of the time to intubation in patients with abnormal airways.<sup>39</sup> This benefit may be explained by the pronounced curvature of the Airtraq blade, which does not require the alignment of oral, pharyngeal and tracheal axes, and the disposition of

its optical components, allowing intubation in patients with reduced mouth opening.<sup>23 40</sup>

As the Airtraq device is a single-use device with significant additional cost compared with the reusable or disposable Macintosh blade, the magnitude of the treatment effect must be considered. The estimated NNT to prevent one intubation failure at first attempt was nine in the present review. While these results may appear convincing given the potential morbidity of failed intubation attempts, they deserve further comment because there were some limitations in the design of the included studies.

First, the intubation failure rate in control subjects who were intubated with the Macintosh blade was unexpectedly high. This may be explained partly by improper immobilization (cervical collar) and intubation technique. Although cervical immobilization was performed by MILS in the majority of studies (19 of 24) and the immobilization technique appeared to have only little impact on the estimated RR in our sensitivity analysis, the use of a cervical collar was associated with a higher rate of intubation failure in control groups, which may have led to an overestimation of the beneficial effect of alternative devices. Previous studies have shown that when MILS was used, the Cormack-Lehane grade was better and mouth opening was less restricted than when a cervical collar was applied.<sup>8</sup> Likewise, the use of a stylet in the control group was specified in only eight of the 24 studies and in none of the studies evaluating the Airtraq device. The absence of a stylet might be associated with an increased incidence of intubation failure in the control groups and may have contributed to an overestimation of the benefit of alternative devices. Unfortunately, the use of a stylet was not documented in about one-half of the included studies. The benefit of alternative devices was not significant after exclusion of studies where a stylet was not used or mentioned, and the benefit of the Airtraq device compared with the recommended standard of care (MILS and use of a stylet) could not be evaluated.

Second, operators were not blinded in any of the included studies, nor were the outcome assessors in the majority of the studies.

