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Respiration and the Airway

RESPIRATION AND THE AIRWAY

Supraglottic airway device *versus* tracheal intubation and the risk of emergent postoperative intubation after general anaesthesia in adults: a retrospective cohort study

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Abstract

Background: We examined the association between emergent postoperative tracheal intubation and the use of supraglottic airway devices (SGAs) *vs* tracheal tubes.

Methods: We included data from adult noncardiac surgical cases under general anaesthesia between 2008 and 2018. We only included cases (n=59 991) in which both airways were deemed to be feasible options. Multivariable logistic regression, instrumental variable analysis, propensity matching, and mediation analysis were used.

Results: Use of a tracheal tube was associated with a higher risk of emergent postoperative intubation (adjusted absolute risk difference [ARD]=0.80%; 95% confidence interval (CI), 0.64–0.97; P<0.001), and a higher risk of post-extubation hypoxaemia (ARD=3.9%; 95% CI, 3.4–4.4; P<0.001). The effect was modified by the use of non-depolarising neuromuscular blocking agents (NMBAs); mediation analyses revealed that 28.9% (95% CI, 14.4–43.4%; P<0.001) of the main effect was attributable to NMBA. Airway management modified the association of NMBA and risk of emergent postoperative intubation ($P_{interaction}$=0.02). Patients managed with an SGA had higher odds of NMBA-associated reintubation compared to patients managed with a tracheal tube (adjusted odds ratio [aOR]=3.65, 95% CI, 1.99–6.67 *vs* aOR=1.68, 95% CI, 1.29–2.18 [P<0.001], respectively).

Conclusions: In patients undergoing procedures under general anaesthesia that could be managed with either SGA or tracheal tube, use of an SGA was associated with lower risk of emergent postoperative intubation. The effect can partly be explained by use of NMBAs. Use of NMBAs in patients with an SGA appears to increase the risk of emergent postoperative intubation.

Keywords: airway management; emergent postoperative intubation; neuromuscular blocking agent; oxygen desaturation; supraglottic airway device; tracheal tube

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Editor's key points

- The risk of emergent postoperative tracheal intubation in relation to the type of airway device remains unclear.
- In a large retrospective study, the authors analysed outcomes in 59 991 adults for whom both airway devices were feasible options.
- The use of a tracheal tube was associated with a higher risk of emergent postoperative intubation and hypoxaemia after tracheal extubation.
- Neuromuscular block appeared to attenuate any benefit of using a supraglottic airway device in reducing the risk of emergent tracheal intubation.

Postoperative respiratory failure requiring emergent postoperative tracheal intubation is a severe complication and associated with significant morbidity and mortality.[1–5] The Agency for Healthcare Research and Quality within the US Department of Health and Human Services has identified emergent postoperative intubation after surgery in adult patients as a quality indicator.[2]

In a randomised trial in paediatric patients the use of a supraglottic airway device (SGA) compared with tracheal intubation reduced the risk of respiratory complications.[6] Although patients with SGA did not receive neuromuscular blocking agents (NMBAs), those were used in one-fifth of the patients who were tracheally intubated. In adults, SGA compared with tracheal tube may reduce airway complications, respiratory complications, or both.[7–9] We hypothesised that SGA, compared with tracheal tube, decreases the risk of emergent postoperative intubation in patients undergoing surgery under general anaesthesia. Furthermore, we hypothesised that differences in NMBA use may, in part, explain differences in risk for emergent postoperative intubation.

Methods

Study design

In this retrospective cohort study, we analysed surgical cases performed at two different hospitals and one ambulatory clinical centre of the Beth Israel Lahey Health Performance Network (BILHPN), Massachusetts, between January 2008 and December 2018. The study used de-identified data from the institutional Anesthesia Research Data Repository, which was approved by the Committee on Clinical Investigations at BIDMC (number #2018P000666). The requirement for informed consent was waived. Data sources are described in Supplementary material, Section 1.1.

