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REVIEW ARTICLE

A comparison of ramping position and sniffing position during endotracheal intubation: a systematic review and meta-analysis

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KEYWORDS
Ramping position;
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Laryngeal exposure;
Intubation success

Abstract
Objectives: Positioning during endotracheal intubation (ETI) is critical to ensure its success. We aimed to determine if the ramping position improved laryngeal exposure and first attempt success at intubation when compared to the sniffing position.
Methods: PubMed, EMBASE, and Cochrane CENTRAL databases were searched systematically from inception until January 2020. Our primary outcomes included laryngeal exposure as measured by Cormack-Lehane Grade 1 or 2 (CLG 1/2), CLG 3 or 4 (CLG 3/4), and first attempt success at intubation. Secondary outcomes were intubation time, use of airway adjuncts, ancillary maneuvers, and complications during ETI.
Results: Seven studies met our inclusion criteria, of which 4 were RCTs and 3 were cohort studies. The meta-analysis was conducted by pooling the effect estimates for all 4 included RCTs (n = 632). There were no differences found between ramping and sniffing positions for odds of CLG 1/2, CLG 3/4, first attempt success at intubation, intubation time, use of ancillary airway maneuvers, and use of airway adjuncts, with evidence of high heterogeneity across studies. However, the ramping position in surgical patients is associated with increased likelihood of CLG 1/2 (OR = 2.05, 95% CI 1.26 to 3.32, $p = 0.004$) and lower likelihood of CLG 3/4 (OR = 0.49, 95% CI 0.30 to 0.79, $p = 0.004$), moderate quality of evidence.

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Conclusion: Our meta-analysis demonstrated that the ramping position may benefit surgical patients undergoing ETI by improving laryngeal exposure. Large scale well designed multicentre RCTs should be carried out to further elucidate the benefits of the ramping position in the surgical and intensive care unit patients.

PALAVRAS-CHAVE
Posição de rampa;
Posição olfativa;
Intubação traqueal;
Visualização laríngea;
Êxito na intubação

Comparação entre a posição de rampa e posição olfativa durante intubação traqueal: revisão sistemática e meta-análise

Resumo
Objetivos: A posição do paciente durante a Intubação Traqueal (IT) é fundamental para o sucesso do procedimento. Nosso objetivo foi determinar se a posição de rampa melhorou a visualização laríngea e o êxito na primeira tentativa de intubação quando comparada à posição olfativa.
Métodos: Os bancos de dados PubMed, EMBASE e Cochrane CENTRAL foram pesquisados de forma sistemática a partir da data em que os bancos de dados foram estabelecidos até janeiro de 2020. Nossos desfechos primários incluíram a visualização laríngea avaliada como Cormack-Lehane Grau 1 ou 2 (CLG 1/2), Cormack-Lehane Grau 3 ou 4 (CLG 3/4) e o êxito na primeira tentativa de intubação. Os desfechos secundários foram o tempo de intubação, uso de dispositivos adjuvantes para manuseio de vias aéreas, manobras auxiliares e complicações durante a IT.
Resultados: Sete estudos preencheram nossos critérios de inclusão, dos quais 4 eram Estudos Clínicos Randomizados (ECR) e 3 eram estudos de coorte. A meta-análise foi conduzida combinando as estimativas de efeito para todos os 4 ECR incluídos (n = 632). Não foram encontradas diferenças entre as posições de rampa e olfativa para razão de chances de CLG 1/2, CLG 3/4, sucesso na primeira tentativa de intubação, tempo de intubação, uso de manobras auxiliares das vias aéreas e uso de dispositivos adjuvantes de vias aéreas, havendo evidência de alta heterogeneidade nos estudos. No entanto, a posição de rampa em pacientes cirúrgicos está associada com maior probabilidade de CLG 1/2 (OR = 2,05; 95% IC 1,26 a 3,32; p = 0,004) e menor probabilidade de CLG 3/4 (OR = 0,49; 95% IC 0,30 a 0,79; p = 0,004), com qualidade moderada de evidência.
Conclusão: Nossa meta-análise demonstrou que a posição de rampa pode beneficiar pacientes cirúrgicos submetidos a IT, melhorando a visualização laríngea. ECR multicêntricos bem projetados com amostras grandes devem ser realizados para esclarecer ainda mais os benefícios da posição de rampa nos pacientes cirúrgicos e na unidade de terapia intensiva.

