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ORIGINAL ARTICLE

Risk of postoperative pneumonia after extubation with the positive pressure versus normal pressure technique: a single-center retrospective observational study

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Abstract

Purpose A normal pressure extubation technique (no lung inflation before extubation), proposed by the Japanese Society of Anesthesiologists to prevent droplet infection during the coronavirus disease 2019 (COVID-19) pandemic, could theoretically increase postoperative pneumonia incidence compared with a positive pressure extubation technique (lung inflation before extubation). However, the normal pressure extubation technique has not been adequately evaluated. This study compared postoperative pneumonia incidence between positive and normal pressure extubation techniques using a dataset from the University of Tsukuba Hospital.

Methods In our hospital, the extubation methods changed from positive to normal pressure extubation techniques on March 3, 2020 due to the COVID-19 pandemic. Thus, we compared the risk of postoperative pneumonia between the positive (April 1, 2017 to December 31, 2019) and normal pressure extubation techniques (March 3, 2020 to March 31, 2022) using propensity score analyses. Postoperative pneumonia was defined using the International Classification of Diseases, 10th Edition (ICD-10) codes (J13–J18), and we reviewed the medical records of patients flagged with these ICD-10 codes (preoperative pneumonia and ICD-10 codes for prophylactic antibiotic prescriptions for pneumonia).

Results We identified 20,011 surgeries, including 11,920 in the positive pressure extubation group (mean age 48.2 years, standard deviation [SD] 25.2 years) and 8,091 in the normal pressure extubation group (mean age 47.8 years, SD 25.8 years). The postoperative pneumonia incidences were 0.19% (23/11,920) and 0.17% (14/8,091) in the positive and normal pressure extubation groups, respectively. The propensity score analysis using inverse probability weighting revealed no significant difference in postoperative pneumonia incidence between the two groups (adjusted odds ratio 0.98, 95% confidence interval 0.50 to 1.91, $P = 0.94$).

Conclusions These results indicated no increased risk of postoperative pneumonia associated with the normal pressure extubation technique compared with the positive pressure extubation technique.

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Keywords Coronavirus disease 2019 (COVID-19) · Extubation method · Positive pressure technique · Normal pressure technique · Postoperative pneumonia

Introduction

Postoperative pneumonia is a typical complication of general anesthesia [1]. One method of extubation to prevent postoperative pneumonia is the positive pressure extubation technique [2]. In the positive pressure extubation technique, the lungs are inflated with a bag [3–5] or positive end-expiratory pressure [6, 7] before extubation to create positive pressure in the lungs. This method is believed to prevent aspiration of secretions accumulated above the cuff of the tracheal tube during extubation or improve atelectasis to prevent postoperative pneumonia [8, 9].

Extended author information available on the last page of the article

However, the Japanese Society of Anesthesiologists recommended the normal pressure extubation technique after the outbreak of coronavirus disease 2019 (COVID-19) to prevent droplets from the patient during extubation [10]. The normal pressure extubation technique is a method of extubation without creating positive pressure in the lungs before extubation [10]. Therefore, the risk of postoperative pneumonia may be higher with the normal pressure extubation technique than with the positive pressure extubation technique. However, the risk of postoperative pneumonia using a normal pressure extubation technique has not been sufficiently investigated after the COVID-19 pandemic.

Following this recommendation, the Department of Anesthesiology at the University of Tsukuba Hospital completely changed the extubation technique on March 3, 2020. The positive pressure extubation technique was used uniformly before the COVID-19 pandemic and then switched to the normal pressure extubation technique after the pandemic. In this study, we compared the risk of postoperative pneumonia between the positive and normal pressure extubation techniques using a dataset from the University of Tsukuba Hospital.

Methods

Ethics and registration

Ethical approval for this study was obtained from the Institutional Review Board of the University of Tsukuba Hospital, Tsukuba, Ibaraki, Japan, on May 27, 2022 (R03-068). The requirement for informed consent was waived and opt-outs were implemented before the study was conducted. The study protocol was registered in the UMIN Clinical Trials Registry on August 4, 2022 (UMIN000048589). We followed the Strengthening the Reporting of Observational Studies in Epidemiology statement [11].