Patient selection

We included adult surgical patients undergoing surgery under general anaesthesia with planned extubation at the end of the case. To allow comparison between different airway management strategies, we only included surgery types that had been conducted with both SGA or tracheal tube, in reasonable numbers in the past 10 yr of practice. Surgeries were grouped based on previously published Clinical Classifications Software (CCS) categories, a systematic categorisation of Current Procedural Terminology (CPT) codes. For each category, we calculated the percentage of SGAs used and only included categories in which each airway device was used in at least 10% of cases. Surgical procedure types selected for inclusion were manually reviewed for clinical plausibility. A full list of all included CCS categories is presented in Supplementary Table S2. We further excluded cases of brain-dead organ donors and cases that were already intubated prior surgery. Cases with missing data for confounders were excluded for complete case analyses.

SGA device utilisation

Until January 2017, the LMA® Unique™ airway device was predominantly used in our institutions. Since then, the iGel® is used in >90% of all cases in which SGA devices are used.

Exposure

The primary exposure variable was defined by the choice of airway device as either the use of an SGA or tracheal tube. Use of SGA was considered the reference group. If patients were converted from SGA to tracheal tube during the case, they were still considered SGA.

Primary outcome

The primary outcome was respiratory failure requiring emergent postoperative intubation within 7 days after surgery, as previously studied.[10–12] As co-primary endpoints we assessed time-dependency of emergent postoperative intubation using a Cox proportional hazards model and possible mediations of the association between the use of tracheal tubes and emergent postoperative intubations through intraoperative use of non-depolarising NMBAs, succinylcholine, neostigmine, and opioids using path mediation analysis. Details about mediation analysis are presented in the Supplementary material, Section 1.5.

Secondary outcomes

We assessed the following secondary outcomes:

1. Extubation hypoxaemia, defined as peripheral oxygen saturation measurements <90% in the operating room within 10 min after extubation
2. Intraoperative vasopressor use, measured as norepinephrine equivalent dose in mg
3. Time to extubation/SGA removal
4. Duration of stay in the PACU
5. Incidence of pneumonia during the hospital stay as a marker for possible gastric aspiration during surgery

Statistical analyses

We included *a priori* defined, previously established confounding variables for postoperative respiratory complications and predictors of postoperative respiratory complications, and demographic, surgery, and anaesthesia-related covariates into a confounder model.[10,12] (Supplementary material, Sections 1.2 and 1.3). The linearity assumption was tested for all continuous variables. In case of non-linearity, we divided variables into quintiles or clinically meaningful categories.

We conducted logistic or negative binomial regression analyses; results are reported as odds ratios (OR) and absolute risk difference with 95% confidence intervals (CI), respectively. We first tested the primary hypothesis that the use of a tracheal tube as opposed to an SGA was associated with an increased risk of emergent postoperative intubation. Only in case of a significant association, we performed the co-primary analyses, time-dependency of emergent postoperative intubation using a Cox proportional hazards regression analysis including all covariates from the primary logistic regression model and formal mediation analysis. The proportional hazards assumption was tested and confirmed through visual inspection of log–log survival curves and Schoenfeld residuals.

Interaction term analyses were conducted to assess effect modifications. Linear combinations were applied to integrate the effect modification in the effect size calculation. Statistical significance was assumed at $P<0.05$. All analyses were performed using Stata (version 15; StataCorp LLC, College Station, TX, USA).

Sensitivity analyses

We assessed the robustness of the primary findings through multiple sensitivity analyses. First, we performed a propensity score-matched analysis based on the primary confounder model between cases receiving SGA and tracheal tube (Supplementary material, Section 1.4). We then explored the association of airway management choice and emergent postoperative intubations in different categories of a propensity score for tracheal intubation across the range from high to low probability of receiving a tracheal tube. Furthermore, we reconducted the primary analysis after excluding emergency surgeries, cardiothoracic cases, cases converted from SGA to tracheal tube and ambulatory surgeries and with additional confounder control for year of surgery and provider type (attending anaesthesiologist, nurse anaesthetist, or resident). To evaluate effect modification by spontaneous breathing *vs* mechanical ventilation on emergent postoperative intubations, we performed propensity matching with the ventilation mode as an additional matching factor. To address the change in SGA type at our institution in January 2017, we conducted additional sensitivity analyses, (1) excluding all cases performed after January 1, 2017 and (2) examining the primary analysis only in the most recent 5 yr.