Introduction

The process of airway management by endotracheal intubation (ETI) is an essential skill required of every clinician. Failure to secure the airway can lead to severe morbidity and mortality for the patients involved, as well as damaging medicolegal repercussions. One of the most important components of successful laryngoscopy and ETI is good patient positioning. The Difficult Airway Society has recommended that all patients undergoing direct laryngoscopy with Macintosh-style laryngoscope should be placed in the classic supine ''sniffing'' position, defined as neck flexion and head extension at the atlanto-occipital joint. For obese patients, the ''ramped'' position is recommended as it improves the laryngeal view during direct laryngoscopy.[1]

In the past decade, a few clinical trials had shown that the ramping position, defined as the horizontal alignment between the sternal notch and the external auditory meatus, may provide a superior laryngeal view compared to other positioning for tracheal intubation.[2–8] In addition, it has been shown to reduce the risk of airway-related complications, reduce the need for ancillary airway maneuvers, reduce intubation time, and also improve the effectiveness of preoxygenation.[9–12] To date, no complications arising from the ramping position were reported, even though there is a theoretical risk of intracranial hypotension secondary to blood pooling in the lower extremities. However, recently the benefits of ramping position have been challenged. Semler et al conducted a randomized trial comparing the ramping and the sniffing positions in patients undergoing ETI in the Intensive Care Unit (ICU), and in their analysis of secondary outcomes, found that the ramped position worsened laryngoscopic view and reduced the rate of successful intubation at first attempt.[13]

In view of the conflicting data in the literature, there is a need to answer the question of whether the ramping position or the sniffing position is beneficial for patients undergoing ETI. To date, no systematic review or meta-analysis studying the effects of ramping position during ETI has ever been carried out. Hence, we decided to carry out a systematic review and meta-analysis of the literature, to determine if the ramping position improved laryngeal exposure and success at first intubation attempt when compared to the sniffing position for patients undergoing ETI.

Methods

The review protocol was prepared in advance and was registered on Prospero International Prospective Register of Systematic Reviews (PROSPERO ID-CRD42019124092). After a preliminary search of the database, we decided to amend the protocol to remove effectiveness of preoxygenation as one of our primary outcomes, as well as to include observational trials, due to limited studies available in the literature. The reporting of this review was carried out according to the ''Preferred Reporting Items for Systematic Review and Meta-Analysis'' (PRISMA) statement.[14]

Search strategy

We systematically searched for studies comparing the ramping position (intervention) and the sniffing position (control) in adult patients with more than 18 years old undergoing ETI (population). The electronic databases of PubMed, EMBASE, and Cochrane Controlled Register of Trials (CENTRAL) were used from their start date until January 12, 2020. The Clinicaltrials.gov registry and the WHO International Clinical Trials Registry Platform were searched for any ongoing or unpublished studies. All randomized controlled trials (RCTs) and observational studies were included in this review. Case reports, case series, and conference abstracts were excluded. In addition, studies comparing the ramping position with other body positioning apart from sniffing position (such as supine or modified ramping) were excluded. No restrictions were applied on language and date of publication. The reference lists of all the included studies were manually searched for additional studies. The search terms and strategy are shown in Table 1. The search strategy was devised and performed by two authors (SEHT and KTN).

In the literature, there were multiple ways of defining the ramping position. In this review, only studies defining the ramping position as the position in which there is horizontal alignment between the sternal notch (SN) and the external auditory meatus (EAM) (achieved with specialized pillows, blankets, elevation of head of bed, or other methods) would be included. The sniffing position is defined as supine positioning with flexion of the neck and extension of the head at the atlantooccipital joint, regardless of type of headrest used.

Primary and secondary outcomes

The primary outcomes of this review were laryngeal exposure and success rate at first intubation attempt, measured as a proportion. Laryngeal exposure was assessed using Cormack-Lehane (CLG) scale,[15] stratified into two grades; CLG 1 or 2 (CLG 1/2) and CLG 3 or 4 (CLG 3/4). Secondary outcomes included intubation time, use of ancillary maneuvers (external laryngeal maneuver, repositioning), use of airway adjuncts or equipment, and complications that arise during ETI (hypotension, hypoxia and other reported complications).

Study selection and data extraction

Two reviewers (JYL and NLV) independently screened titles and abstracts of articles obtained from the search process. Full texts of qualifying papers were then screened independently by the same two reviewers. Any disagreements between them during the screening and selection process were resolved by a third reviewer (SEHT). A data extraction sheet based on the Cochrane Consumers and Communication Review Group's data extraction template was developed and used after pilot testing. Data extraction was performed on selected studies by two reviewers (JYL and NLV), with any disagreements resolved by a third reviewer (SEHT). The following data items were extracted: citation, year of publication, trial design, country, type of population, sample size, sample characteristics, and outcome measures.

Risk of bias of included RCTs were assessed by using the Cochrane Collaboration Risk of Bias Assessment Tool (https://handbook.cochrane.org). Quality of observational studies was assessed with the Newcastle-Ottawa Scale.[16] Assessment was carried out independently by two authors (JYL and NLV), with disagreements resolved by a third author (SEHT). Selective reporting bias was assessed by comparing the selected studies with published protocols, or by comparing the methods and results sections. Quality of evidence of included RCTs was classified into high, moderate, low, or very low; and assessed with the GRADEpro GDT software (https://gradepro.org/).[17]