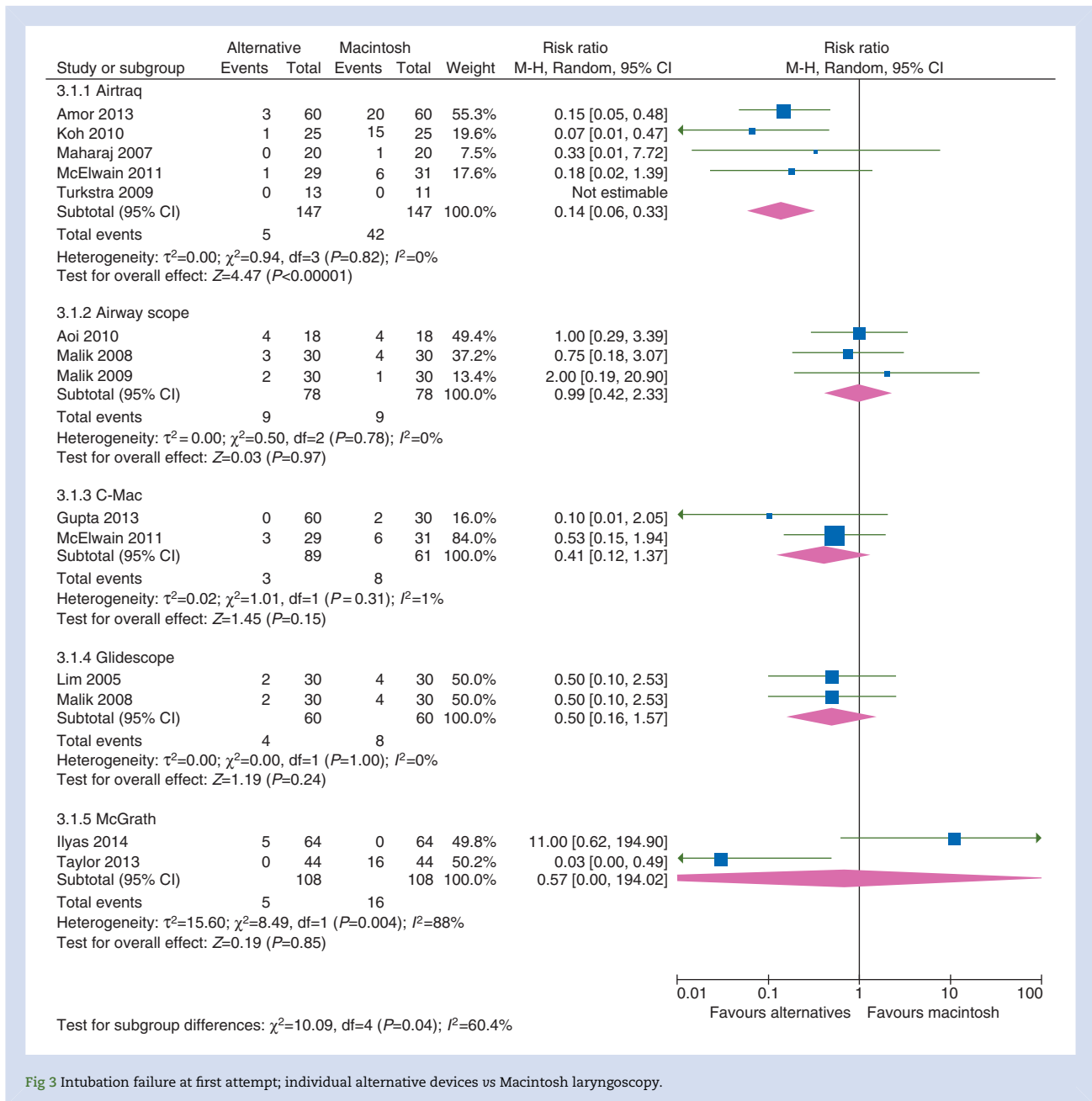


Fig 3 Intubation failure at first attempt; individual alternative devices vs Macintosh laryngoscopy.

Lack of blinding may represent a potential source of observer bias and tends to overestimate treatment effect estimates.<sup>41</sup> Lack of blinding may lead an operator to act (consciously or not) in a manner that increases the failure rate in the control group. Control group bias has previously been reported in studies evaluating the benefit of videolaryngoscopy.<sup>42</sup>

Third, none of these studies included true trauma patients and none used a rapid sequence induction procedure. It may be difficult to perform such studies because of logistic and ethical constraints. Moreover, operators were specifically trained for the use of alternative devices, and their performance may differ in a real-world setting because the use of such devices requires training for acquisition and maintenance of skills. Consequently, data from these trials have to be regarded as surrogates; these results may not necessarily be extrapolated to the real-world setting.

Finally, the present work was dedicated to evaluate the efficacy of alternative devices compared with the Macintosh laryngoscope for tracheal intubation in subjects with cervical spine immobilization but did not evaluate their impact on cervical spine movement during the procedure. Human<sup>34 35 43 44</sup> and cadaveric studies with simulated cervical instability<sup>45</sup> have suggested that alternative intubation devices, such as the Airtraq device, may result in significantly less angular motion and anterior translation compared with Macintosh laryngoscopy.

Despite these limitations, the present work is, to our knowledge, the first systematic review specifically designed to evaluate the benefit of alternative intubation devices compared with Macintosh laryngoscopy in subjects with cervical immobilization and to allow indirect comparisons between different devices. Alternative devices, particularly the Airtraq device, may reduce the rate of intubation failure at the first attempt in patients with