In addition, to account for unmeasured confounding that may have biased results obtained from a standard logistic regression model, we used an instrumental variable analysis.[13] Considering a downward trend of tracheal tube *vs* SGA use during the more recent years, we tested whether year of surgery would be a valid instrumental variable. An instrumental variable analysis can be used in situations where the instrument (year of surgery) is associated with the exposure (choice of airway device, tracheal tube *vs* SGA), whereas it is not associated with the clinical outcome (reintubation) except through its effect on the exposure.[14] We tested year of surgery (dichotomised into two time periods) as an instrumental variable. More details on the instrumental variable analysis are presented in Supplementary material, Section 1.6.

Furthermore, we changed the primary inclusion criteria to derive a more homogenous cohort by only including CCS categories in which >20%, >30%, and >40% of both airway devices were used. In the cohort with >40% of both airway devices used, an additional propensity score matching was conducted. Finally, we re-conducted the primary analyses following multiple imputation of missing values with chained equations (Supplementary material, Section 3). Additional sensitivity analyses are presented in Supplementary material, Section 2.

Exploratory analyses

We assessed if the association between the airway device and emergent postoperative intubation was modified by the duration of surgery or by a high patient comorbidity load, defined as ASA physical status ≥3. In addition, we explored the association between the airway device and emergent postoperative intubation in subgroups of low and high procedural complexity, as defined by lowest and highest quintile of work-relative value units (work RVU), and in subgroups of surgical duration (<60, 60–119, and ≥120 min). In addition, we conducted interaction term analyses between (a) non-depolarising NMBAs and (b) obesity, defined as a BMI >30, and the airway device for the primary outcome.

Analysis of provider variability

We assessed variability in the preference for a specific airway device between anaesthesia providers as previously conducted for other intraoperative factors.[12] We then tested whether the association between the airway device and emergent postoperative intubation remained robust when accounting for the individual anaesthesia provider as random effect in a mixed-effects logistic regression model (Supplementary material, Section 4).

Results

Study population

In total, 59 991 adult surgical patients were included in our study. After exclusion of ineligible cases and cases with missing confounder variable information, the final primary study cohort consisted of 56 068 cases (Fig. 1). Overall, 27 398 (48.9%) cases received an SGA, whereas 28 670 (51.1%) received a tracheal tube. Baseline characteristics are shown in Table 1. Supplementary Figure S1 depicts changes over time in the rate of reintubation and the choice of airway device.

Primary outcome

Sixty-nine out of 27 398 (0.3%) SGA cases and 367 out of 28 670 (1.3%) tracheal tube cases required emergent postoperative intubation. In adjusted analyses, the use of a tracheal tube was associated with a higher risk of emergent postoperative intubation compared with the use of an SGA (adjusted odds ratio [aOR]=3.89, 95% CI, 2.85–5.31, $P<0.001$; adjusted absolute risk difference=0.80%, 95% CI, 0.64–0.97, $P<0.001$). Time-to-event analyses revealed a higher hazard ratio for emergent postoperative intubation in cases undergoing tracheal tube intubation (hazard ratio=3.80; 95% CI, 2.81– to 5.16; $P<0.001$), particularly on the day of surgery (Fig. 2). The formal mediation analysis found that NMBA use was higher in patients receiving a tracheal tube (aOR=102.39; 95% CI, 93.08–112.63; $P<0.001$; Fig. 3; Supplementary Table S3). Intraoperative NMBA use was associated with higher risk of emergent postoperative intubation within 7 days after surgery (aOR=1.87; 95% CI, 1.45–2.40; $P<0.001$). The intraoperative use of NMBA mediated 28.9% (95% CI, 14.4–43.3%; $P<0.001$) of the effect of tracheal tube use on emergent postoperative intubation, whereas opioids, succinylcholine, and neostigmine did not mediate the observed effect ($P=0.45$, $P=0.33$, and $P=0.73$, respectively).