Summary measures and statistical analysis

The RevMan Review Manager Version 5.3 (The Cochrane Collaboration, Copenhagen, Denmark) was used to pool all the effect estimates of the measured outcomes. Pooled analysis was carried out separately for RCTs and observational trials. For dichotomous outcomes, the Mantel-Haenszel (M-H) model was used, and the findings were reported as odds ratio with 95% confidence intervals (CI). Continuous outcomes were analyzed with the inverse variance method and reported as mean difference (MD) with 95% CI. A two-sided *p*-value of less than 0.05 was considered as statistical significance. Heterogeneity was assessed with the Q test and quantified with I^2 test. Values of I^2 less than 40%, 40% to 60%, and more than 60% were classified as low, moderate and high heterogeneity, respectively. In anticipation of heterogeneity across the studies, the random-effects model was used to pool estimate. Prespecified exploratory subgroup analyses were performed for the primary outcomes, by stratifying the patients into population studied (surgical patients or patients in Intensive Care Unit – ICU) and presence of morbid obesity (defined as Body Mass Index – BMI $\geq$ 35 kg.m^{-2}).

Table 1 Search terms and strategy.

Database	Search string used	Articles
Pubmed	(B̈ack up[̈All Fields] OR ḧead Elevated[̈All Fields] OR ((b̈eds[̈MeSH Terms] OR b̈eds[̈All Fields] OR b̈ed[̈All Fields]) AND up[All Fields] AND (ḧead[̈MeSH Terms] OR ḧead[̈All Fields]) AND elevated[All Fields]) OR r̈amp*[̈All Fields]) AND ((ïntubation[̈MeSH Terms] OR ïntubation[̈All Fields]) OR (l̈aryngoscopy[̈MeSH Terms] OR l̈aryngoscopy[̈All Fields]) OR äirway management[̈All Fields] OR preoxygenation[All Fields])	86
EMBASE	((back up.mp.) OR (ramp*.mp.)) AND ((exp body position/or exp laryngoscopy/or exp head position/or exp body posture/or head elevated.mp. or exp endotracheal intubation/) OR (exp sniffing/or sniff.mp.) OR (airway management.mp.) OR (exp oxygenation/ or exp positive end expiratory pressure/or preoxygenation.mp.)) LIMIT to human	500
CENTRAL	ramp* or back up or head elevated or bed* AND sniff* AND airway management OR intubation OR laryngoscopy	21

Results

The search strategy yielded 607 articles for titles and abstracts screening, of which 18 articles were retrieved for full text screening. After applying inclusion and exclusion criteria, 7 studies with a total of 1917 patients were included in this review. No additional studies were found from searching references of reviews and included articles. The study selection process is summarized in the PRISMA flow diagram (Fig. 1). The list of excluded studies is shown in Table S1 (supplementary information), along with the reasons for exclusion. One relevant ongoing study was found for which no preliminary results had been published (Table S2, supplementary information).

Study characteristics

The clinical characteristics of included studies are shown in Table 2 . Four studies were RCTs,[3,4,7,13] while three were prospective cohort studies.[5,12,18] Four of the included studies examined the population of patients undergoing elective surgeries,[3,7,12,18] two on patients undergoing elective and emergency surgeries,[4,5] and one on the population of ICU patients.[13] One trial focused on morbidly obese patients,[3] whereas the rest of the studies included patients with BMI < 35 $kg.m^{-2}$.[4,5,7,12,13,18] Six of the included studies were conducted in a single centre,[3–5,7,12,18] while one study was conducted in four centres.[13] The interventions used to align the SN and EAM in these studies were ramping position via folded blankets,[3,4,7,18] troop elevation pillow,[5] and elevation of the head-of-bed.[12,13] The control group in all studies included patients placed in the supine sniffing position, which was achieved by flexing the neck (elevation of the occiput by using fixed size pillow or head rings) and extending the head (at the atlanto-occipital joint).

Overall, all included RCTs had low risk of bias for the majority of the domains. However, all RCTs had a high risk of bias for blinding of personnel, as it was impossible to blind the investigators to the positions the patients were placed in. Three RCTs were at high risk for the domain of blinding of outcome assessment,[4,7,13] while the study by Dhar et al. were found to have not carried out allocation concealment (Table 3).[4] All three prospective cohort studies achieved seven stars for all domains of the Newcastle-Ottawa Scale (Table S3, supplementary information). The PRISMA checklist is outlined in Table S4 (supplementary information). We did not perform an assessment for risk of publication bias as there were fewer than ten selected studies, in addition to the presence of significant heterogeneity across included studies.[19–21] The summary of findings/GRADE assessment of evidence quality is summarized in Table 4.