Study design and data sources

This single-center, retrospective, observational study was conducted using the University of Tsukuba Hospital Perioperative Dataset. This dataset combines electronic perioperative data warehouse (Vi-pros, Philips Japan, Ltd., Japan), intensive care unit electronic records (ACSYS and PIMS, Philips Japan, Ltd., Japan), a data warehouse including administrative claims and discharge abstract data (Diagnosis Procedure Combination [DPC] data) [12] (Fujitsu Japan Ltd., Japan), and electronic medical records (Fujitsu Japan Ltd.) without dental surgeries and then anonymizes personal information to make it available for research purposes. Medical record data for chart review were similarly anonymized for personal information. In this study, patient characteristics and information on anesthesia and surgery were obtained from electronic anesthesia records; in contrast, complications and outcomes were mainly obtained from the DPC data. The DPC data classify diseases according to the International Classification of Diseases, 10th Edition (ICD-10) codes. Contrarily, our dataset does not include image data, such as simple radiography and computed tomography. The details of the data sources are provided in Table S1.

Study population

We identified surgeries performed under general anesthesia between April 1, 2017 and March 31, 2022. The exclusion criteria were as follows: surgeries without tracheal intubation (including surgeries without intubation or with missing intubation records); patients who were already intubated at entry into operating rooms; patients who were not extubated upon leaving the operating rooms; multiple intubations or extubations in the operating rooms; surgeries with incomplete intubation and extubation records; the use of a supraglottic airway, double-lumen tube, or bronchial blocker; the use of a tracheostomy tube; American Society of Anesthesiologists physical status (ASA-PS) ≥ 4; second or subsequent surgeries during one hospitalization; upper airway or lung infection on admission (such as acute upper airway infection, pneumonia, COVID-19, acute respiratory distress syndrome, lung abscess, or pyothorax); surgeries under one-lung ventilation; surgeries under cardiopulmonary bypass; and unreasonable values (such as no ASA-PS input, no body mass index [BMI] input, BMI < 10 kg/m^2 or > 150 kg/m^2). The ICD-10 codes for upper airway or lung infections upon admission are presented in Table S2.

Group definitions

Since the first patient with COVID-19 was confirmed in Japan in January 2020, surgeries performed between April 1, 2017 and December 31, 2019 were included in the positive pressure extubation technique group. Then, on March 3, 2020, the Japanese Society of Anesthesiology announced a notice recommending the normal pressure extubation technique [10]; thus, surgeries performed from this date to March 31, 2022 were included in the normal pressure extubation technique group. Surgeries performed between January 1 and March 2, 2020, determined a transition period, were excluded from the analysis.

Positive pressure extubation technique

In our operating room, a positive pressure extubation technique method was used to pressurize the ventilator bag and to inflate the lungs manually, then to deflate the cuff if the tube had a cuff and to extubate [3–5]. This method

was standardized for education in our hospital. We did not use the suctioning extubation technique, which comprises introducing a suction catheter into an endotracheal tube and applying continuous suctioning during cuff deflation and extubation [2]. The oral cavity and intra-trachea space were to be adequately suctioned prior to extubation. In addition, oxygen (pure oxygen or a mixture of oxygen and air, often mixed at 1:1) was administered before extubation, while the decision was left to anesthesiologists. Other intraoperative ventilator settings (including ventilatory mode, positive end-expiratory pressure, and whether to perform recruitment maneuvers) were likewise left to each anesthesiologist's discretion.

Normal pressure extubation technique

The normal pressure extubation technique is a method of extubation that omits this pressurization with the bag [10]. Although oral cavity suctioning was performed, intra-trachea suctioning was not, except when necessary for preventing droplet infection. Continuous suctioning during cuff deflation and extubation was also not performed. Oxygen administration prior to extubation and other intraoperative ventilator setting were dependent on anesthesiologists as well as the pre-COVID-19 period.