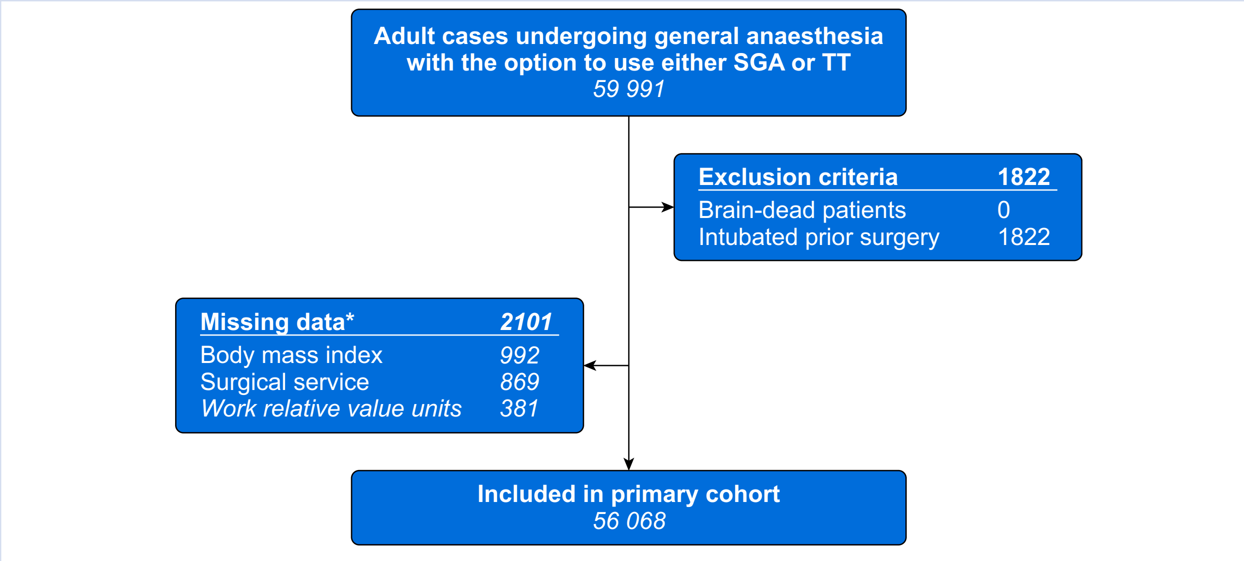

Fig 1. Study flow diagram. Study flow diagram depicting number of cases in our study cohort. SGA, supraglottic airway device; TT, tracheal tube.

Secondary outcomes

The use of tracheal tubes was associated with a higher risk of post-extubation hypoxaemia when compared with SGA (aOR=1.74, 95% CI, 1.61–1.87, *P*<0.001; adjusted absolute risk difference=3.9%, 95% CI, 3.4–4.4, *P*<0.001). There was no association between the airway device and vasopressor requirements during surgery (adjusted coefficient=0.001 mg phenylephrine equivalents; 95% CI −0.030 to 0.032; *P*=0.95). In subgroups with available data, the use of a tracheal tube was associated with an increased time between end of procedure and airway device removal (adjusted time difference=1.8 min; 95% CI, 1.7–1.9; *P*<0.001, *n*=55 588) and length of stay in the PACU (adjusted time difference=13.4 min; 95% CI, 11.9–14.9; *P*<0.001, *n*=53 236). Tracheal tube use was associated with a higher risk for pneumonia during the hospital stay compared with SGA (aOR=1.86; 95% CI, 1.48–2.34; *P*<0.001).

Sensitivity analyses

Primary findings remained robust in sensitivity analyses (Supplementary material, Section 2; 30 688 cases [15 344 with SGA, 15 344 with tracheal tube]) were matched based on their propensity for receiving an SGA, confirming results from the primary analysis (aOR for emergent postoperative intubation with tracheal tube=3.97, 95% CI, 2.72–5.78, *P*<0.001; adjusted absolute risk difference=0.65%, 95% CI, 0.49–0.82%, *P*<0.001). Matched cohort characteristics are presented in Supplementary Table S6. Findings from the primary analysis were further reflected in subgroup analyses based on quintiles of the propensity score to receive a tracheal tube (Supplementary material, Section 2.1.2; Supplementary Table S7). Furthermore, our results remained robust after exclusion of emergency surgeries, cardiothoracic cases, cases converted from SGA to tracheal tube, and outpatient surgeries. Also, the unique association of SGA and reintubation risk remained stable after additionally adjusting for the year of surgery, spontaneous vs controlled breathing and provider profession (Supplementary material, Section 2).