We had to contact the authors of three studies to obtain further data to conduct meta-analysis.[4,5,13] All responded, with only the study by Lebowitz et al. unable to provide the data requested as the principal investigator had retired, and the original trial data was not available.[5] As a result, we were unable to include Lebowitz et al. in the pooled estimates for the included observational trials. In total, seven studies were included for qualitative synthesis in the systematic review, while four RCTs and two observational trials were separately analyzed in the meta-analysis.[3,4,7,12,13,18]

Laryngeal exposure

All seven studies looked at the glottic exposure during laryngoscopy as part of their outcome assessment. When data from 4 RCTs (n = 632) were combined for statistical analysis, the ramping position was not significantly associated with higher odds for CLG 1/2 (M-H OR, random-effects 1.11, 95% CI 0.37 to 3.32; $p = 0.85$, very low quality of evidence), or a lower odds for CLG 3/4 (M-H OR, random-effects 0.90, 95% CI 0.30 to 2.70; $p = 0.85$, very low quality of evidence) when compared with the sniffing position. Significant heterogeneity was found for both outcomes ($I^2 = 82\%$) (Fig. 2).

Exploratory subgroup analysis of surgical patients (Fig. 3) showed significantly higher odds of CLG 1/2 (M-H OR, random-effects 2.05, 95% CI 1.26 to 3.32; $p = 0.004$; participants = 372; $I^2 = 0\%$; moderate quality of evidence), and lower odds for CLG 3/4 (M-H OR, random-effects 0.49, 95% CI 0.30 to 0.79; $p = 0.004$; participants = 372; $I^2 = 0\%$; moderate quality of evidence). On the other hand, only one study

Table 2 Characteristics of included studies.

Study	Country	Setting	Design	Sample size	Population	Interventions	Outcome measure(s)
Collins (2004)	USA	Single center OT	RCT	60	Obesity III (BMI $\geq$ 40) undergoing elective surgeries	1. Sniffing[a] 2. Ramped[a]	1. Glottic view (CLG) 2. Number of intubation attempts 3. Time to successful intubation
Lee (2015)	South Korea	Single center OT	RCT	193	General adult undergoing elective surgeries	1. Sniffing[b] 2. Ramped[b]	1. Glottic view (CLG) 2. Number of intubation attempts 3. Use of ancillary maneuvers
Semler (2017)	USA	Multicenter ICU	RCT	260	General adult ICU patients	1. Sniffing[c] 2. Ramped[c]	1. Lowest arterial oxygen saturation 2. Incidence of hypoxemia 3. Glottic view (CLG) 4. Difficulty of intubation 5. Number of intubation attempts 6. Time to successful intubation 7. Use of airway adjuncts 8. Use of ancillary measures
Dhar (2018)	India	Single center OT	RCT	134	General adult undergoing elective/emergency surgeries	1. Sniffing[d] 2. Ramped[d]	1. Glottic view (CLG) 2. Time to successful intubation 3. Number of intubation attempts 4. Use of airway adjuncts 5. Use of ancillary maneuvers
Lebowitz (2012)	USA	Single center OT	Prospective cohort study	189	General adult undergoing elective/emergency surgeries	1. Sniffing[e] 2. Ramped[e]	1. Glottic view (CLG)
Reddy (2016)	UK	Single center OT	Prospective cohort study	781	General adult undergoing elective surgeries	1. Sniffing[f] 2. Ramped[f]	1. Glottic view (CLG and POGO) 2. Number of intubation attempts 3. Use of airway adjuncts 4. Use of ancillary maneuvers 5. Time to successful intubation
Nayak (2019)	India	Single center OT	Prospective cohort study	300	General adult undergoing elective surgeries	1. Sniffing[g] 2. Ramped[g]	1. Glottic view (CLG)

USA, United States of America; UK, United Kingdom; OT, Operating Theatre; ICU, Intensive Care Unit; RCT, Randomized Controlled Trial; CLG, Cormack Lehane Grade; POGO, Percentage Of Glottic Opening scale; EAM, External Auditory Meatus; SN, Sternal Notch.

[a] Sniffing (7 cm occiput elevation); Ramped (EAM aligned with SN by stacking multiple folded blankets).
[b] Sniffing (8 cm occiput elevation); Ramped (Folded blanket placed on a flat OT table).
[c] Sniffing (neck flexed; head extended); Ramped (Head of bed elevated to 25°).
[d] Sniffing (fixed sized pillow); Ramped (EAM aligned with SN by custom-sized pillow with additional folded sheets).
[e] Sniffing (7 cm occiput elevation); Ramped (Troop elevation pillow).
[f] Sniffing (head ring or non-compressible pillow); Ramped (25° back of table elevation with break at the middle of the OT table).
[g] Sniffing (method not specified); Ramped (pillow 10 cm below head, with drapes and table tilt to endpoint of EAM alignment with SN).