Outcomes

The primary outcome of interest was the incidence of postoperative pneumonia. Postoperative pneumonia was defined using the ICD-10 codes for subsequent onset after hospitalization in the DPC data (J13–J18), and we reviewed the medical records of patients flagged with these codes. Specifically, we referred to the medical records of patients with postoperative pneumonia flagged by ICD-10 codes 1 month preoperatively and postoperatively. Thereafter, we removed the postoperative pneumonia flags from surgeries in the following patients: (i) those who had pneumonia preoperatively and (ii) whose ICD-10 codes may have been attributed to prophylactic antibiotic prescriptions for pneumonia (e.g., immunocompromised patients). A validation study of respiratory diseases recorded in the DPC database reported that "bacterial pneumonia (A481, J100, J110, J12–16, J170, J178, J18, J85, J86)", the definition of which was the closest to our definition of postoperative pneumonia, had the sensitivity 63.0%, specificity 94.8%, positive predictive value 73.0%, and negative predictive value 92.0% [13].

We also prepared two additional definitions of outcome: broad and strict. In the broad definition, all flagged surgeries by ICD-10 codes were considered to have postoperative pneumonia. In the strict one, from the surgeries with pneumonia flags in the primary outcome, we flagged only those where postoperative pneumonia was likely to have occurred (description of pneumonia or equivalent descriptions, description of laboratory findings suggestive of pneumonia, or description of infections of unknown focus in the medical records within 1 month postoperatively). Finally, we unflagged the other surgeries.

Two authors (K.S. and H.U.) independently reviewed the medical records. In case of disagreements, a consensus was reached via discussion.

Covariates

Based on the previous literature and our clinical knowledge, we extracted patient and surgical characteristics that may have affected postoperative pneumonia [1, 14–20]. The patient characteristics included age, sex, BMI, ASA-PS, and complications on admission (including chronic obstructive pulmonary disease, asthma, other diseases of the respiratory system, hypertension, ischemic heart disease, valvular heart disease, cerebrovascular disease, diabetes mellitus, liver disease, renal disease, neoplasms, and history of organ transplantation). Complications on admission were defined using the ICD-10 codes in the DPC data (Table S2). Surgical characteristics included emergency surgery, clinical department (including orthopedic surgery, gastroenterology, breast and endocrine surgery, gynecology, pediatric surgery, neurosurgery, urology, head and neck surgery/otorhinolaryngology, plastic and reconstructive surgery, ophthalmology, pediatrics, cardiovascular surgery, cardiology, dermatology, emergency and critical care medicine, obstetrics, and others), total intravenous anesthesia (TIVA), epidural anesthesia, regional anesthesia, use of an uncuffed endotracheal tube, nasotracheal intubation, operative time, and use of laparoscopy.

Statistical analysis

Continuous variables are presented as means ± standard deviations (SDs), and categorical variables are presented as numbers (percentages). Logistic regression models were used to determine the incidence of postoperative pneumonia in all analyses. The primary analysis used inverse probability weighting (IPW) with a propensity score to adjust for the covariates. The propensity scores were estimated for individual surgeries using a multivariate logistic regression model, with the extubation group as the dependent variable. The patient and surgical characteristics mentioned above were included in the model. The weights were calculated as follows: "1 / propensity score" for the normal pressure extubation group and "1 / (1—propensity score)" for the positive pressure extubation group. A standardized mean difference (SMD) of < 0.1 was considered balanced [21].

The odds ratio (OR) and its 95% confidence interval (CI) for postoperative pneumonia were estimated after weighting.

We performed a one-to-one matched analysis with nearest-neighbor matching using the propensity score calculated in the primary analysis for sensitivity analyses. A match occurred when surgery in the positive pressure extubation group had an estimated propensity score within a caliper width of 0.2 of the SD of the propensity score of surgery in the normal pressure extubation group. We also applied two logistic models to postoperative pneumonia: a crude model without adjustment for covariates and a multivariate model to adjust for the propensity score calculated above. Subgroup analysis for the child population (age < 18 years) was performed in the same manner as that mentioned above, because previous studies have suggested that the positive pressure extubation technique is particularly effective in reducing complications in children compared with adults [2, 4, 22].