Instrumental variable analysis

Year of surgery (dichotomised into two time periods) was a valid instrumental variable that was related to the exposure (choice of airway device) but not directly to the outcome (emergent postoperative intubation). We therefore assumed that the patient population at risk for postoperative reintubation did not vary much across the study period[15]; however, patients undergoing surgery during the more recent years were more likely to receive an SGA. Our instrument yielded a Wald *F*-statistic of 124.4, indicating the required instrument strength (i.e. Wald *F*-statistic >10).[16] The instrumental variable analysis confirmed our finding, regarding the association between the use of tracheal tube *vs* SGA and emergent postoperative intubation (adjusted absolute risk difference=3.2%; 95% CI, 2.0–4.4%; *P*<0.001). Results remained robust stricter cut-off values for inclusion of CCS categories (Table 2). Multiple imputation of missing data added 2101 patients to the primary analysis and confirmed results from the primary analysis (Supplementary material, Section 3). Further exploratory analyses are provided in Supplementary material.

Analysis of provider variability

In our cohort, anaesthesia care was provided by 423 individual providers. The individual provider's mean predicted probability for using tracheal tube *vs* SGA ranged from 20% to 89% (Supplementary Fig. S2). Provider variability had no impact on the association between the airway device and emergent postoperative intubation (aOR=3.84; 95% CI, 2.79–5.28; *P*<0.001). Details are presented in Section 4 of the Supplementary material.

Table 1 Patient cohort characteristics.

Factor	Use of supraglottic airway	Use of tracheal intubation
N	27 398 (48.9%)	28 670 (51.1%)
Emergent postoperative intubations within 7 days after surgery	69 (0.25%)	367 (1.28%)
Post-extubation desaturation <90% SpO_2	1538 (5.6%)	3362 (11.7%)
Patient characteristics		
Age, yr	52 [16]	54 [17]
Male	12 972 (47.3%)	14 293 (49.9%)
BMI, kg m^{-2}	27.2 [5.5]	29.3 [7.4]
ASA physical status	2 (2, 2)	2 (2, 3)
Emergency surgery	809 (3.0%)	2847 (9.9%)
Comorbidities		
Charlson comorbidity index	0 (0, 2)	0 (0, 2)
Chronic obstructive pulmonary disease	1060 (3.9%)	1205 (4.2%)
Congestive heart failure	830 (3.0%)	1540 (5.4%)
Smoking	1976 (7.2%)	2752 (9.6%)
High SPORC	513 (1.9%)	1002 (3.5%)
Surgical service		
Cardiothoracic	2236 (8.2%)	648 (2.3%)
General/Abdominal	2718 (9.9%)	2199 (7.7%)
Gynaecology	3140 (11.5%)	2712 (9.5%)
Neurosurgery	162 (0.6%)	656 (2.3%)
Oncology	1471 (5.4%)	1241 (4.3%)
Oral/maxillofacial/eye	1485 (5.4%)	1981 (6.9%)
Orthopaedic	10 997 (40.1%)	10 401 (36.3%)
Plastic	909 (3.3%)	2862 (10.0%)
Trauma	162 (0.6%)	545 (1.9%)
Urology	3589 (13.1%)	4077 (14.2%)
Vascular	529 (1.9%)	1348 (4.7%)
Intraoperative factors		
Work relative value units	7.03 (4.47, 9.38)	8.41 (5.37, 13.78)
Duration of surgery, min	72 (54, 102)	113 (79, 159)
Intraoperative fluid volume, ml	700 (500, 900)	1000 (700, 1200)
NMBA, multiples of ED_{95}	0.00 (0.00, 0.00)	1.10 (0.00, 2.03)
Age-adjusted mean alveolar concentration	0.97 (0.82, 1.11)	0.98 (0.85, 1.12)
Use of neostigmine	283 (1.0%)	13 764 (48.0%)
Mean arterial pressure <55 mm Hg, min	0.00 (0.00, 1.00)	0.00 (0.00, 3.00)
Vasopressors dose, mg of phenylephrine equivalent	0.00 (0.00, 0.00)	0.00 (0.00, 0.04)
FiO_2	60.30 [18.46]	57.01 [16.15]
PEEP, mbar	2.00 (1.52, 3.00)	4.00 (2.00, 5.07)
PIP, mbar	11.64 [4.80]	20.86 [5.47]
Median tidal volume, ml	346.64 [109.89]	559.17 [111.22]
Tidal volume, ml kg body $weight^{-1}$	5.51 [1.72]	8.90 [2.15]
SF ratio	178.23 [54.09]	186.47 [52.78]
Harmful ventilation	1169 (4.3%)	6718 (23.4%)
Long-acting opioid dose, mg oral morphine equivalent dose	0.00 (0.00, 0.00)	0.00 (0.00, 13.60)
Short-acting opioid dose, mg oral morphine equivalent dose	18.75 (6.25, 25.00)	25.00 (25.00, 50.00)