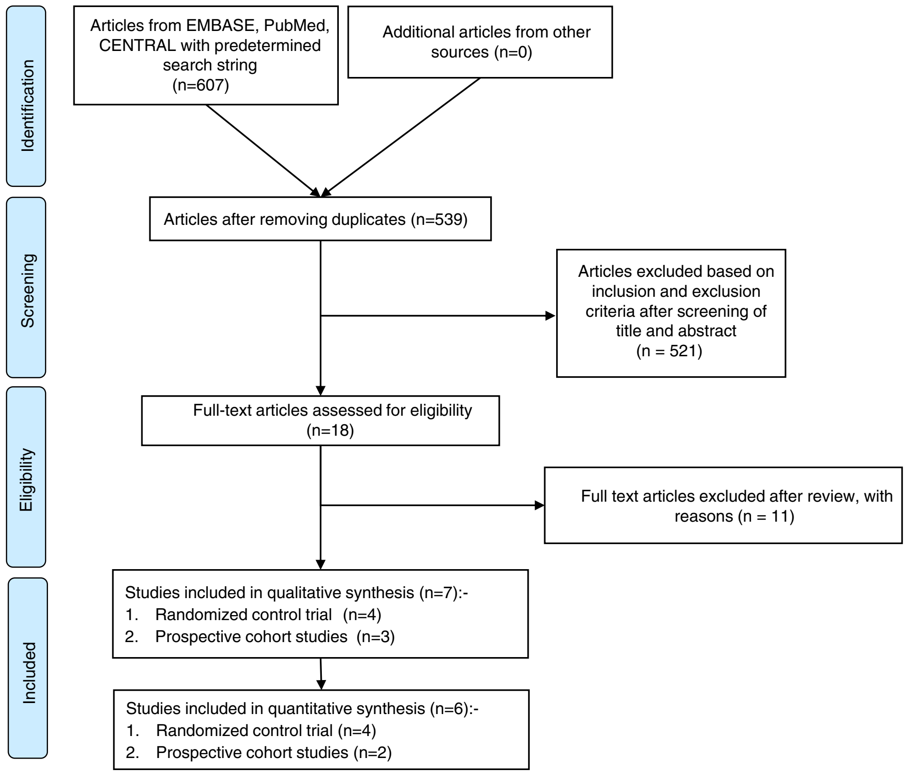

Figure 1 PRISMA flow diagram.

Table 3 Cochrane risk of bias assessment for included randomized controlled trials.

Study	Domains						
	Sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective outcome reporting	Other sources of bias
Collins, 2004	Low	Low	High	Low	Low	Low	Low
Lee, 2015	Low	Unclear	High	High	Low	Low	Low
Semler, 2017	Low	Low	High	High	Low	Low	Low
Dhar, 2018	Low	High	High	High	Low	Low	Low

looked at the patients in ICU, which found that the ramping position was significantly associated with less CLG 1/2 and more CLG 3/4 views compared to the sniffing position. Subgroup analysis of morbidly obese patients showed similar results for both ramping and sniffing, with no statistical difference between both groups for both CLG 1/2 and CLG 3/4 views (Fig. S1, supplementary information).

For the prospective cohort studies done in surgical patients undergoing ETI, pooled estimates from two studies did not find any significant difference in glottic views between the two groups (Fig. S2, supplementary information). Lebowitz et al. found that anesthetists reported significantly better or equal laryngeal exposure in the ramping position compared to the sniffing position, regardless of BMI (*p*-values ranging from 0.0116 to < 0.0001).

First attempt success at intubation

Reddy et al., in a prospective cohort study, found no difference between first attempt success at intubation between the ramping and sniffing positions (90.5% success at first laryngoscopy and first intubation attempt). In this meta-analysis combining four RCTs involving 632 patients, we found that the ramping position was not significantly superior compared to the sniffing position (M-H OR, random-effects 0.89, 95% CI 0.33 to 2.41; $p = 0.82$; $I^2 = 77\%$; very low quality of evidence) (Fig. 2). Subgroup analysis of surgical/ICU population (Fig. 3) and morbidly obese patients (Fig. S1, supplementary information) were similarly not significant.

Table 4 Summary of findings and GRADE assessment of quality of evidence.

Outcomes	Nº of participants (studies) follow-up	Certainty of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with sniffing	Risk difference with ramping
CLG 1/2	632 (4 RCTs)	⊕◯◯◯ Very low[a,b,c,d]	OR 1.11 (0.37 to 3.32)	710 per 1,000	21 more per 1,000 (235 fewer to 180 more)
CLG 3/4	632 (4 RCTs)	⊕◯◯◯ Very low[a,b,c,d]	OR 0.9 (0.3 to 2.7)	290 per 1,000	21 fewer per 1,000 (181 fewer to 234 more)
Success at first intubation attempt	632 (4 RCTs)	⊕◯◯◯ Very low[a,b,c,d]	OR 0.89 (0.33 to 2.41)	682 per 1,000	26 fewer per 1,000 (268 fewer to 156 more)
CLG 1/2 in OT patients	372 (3 RCTs)	⊕⊕⊕◯ Moderate[a,d]	OR 2.05 (1.26 to 3.32)	587 per 1,000	157 more per 1,000 (55 more to 238 more)
CLG 3/4 in OT patients	372 (3 RCTs)	⊕⊕⊕◯ Moderate[a,d]	OR 0.49 (0.30 to 0.79)	413 per 1,000	157 fewer per 1,000 (239 fewer to 56 fewer)

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

CLG 1/2, Cormack-Lehane Grade 1 or 2; CLG 3/4, Cormack-Lehane Grade 3 or 4; OT, operating theatre; CI, Confidence Interval; OR, Odds Ratio; MD, Mean Difference.