We used R version 4.3.0 for all the statistical analyses. All reported P values were two-sided, and $P < 0.05$ was considered statistically significant.

Results

Selection of surgeries and baseline characteristics

We identified 32,576 surgeries performed under general anesthesia in the dataset during the study period. After applying the exclusion criteria, 20,732 surgeries were included. After excluding surgeries during the transition period, 20,011 were analyzed, including 11,920 and 8,091 in the positive and normal pressure extubation groups, respectively (Fig. 1).

The surgical characteristics are presented in Table 1. There were some notable differences in the breakdown of clinical department (ophthalmology) and the proportion of TIVA between the groups. After IPW, the SMDs for all the variables were < 0.1.

Outcomes

The incidence of postoperative pneumonia for each definition is summarized in Table 2. Based on only the ICD-10 codes, 0.22% (26 of 11,920 surgeries) and 0.19% (15 of 8,091 surgeries) in the positive and normal pressure extubation groups, respectively, were flagged as postoperative pneumonia (broad definition). Among them, three flags in the positive pressure extubation group were removed (one with preoperative pneumonia and two surgeries of which ICD-10 codes were attributed to prophylactic antibiotic prescriptions for pneumonia). One flag in the normal pressure extubation group was likewise removed (ICD-10 codes were attributed to prophylactic antibiotic prescriptions for pneumonia). Thus, the frequency of postoperative pneumonia was 0.19% (23/11,920 surgeries) and 0.17% (14/8,091 surgeries) in the positive and normal pressure extubation groups, respectively (primary outcome). The strict definition further removed 20 flags from the primary outcome. Thus, the frequency of postoperative pneumonia based on the strict definition was 0.07% (8/11,920 surgeries) and 0.11% (9/8091 surgeries) in the positive and normal pressure extubation groups, respectively.

Primary analysis

In the case of the definition of the primary outcome, after IPW, the adjusted frequency for postoperative pneumonia was 0.19% and 0.18% in the positive and normal pressure extubation groups. The adjusted OR of the normal pressure extubation group to the positive pressure extubation group for postoperative pneumonia was 0.98 (95% CI 0.50–1.91, $P = 0.94$) (Table 3). Similar to the primary outcome, there were no significant differences in the outcomes between the two groups when the broad and strict definitions were used (Table S7).

Sensitivity analysis

Table 3 also presents the OR of postoperative pneumonia in the propensity score-matched and logistic regression analyses for the definition of the primary outcome. One-to-one propensity score matching generated 7,874 pairs of surgeries in the positive and normal pressure extubation groups. After matching, the SMDs for all variables were < 0.1 (Table S3 and Fig. S1). The propensity score-matched analysis showed no significant difference in the frequency of postoperative pneumonia (OR 1.00, 95% CI 0.47–2.12, $P = 1.00$). Similarly, the logistic regression analyses showed no significant differences (crude model, OR 0.90, 95% CI 0.45–1.72, $P = 0.75$; adjusted model, OR 0.98, 95% CI 0.49–1.90, $P = 0.96$). There were no significant differences between the two groups when the broad and strict definitions of outcomes were used (Table S7).

Subgroup analysis

Of the 20,011 surgeries in the primary analysis, 3,798 were performed on patients aged < 18 years; 2,191 and 1,607 in the positive and normal pressure extubation groups, respectively. The characteristics of surgeries are presented in Table S4. Based on only ICD-10 codes, 4 of 2,191 surgeries in the positive pressure extubation group and 4 of 1,607 surgeries were flagged as postoperative pneumonia. Among them, one flag in the normal pressure extubation group was removed because of preoperative pneumonia. Thus, the