Data represent mean [standard deviation], median [inter-quartile range] or number (percentage). ASA, American Society of Anesthesiologists; FiO_2, fraction of inspired oxygen; NMBA, non-depolarising neuromuscular blocking agents; PIP, peak inspiratory pressure; SF, SpO_2/FiO_2. SPORC, Score for the Prediction of Postoperative Respiratory Complications.

Discussion

In this study, adult patients undergoing urologic, gynaecologic, ENT, ophthalmologic, and orthopaedic procedures who underwent procedures which can be conducted equally well using an SGA or a tracheal tube were studied. SGA was associated with a lower risk of emergent postoperative intubation and early oxygen desaturation. The effect can partly be explained by the use of NMBA, as the use of NMBA in patients with SGA eliminated the preventive effects of SGA on emergent intubation risk.

There are no data on consequences of SGA *vs* tracheal tube on emergent postoperative intubation risk, a rare complication that requires a high sample size to be studied. In a recently published meta-analysis the authors concluded that there is insufficient evidence to draw conclusions on the influence of using an SGA device *vs* a tracheal tube to prevent postoperative respiratory complications.[17] We hypothesised that the beneficial effect of an SGA is possibly mediated through higher doses of opioids or NMBAs in patients with tracheal tube. A mediation analysis was used to study this hypothesis and revealed that 28.9% of the effect was mediated by non-depolarising NMBAs. In contrast, succinylcholine, intraoperatively administered opioids, or neostigmine – although potentially increasing the risk of postoperative

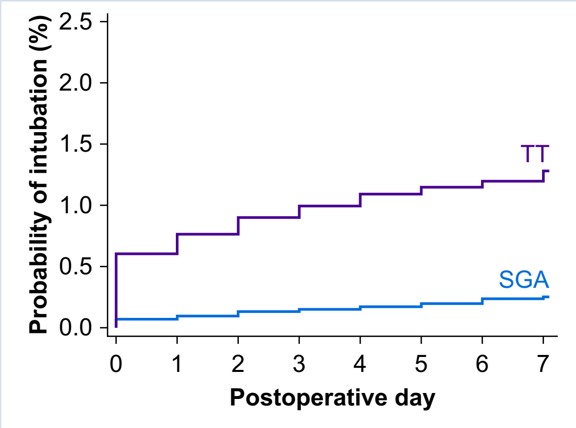

Fig 2. Probability of emergent postoperative intubation. Probability of emergent postoperative intubation during 7 postoperative days for patients undergoing general anaesthesia with the use of an tracheal tube compared with SGA, according to multivariable Cox proportional hazard model. Patients with a tracheal tube were significantly more likely to require emergent postoperative intubation within 7 postoperative days, with most emergent postoperative intubation occurring during the first postoperative day. SGA, supraglottic airway device; TT, tracheal tube.

complications and reintubation[1,18–22] – did not mediate the higher risk for emergent postoperative intubation associated with tracheal tube in our study.

Although an SGA, compared with a tracheal tube in general, does not provide a tight airway seal protecting from aspiration, we interestingly found that SGA use compared with tracheal tube was associated with lower risk of pneumonia. This adds to our primary finding that SGA use is associated with a lower risk of emergent postoperative intubations, but this changes markedly with the administration of NMBAs. Importantly, in patients who received non-depolarising NMBA, SGA *vs* tracheal tube was no longer associated with a lower risk of reintubation. Clinicians who use NMBA in patients with SGA should use caution and make sure the train-of-four (TOF) ratio would be completely recovered at the end of the case.