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.

[a] High risk of bias due to no blinding of personnel during intubation.

[b] Heterogeneity more than 60%.

[c] Wide confidence interval.

[d] Very few published studies available in the literature (< 10 studies).

Secondary outcomes

Three RCTs involving 439 patients studied the intubation time. There was no significant difference between groups (MD, random-effects -0.20, 95% CI -4.58 to 4.18; $p = 0.93$; $I^2 = 70\%$) (Fig. S3, supplementary information). In view of the large heterogeneity caused by Semler et al.'s study, which was carried out in patients in ICU, we decided to perform a post hoc subgroup analysis of surgical patients by excluding data from the Semler et al. study. This subgroup analysis showed a non-significant trend for shorter intubation time in the ramping position (MD, random-effects -1.61, 95% CI -3.25 to 0.03; $p = 0.05$; 179 participants; $I^2 = 0\%$) (Fig. S4, supplementary information). Reddy et al. reported significantly shorter duration in the ramping position when compared to the sniffing position (median time 24 vs. 28 s, $p = 0.001$), regardless of experience level of intubating anesthetists.

Three RCTs involving 572 patients were included in the meta-analysis for usage of ancillary laryngeal maneuvers during intubation, and no significant difference in odds was found between the ramping and sniffing positions (M-H OR, random-effects 0.79, 95% CI 0.33 to 1.91; $p = 0.61$; $I^2 = 73\%$) (Fig. S3, supplementary information). A post hoc subgroup analysis was conducted investigating the use of ancillary laryngeal maneuvers in the surgical population (by excluding Semler et al.'s study), and we found that the ramping position demonstrated a non-significant trend for reduced odds of requiring ancillary laryngeal maneuvers (M-H OR, random-effects 0.54, 95% CI 0.28 to 1.05; $p = 0.07$; 312 participants; $I^2 = 52\%$) (Fig. S4, supplementary information). Additionally, Reddy et al. demonstrated that the ramping position is associated with less frequent usage of ancillary laryngeal maneuvers (19.6% vs. 24.6%, $p = 0.004$).

Only two RCTs involving 379 patients reported use of airway adjuncts or equipment during intubation comparing between ramping and sniffing positions. There was no difference between groups (M-H OR, random-effects 1.76, 95% CI 0.43 to 7.27; $p = 0.43$), with evidence of high heterogeneity ($I^2 = 83\%$) (Fig. S3, supplementary information). Similarly, Reddy et al. reported no difference in use of ancillary equipment during intubation between the ramping and sniffing positions.

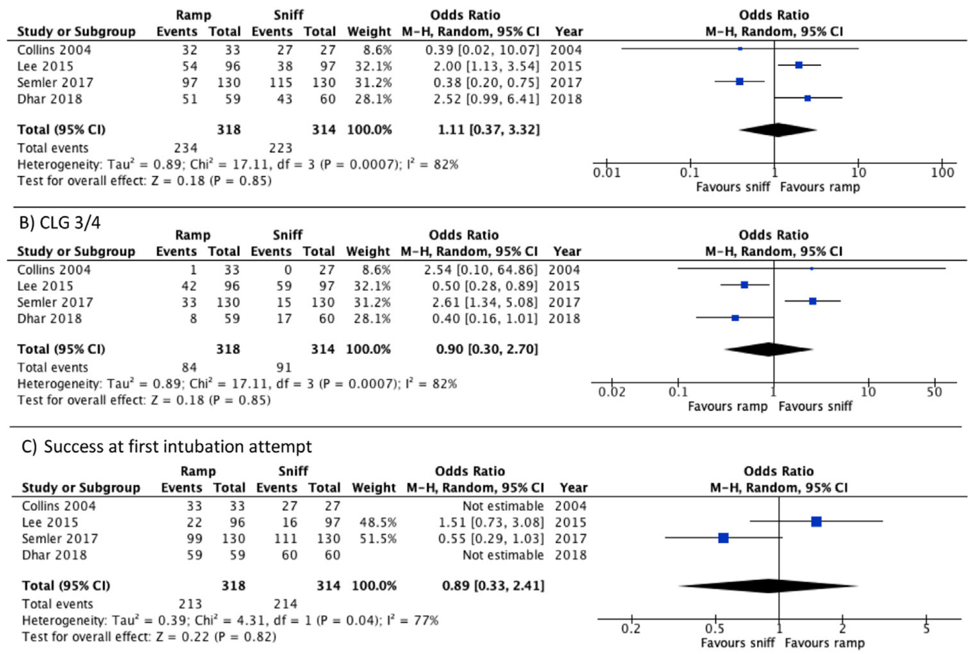

Figure 2 Meta-analysis of primary outcomes comparing between ramping and sniffing positions. A) Forest plot of incidence of CLG 1/2; B) Forest plot of incidence of CLG 3/4; C) Forest plot of incidence of success at first intubation attempt. Random-effects model used for data analysis. CLG 1/2, Cormack-Lehane Grade 1 or 2; CLG 3/4, Cormack-Lehane Grade 3 or 4; M-H, Mantel-Haenszel.