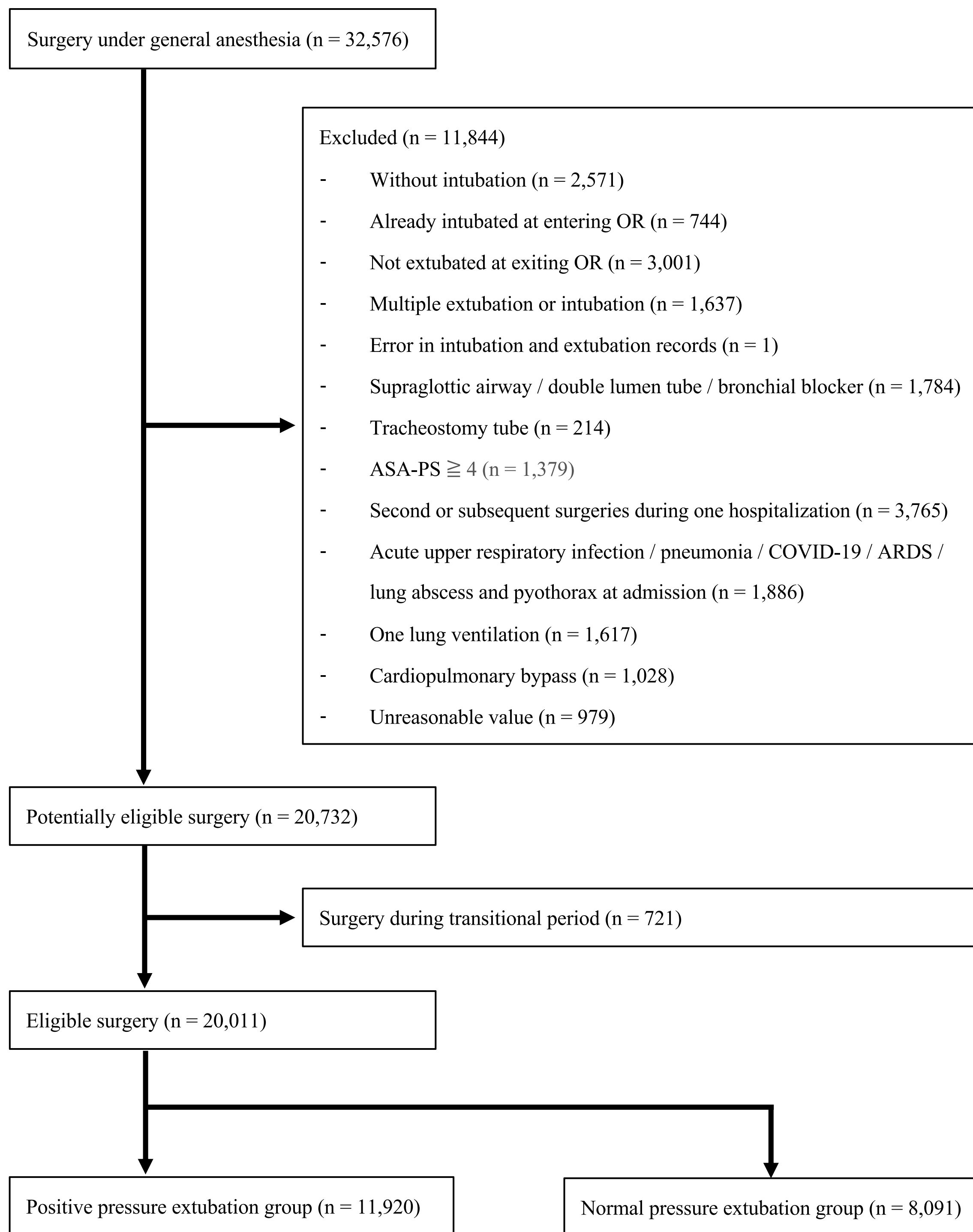

Fig. 1 Flow chart of surgery selections. *ARDS,* acute respiratory distress syndrome; *ASA-PS*, American Society of Anesthesiologists physical status; *COVID-19*, coronavirus disease 2019; *OR*, operating room

frequency of postoperative pneumonia in the positive and normal pressure extubation groups was 0.18% (4/2,191 surgeries) and 0.19% (3/1,607 surgeries), respectively. There were some notable differences in the proportions of emergency surgery, clinical department (ophthalmology), TIVA, regional anesthesia, uncuffed endotracheal tubes, and laparoscopy. After IPW, the SMDs for all variables were < 0.1 (Table S4) and the adjusted frequency for postoperative pneumonia was 0.21% and 0.19% in the positive and normal pressure extubation techniques, respectively. Similar to