Of note, whereas approximately 30% of the effects of the protective effect of SGA *vs* tracheal intubation on emergent postoperative intubation was mediated by the use of NMBAs, our analysis also revealed that 70% of the effect is mediated by other mechanisms. Future studies are warranted to identify the preventive mechanisms – the authors speculate that tracheal intubation associated laryngeal trauma may increase the vulnerability to postoperative respiratory complications – hoarseness or soreness of the throat are more likely to occur after tracheal intubation than after an insertion of an

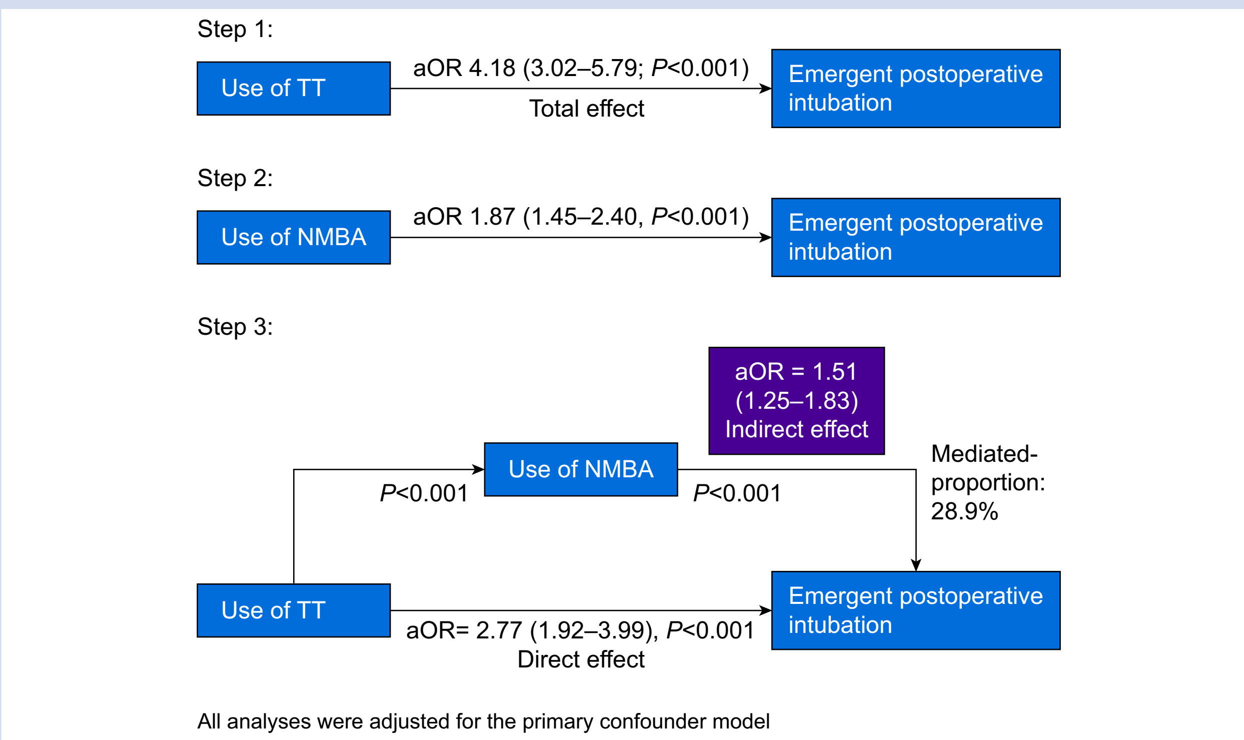

Fig 3. Mediation analysis of NMBA as a mediator in the primary association between the choice of the airway device and emergent postoperative intubations. As a first step, we demonstrated that the use of a tracheal tube had an impact on the odds of emergent postoperative intubation (Total Effect). In a second step, we analysed the effect of the mediator on the outcome and found that the use of NMBA was associated with higher odds for emergent postoperative intubation. Finally, in formal mediator analysis a significant indirect effect through the mediator NMBA use on the association between use of tracheal tube and emergent postoperative intubation was confirmed. Solid arrows in the path diagram present significant association between variables, with left to right direction representing an independent to dependent relationship. aOR, adjusted odds ratio; TT, tracheal tube; NMBA, neuromuscular blocking agents.