None of the included trials reported complications related to the ramping or sniffing position. There was also no report of occurrences of hypotension in the ramping group.

Discussion

To our knowledge, this is the first systematic review and meta-analysis comparing ramping and sniffing positions for ETI. In this meta-analysis, we found no differences between ramping or sniffing position with regards to laryngeal exposure, success at first intubation attempt, intubation time, and use of ancillary laryngeal maneuvers or equipment during ETI. However, these results should be interpreted with caution in view of the high level of heterogeneity (I^2 more than 60%). Subgroup analysis showed that surgical patients were more likely to have better laryngeal exposure during intubation with ramping position. No complications of the ramping position were reported in all the included trials.

This meta-analysis did not investigate the benefits of preoxygenation in the ramping position, since there were no trials comparing the ramping and sniffing positions with regards to this outcome (trials compared the ramping and supine positions). This potential benefit of the ramping position is attributed to the increase in patients' functional residual capacity and is a topic for future meta-analysis. Also, none of the included trials reported any complication in the ramping position. There is a possible risk of intracranial hypotension in patients placed in the ramping position when coupled with induction of anesthesia, and this should be investigated in future studies.

In this systematic review and meta-analysis, we have chosen laryngeal exposure as one of our primary outcomes. It has been shown that difficult laryngoscopy is not always associated with difficult intubation.[22] However, poor visualization of the vocal cords is a known cause of difficult intubation. The American Society of Anesthesiologists reported difficult laryngoscopy, where no portion of the glottis can be visualized, as one of the descriptors of difficult airway.[23] Also, the Intubation Difficulty Scale, a more objective indicator of total intubation difficulty, has included glottic exposure as one of its parameters, potentially contributing up to 3 points, with counts above zero indicating slight, moderate, or major difficulty.[24] Hence, we believe that laryngeal exposure is a clinically important outcome, contributing to the success of ETI.

We noted significant heterogeneity in the results of this meta-analysis. . We attempted to reduce it by standardizing the definitions of the ramping and sniffing positions a priori and excluded studies that do not conform to this definition. When exploratory subgroup analysis was carried out, we identified one of the sources of heterogeneity being the different types of patient populations. Among the 4 included RCTs, Semler et al.'s study was conducted in patients in ICU. They studied ETI in critically ill patients, and in their analysis of secondary outcomes found that the ramping position increased the incidence of CLG 3/4 views and the number of laryngoscopy attempts required for successful intubation.[13] These results differed markedly from other trials conducted in surgical patients. Excluding Semler et al.'s study significantly reduced the heterogeneity as measured by the I^2 value across all our outcomes. The differences between intubations in the surgical patients and patients in ICU have been attributed to factors related to the operator, patient, and environment. Surgical patients are optimized preoperatively and intubated in a strictly controlled environment. On the other hand, intubations in ICU usually occur in emergency scenar-