Table 1 Characteristics of surgeries under general anesthesia before and after inverse probability weighting

	Before weighting			After weighting
	Positive pressure extubation group ($n = 11,920$)	Normal pressure extubation group ($n = 8,091$)	SMD[a]	SMD[a]
Patient characteristics				
Age (years)	48.2 ± 25.2	47.8 ± 25.8	0.02	< 0.01
Male	5,473 (45.9)	3,755 (46.4)	0.01	< 0.01
BMI (kg m^{-2})	22.4 ± 4.9	22.5 ± 5.1	0.02	< 0.01
ASA-PS				
1	2,401 (20.1)	1,708 (21.1)	0.02	< 0.01
2	6,104 (51.2)	4,020 (49.7)	0.03	< 0.01
3	3,215 (28.6)	2,363 (29.2)	0.01	< 0.01
COPD	42 (0.4)	17 (0.2)	0.03	< 0.01
Asthma	234 (2.0)	115 (1.4)	0.04	< 0.01
Other diseases of the respiratory system	1,130 (9.5)	592 (7.3)	0.08	< 0.01
Hypertension	474 (4.0)	471 (5.8)	0.09	< 0.01
Ischemic heart disease	528 (4.4)	331 (3.8)	0.03	< 0.01
Valvular heart disease	255 (2.1)	158 (2.0)	0.01	< 0.01
Cerebrovascular disease	412 (3.5)	306 (3.8)	0.02	< 0.01
Diabetes mellitus	1,566 (13.1)	932 (11.5)	0.05	< 0.01
Liver disease	448 (3.8)	269 (3.3)	0.02	< 0.01
Renal disease	506 (4.2)	308 (3.8)	0.02	< 0.01
Neoplasms	4,493 (37.7)	3,105 (38.4)	0.01	< 0.01
History of organ transplant	7 (0.1)	15 (0.2)	0.04	< 0.01
Surgical characteristics				
Emergency surgery	686 (5.8)	315 (3.9)	0.09	< 0.01
Clinical department				
Orthopedic Surgery	1,698 (14.2)	1,097 (13.6)	0.02	< 0.01
Gastroenterology	1,516 (12.7)	1,111 (13.7)	0.03	< 0.01
Breast and endocrine surgery	1,212 (10.2)	843 (10.4)	< 0.01	< 0.01
Gynecology	1,150 (9.1)	800 (9.9)	< 0.01	< 0.01
Pediatric Surgery	1,045 (8.8)	701 (8.7)	< 0.01	< 0.01
Neurosurgery	1,084 (9.1)	627 (7.7)	0.05	< 0.01
Urology	996 (8.4)	662 (8.2)	< 0.01	< 0.01
Head and neck surgery / Otorhinolaryngology	1,016 (8.5)	597 (7.4)	0.04	< 0.01
Plastic and reconstructive surgery	718 (6.0)	470 (5.8)	< 0.01	< 0.01
Ophthalmology	338 (2.8)	404 (5.0)	0.11	< 0.01
Pediatrics	232 (1.9)	209 (2.6)	0.04	< 0.01
Cardiovascular surgery	218 (1.8)	163 (2.0)	0.01	< 0.01
Cardiology	155 (1.3)	135 (1.7)	0.03	< 0.01
Dermatology	163 (1.4)	95 (1.2)	0.02	< 0.01
Emergency and critical care medicine	165 (1.4)	71 (0.9)	0.05	< 0.01
Obstetrics	143 (1.2)	77 (1.0)	0.02	< 0.01
Others	71 (0.6)	29 (0.4)	0.03	< 0.01
Total intravenous anesthesia	1,316 (11.0)	1,207 (14.9)	0.12	< 0.01
Epidural anesthesia	829 (7.0)	594 (7.3)	0.02	< 0.01
Regional anesthesia	3,585 (30.1)	2,388 (29.5)	0.01	< 0.01
Use of uncuffed endotracheal tube	47 (0.4)	13 (0.2)	0.04	< 0.01
Nasotracheal intubation	25 (0.2)	6 (0.1)	0.04	< 0.01
Operative time (min)	169.2 ± 131.7	166.0 ± 128.9	0.02	< 0.01
Blood loss (ml)	156.8 ± 440.0	129.7 ± 377.7	0.07	< 0.01
Use of laparoscopy	1,968 (16.5)	1,338 (16.5)	< 0.01	< 0.01