Table 2 Different sub-cohort definitions based on the ratio of tracheal intubation *vs* supraglottic airway device utilisation. As a sensitivity analysis, we used alternative cohort definitions based on the ratio of tracheal intubation to supraglottic airway device utilisation. Across all cut-off values used the use of tracheal tube compared with SGA is associated with a higher risk of postoperative reintubation within 7 days. *P*-values and adjusted odds ratio (aOR) are derived from the multivariable logistic regression using the full primary confounder model. CI, confidence interval; SGA, supraglottic airway device.

Used cut-off (%)	Number of cases	aOR (95% CI)	*P*-values
10–90	56 068	3.89 (2.85–5.31)	<0.001
20–80	44 854	2.91 (2.06–4.10)	<0.001
30–70	32 932	3.16 (1.89–5.27	<0.001
40–60	15 085	6.09 (2.49–14.88)	<0.001

SGA.[7–9,23–27] Laryngeal trauma can clinically present as upper airway obstruction, which increases the vulnerability to negative pressure pulmonary oedema.[28,29]

Emergent postoperative intubations are often performed in non-routine settings and with limited precautions compared with elective intubation, compromising patient safety by increasing the risk of intubation-associated complications and mortality.[30] Therefore, avoidance of emergent postoperative intubation becomes of paramount importance to increase patient safety and outcome.

We found that most emergent postoperative intubations occurred on the day of surgery, indicating that acute changes in airway physiology, respiratory physiology, or both may contribute to an increased risk of emergent postoperative intubation. There was a substantial variability across providers in the use of SGA and tracheal tube which could not be explained by patient or procedural factors, suggesting that a quality improvement initiative may be warranted.

We must take several limitations into account. We cannot rule out that unidentified confounding factors have influenced our results. To account for this, we performed an instrumental variable analysis which creates a pseudo randomisation based on an instrument that is significantly associated with the exposure (in our case: a significant increase in the use of SGA devices during the past few years); our results remained robust. Furthermore, the anaesthesia provider's choice of airway device may reflect patient comorbidity load and severity of the procedure, with SGA being used in patients with less comorbidity load and procedures of lower complexity. To account for this, we only included surgery types where at least 10% of either airway device was used in our primary analysis, thereby allowing a choice between the two devices. However, as a sensitivity analysis, we also used stricter cut-off values for inclusion in the cohort and found an even stronger association of airway choice and emergent postoperative intubations (Table 2). In addition, we found that the association between SGA and reduced risk of emergent postoperative intubation was consistent across subgroups of surgical duration and complexity. Finally, our results did not change in multiple sensitivity analyses including propensity score matching, accounting for potential interactions between the choice of the airway device and length and complexity of the surgical procedure, indicators of a higher comorbidity burden or after excluding cases with a conversion from SGA to tracheal tube, cardiothoracic cases, ambulatory, or emergency surgeries. A randomised controlled study may be reasonable. Given the observed incidence of emergent postoperative intubation, the sample size of an RCT would require 2500 patients.

In conclusion, the choice of using a tracheal tube *vs* an SGA during general anaesthesia was associated with a higher risk of emergent postoperative intubations. The effect can partly be explained by the use of NMBA; the use of NMBA in patients with SGA eliminated the preventive effects of SGA on emergent intubation risk. In patient undergoing procedures under general anaesthesia that could be managed with either SGA or tracheal tube, the use of SGA may reduce the risk of emergent postoperative intubation.

Authors' contributions

Study concept and design: MH, PS, MSS, ME, PF
Data collection: MH, PS, MSS, ME, PF
Data analysis: MH, MSS, FCA, KW, XU, ME, PF
Interpretation of data: MH, PS, MSS, ME, PF
Drafting of the manuscript: MH, MSS, FCA, KW, UHF, XU, ME, PF
All authors were involved in the critical revision of the manuscript, approved the final manuscript version to be published, and agreed to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.
The manuscript's guarantor is Philipp Fassbender. He affirms that this manuscript is an honest, accurate, and transparent account of the study being reported. No important aspects of the study have been omitted.

Declarations of interest

ME is a member of the Associate Editorial Board of the *British Journal of Anaesthesia*. He has received funding for investigator-initiated trials not related to this manuscript from MERCK Inc., and serves on the advisory board for the drug sugammadex. All other authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2020.10.040.

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