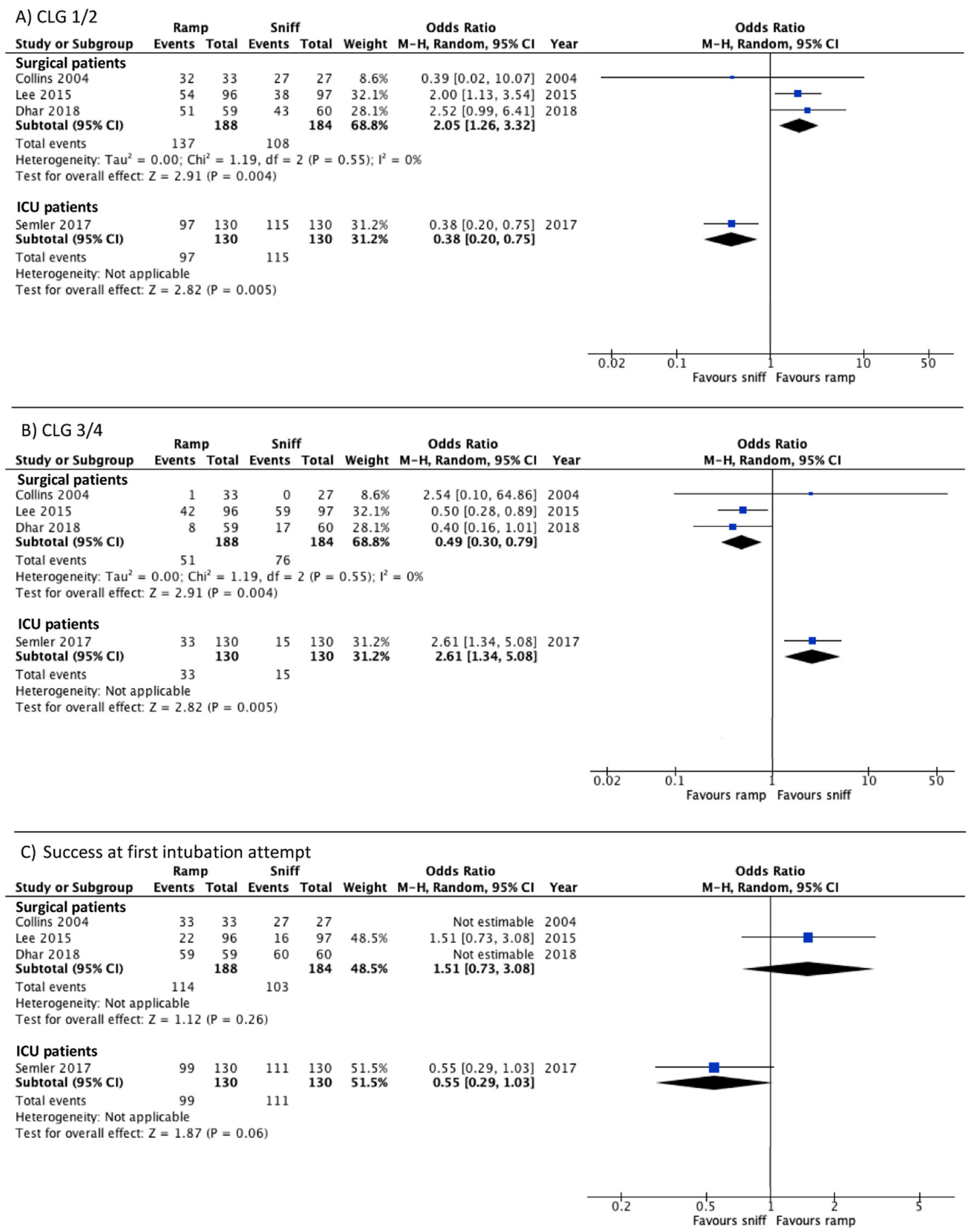

Figure 3 Subgroup analysis based on surgical patients and ICU patients for primary outcomes, comparing between ramping and sniffing positions. A) Forest plot of incidence of CLG 1/2; B) Forest plot of incidence of CLG 3/4; C) Forest plot of incidence of success at first intubation attempt. Random-effects model used for data analysis. CLG 1/2, Cormack-Lehane Grade 1 or 2; CLG 3/4, Cormack-Lehane Grade 3 or 4; M-H, Mantel-Haenszel.

ios, with patients having diverse physiological disturbances, and taking place in a suboptimal environment (limited space, poor lighting, suboptimal bed characteristics).[25] These may be the reasons for the observed differences between trials investigating surgical patients and patients in ICU.

In this review, we did not find a significant difference between the ramping and sniffing positions with regards to success at first intubation attempt. Out of the 4 included RCTs, 2 studies did not find any incidence of failure at first intubation attempt, and hence no odds ratios were able to be computed. This may be due to the low incidence of difficult intubation in the surgical population, ranging from 1 in 1,000 to 2,000.[26] In order to detect a difference between the ramping and sniffing position, studies would require very large sample sizes, which may not be feasible due to various constraints. This could also explain the lack of differences seen between both groups with regards to our primary and secondary outcomes. In the future, large-scale multicenter trials which have been adequately powered should be carried out to determine whether the ramping position is more superior to the sniffing position.

This review has some limitations. First, we included prospective cohort studies into the review as there were few RCTs available in the literature based on our search criteria. This may have lowered the strength of the evidence. However, we performed the meta-analysis separately, by pooling the effects of included RCTs and observational studies independently. Second, all included RCTs had a high risk of bias, mainly due to no blinding of personnel, as theintubators could not be blinded to the head position of patients. In addition, three studies did not perform blinding of outcome assessment. All these could have introduced bias into the results obtained in these trials. Third, we excluded case reports, case series, and conference abstracts from inclusion into the meta-analysis, potentially contributing to risk of publication bias in this review. However, we accepted this risk in order to ensure only good quality trials that have underwent peer review are included in the review, thereby increasing the reliability of our findings. We did not perform an assessment of publication bias due to the small number of included trials, as current methods of publication bias assessment are of insufficient power.[21] Finally, there was evidence of significant heterogeneity in our review, due to differences in both clinical and methodological factors in the included studies. However, we attempted to reduce this heterogeneity by performing subgroup analysis of our findings. Further large scale multicenter RCTs should be performed to reduce the occurrences of these confounders and determine the differences between ramping and sniffing position during ETI.

Our meta-analysis found that the ramping position and sniffing positions did not differ significantly regarding laryngeal exposure and success at first attempt intubation. However, the ramping position is associated with improved laryngeal exposure in surgical patients. We recommend that clinicians should consider using the ramping position as a starting position for intubation in all surgical patients, in view of this benefit and no proven adverse effects. Well-designed, large-scale, multicenter trials should be carried out in the future to further elucidate the advantages and disadvantages of the ramping position in the surgical and ICU patients.

Conflicts of interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.bjane.2020.10.007.

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