ASA-PS, the American Society of Anesthesiologists physical status; *BMI*, body mass index; *COPD*, chronic obstructive pulmonary disease; *SMD*, standardized mean difference. Data are presented as mean ± standard deviation or number (%)

[a]A standardized mean difference of > 0.1 was considered to be imbalanced

Table 2 Outcome definition and incidence of postoperative pneumonia

Outcome	Definition of postoperative pneumonia	Positive pressure extubation group ($n = 11{,}920$)	Normal pressure extubation group ($n = 8{,}091$)
Broad	"ICD-10 (J13–J18)"[a]	26 (0.22)	15 (0.19)
Primary	"Broad definition" and "Review of the medical record (to exclude cases that were clearly not postoperative pneumonia)"[b]	23 (0.19)	14 (0.17)
Strict	"Primary definition" and "Review of the medical record (to restrict to cases that likely to have had postoperative pneumonia)"[c]	8 (0.07)	9 (0.11)

DPC; Diagnosis Procedure Combination; *ICD-10*, International Classification of Diseases, 10th Edition. Data are presented as numbers (%). [a]ICD-10 codes (J13–J18) for subsequent onset after hospitalization in the DPC data. [b]To exclude the following surgeries by the review of the medical record 1 month before and after surgery: (i) who had pneumonia preoperatively and (ii) whose ICD-10 codes may have been attributed to prophylactic antibiotic prescriptions for pneumonia (e.g., immunocompromised patients). [c]To restrict to cases that are likely to have bad postoperative pneumonia by the review of the medical record 1 month preoperatively and postoperatively: description of pneumonia or equivalent descriptions, description of laboratory findings suggestive of pneumonia, or description of infections of unknown focus in the medical records within 1 month postoperatively

Table 3 Odds ratios of the normal pressure extubation group to the positive pressure extubation group for postoperative pneumonia

	OR (95% CI)	*P* value
Primary analysis		
Inverse probability weighting	0.98 (0.50–1.91)	0.94
Sensitivity analysis		
Propensity score matching	1.00 (0.47–2.12)	1.00
Logistic regression		
Crude model[a]	0.90 (0.45–1.72)	0.75
Adjusted model[b]	0.98 (0.49–1.90)	0.96

CI, confidence interval; *OR*, odds ratio

[a]No adjustment by covariates

[b]Propensity score adjusted

the primary and sensitivity analyses, the subgroup analyses showed no significant differences in the frequency of postoperative pneumonia between the two groups (Tables S5, S6, and Fig. S2).

Discussion

In this single-center observational study, the frequency of postoperative pneumonia did not differ between the positive and normal pressure extubation groups. In addition, the same results were obtained in the subgroup analysis of children. The post-hoc analyses also showed no differences between the groups.

The COVID-19 pandemic has led to the advocacy of methods for preventing droplets from patients during extubation. D'Silva et al. [23] proposed a mask-over-tube extubation technique, which covered the face of the patient with a filtered face mask immediately after extubation. Juang et al. [24, 25] proposed a deep extubation technique that extubated under deep anesthesia after regular spontaneous breathing, which demonstrated safety of the deep extubation. However, to the best of our knowledge, the normal pressure extubation technique proposed in Japan has not been sufficiently evaluated.

Before the COVID-19 pandemic, our anesthesiology department standardized the extubation method as a positive pressure extubation technique. After the pandemic, the extubation method was switched to the normal pressure extubation technique in accordance with the recommendations of the Japanese Society of Anesthesiologists [10]. Therefore, comparing extubation methods before and after the COVID-19 pandemic became possible. A comparison with observational studies is appropriate, because the incidence of postoperative pneumonia is low (approximately 0.2%).