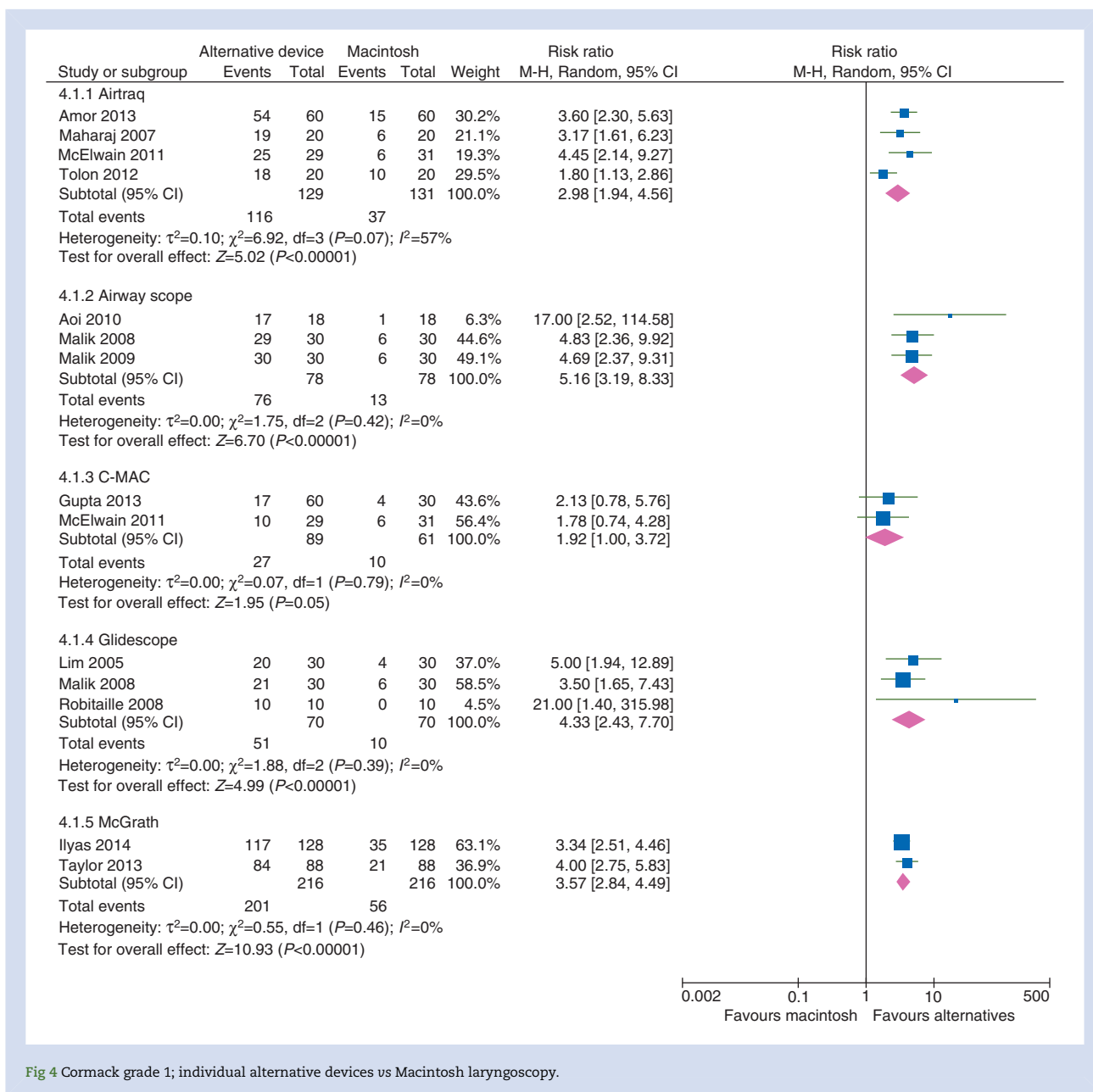


Fig 4 Cormack grade 1; individual alternative devices vs Macintosh laryngoscopy.

cervical spine immobilization. Given their higher cost and some limitations in the available evidence, it remains unclear whether the Airtraq device should be recommended as the first intention. Insufficient evidence is available to recommend the use of other devices. Further studies testing alternative devices in a rapid sequence setting, using proper immobilization (MILS), and adequate intubation technique in the control group (use of a stylet) are warranted to confirm our conclusions.

## Conclusions

Using conventional laryngoscopy with a Macintosh blade, intubation failure is frequent in patients with cervical immobilization. In such situations, the Airtraq device reduces the risk of intubation failure. There is a lack of evidence of the usefulness of other alternative intubation devices.

## Authors' contributions

L.S. and C.M. conceived the study, wrote the protocol draft, performed the literature searches, extracted the data, carried out the statistical analysis, and wrote the article draft. M.R.T. participated in the study conception, analysis interpretation, and article writing by critically revising the study protocol and the article draft. O.G. and M.N. participated in interpretation of the analysis and article writing by critically revising the study protocol and the article draft.

## Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.



## Declaration of interest

None declared.

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