Although the comparator was different from our study, a pre-COVID-19 pandemic study of the normal pressure extubation technique was reported by Lai et al. [26]. This was a single-center retrospective observational study of 3,794 patients who underwent ophthalmic surgery under general anesthesia. The authors attempted to compare the incidence of postoperative pneumonia after extubation between the normal pressure and suction extubation techniques using the anesthesiologist's preference for the extubation method. No postoperative pneumonia was observed in the two groups. Although the authors could not analyze the results, they considered that normal pressure extubation may not be a risk factor for postoperative pneumonia. In contrast to that study, our study had incidences of postoperative pneumonia, possibly due to the large number of severe cases involving surgeries.

No difference was found in the child population, who would have benefited more from the positive pressure extubation technique. Previous studies showed the effectiveness of the positive pressure extubation technique compared with that of the suctioning extubation technique (introducing a suction catheter into an endotracheal tube and applying continuous suctioning during cuff deflation and extubation). Therefore, the suctioning extubation technique might have more side effects in children compared with the positive pressure extubation technique, which is thus relatively more effective [2, 4, 22]. In addition, since our study only evaluated the efficacy of the positive pressure extubation technique in postoperative pneumonia, its efficacy in complications other than the postoperative pneumonia may have been overlooked.

This study had some limitations. First, in addition to postoperative pneumonia, post-extubation complications included oxygen desaturation, airway obstruction, aspiration, and atelectasis [2]. However, these outcomes could not be defined in our dataset. For example, oxygen desaturation might have happened more frequently in the normal pressure extubation group. This is because oxygenation immediately before extubation is theoretically more likely to be inadequate using the normal pressure extubation technique compared with the positive pressure extubation technique. Therefore, further research on post-extubation complications other than pneumonia is needed. Second, the incidence of postoperative pneumonia was low. A report from US databases from 2009 to 2013 had an incidence rate of postoperative pneumonia ranging from 0.4% to 1.73% (excluding cardiac surgery) [27], higher than the about 0.2% in this study; however, our results were probably within a reasonable range given the development of perioperative medicine. However, due to a lack of statistical power, the difference between the positive and normal pressure extubation techniques might not have been detected. Therefore, comparisons with larger databases are required. Third, the sensitivity of our outcomes could be low. Previous reports have indicated that the sensitivity of pneumonia using the ICD-10 codes was 63.0% [13], which may have influenced our second limitation. Fourth, these data did not include imaging data, such as simple radiography and computed tomography. In addition, the review of the medical record was performed after processing to remove personal information. Therefore, defining outcomes with less information than the actual medical record data may have compromised the accuracy of the results. Fifth, the positive pressure and normal pressure extubation techniques were performed on completely different occasions in this study. Thus, this potential confounder that was not included in the propensity score model may have influenced the analysis results. Particularly, other COVID-19-related management changes may have influenced the incidence of postoperative pneumonia. For example, intraoperative endotracheal suctioning may have been performed less frequently to avoid aerosol generation, which may have increased the risk of postoperative pneumonia after the COVID-19 pandemic; although the risk of postoperative pneumonia may have been lowered owing to more rigorous checking for infection at the time of admission after the pandemic. Regardless of the COVID-19 pandemic, the potential risk of postoperative pneumonia may have changed over time. However, in our analysis, we assumed that factors not included in the propensity score model did not change before and after the COVID-19 pandemic. Sixth, we did not use endotracheal tubes with subglottic secretion drainage, which have been reported to prevent ventilator-associated pneumonia [28]. Finally, because this was a single-center observational study, a study with multicenter data is desirable.

In conclusion, this single-center retrospective observational study found no difference in the risk of postoperative pneumonia between the positive and normal pressure extubation techniques.

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Data availability No permission was given to disclose data to third parties.

Declarations

Conflicts of interest The authors declare that they have no conflicts of interest.

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