Intraoperative management of mechanical ventilation in non-cardiothoracic surgery: a national survey in China

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Research Article

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Abstract

Background

The current clinical practice regarding intraoperative ventilation management in non-cardiothoracic surgical setting among anesthesia providers in China is unclear.

Methods

We developed a 25-question anonymous survey which was distributed to anesthesia departments from 81 tertiary/university hospitals in China between August 2021 and September 2021. Information including participant characteristics, ventilatory settings, and opinions on lung-protective ventilation were obtained by electronic survey. Results were reported descriptively.

Results

The survey was completed by 1089 anesthesiologists from 57 institutions (70% institution response rate). The vast majority of respondents (1010/1089; 92.7%)used low tidal volume (6–8 ml kg^{-1}) ventilation. About three quarters (840/1089; 77.1%) utilized positive end-expiratory pressure, and most anesthesiologists set positive end-expiratory pressure of 1–5 cmH_2O in either laparoscopic (639/840; 76.1%) or non-laparoscopic surgery (736/840; 87.6%). The majority of respondents (921/1089; 84.6%) performed alveolar recruitment maneuver intraoperatively. Approximate 20% of respondents routinely implemented lung-protective ventilation with bundles of low tidal volume, positive end-expiratory pressure, and alveolar recruitment maneuver.

Conclusions

We found that heterogeneity exists between individual practices regarding intraoperative ventilation management in the setting of non-cardiothoracic surgery, indicating the potential knowledge-practice gap among Chinese anesthesiologists.

Trial registration number:

ChiCTR2100047653; **Registration date**: June 21, 2021 **Registry URL**: Chictr.org.cn.

Background

Patients undergoing major non-cardiothoracic surgery under general anesthesia and mechanical ventilation may experience postoperative pulmonary complications (PPCs). Prevention of PPCs may in part be achieved by the optimization of intraoperative ventilation management. Over the past two decades, lung-protective ventilation (LPV) containing low tidal volume (V_T), positive end-expiratory pressure (PEEP) and alveolar recruitment maneuvers (ARMs), has been initially implemented in patients with acute respiratory distress syndrome[1], and then gradually adopted in surgical settings to decrease the risk of developing adverse pulmonary outcomes[2−4].

Although an 2019 international expert panel–based consensus recommendations suggested LPV for the surgical patient, there are substantial practice pattern variations in intraoperative ventilation management. Several studies indicated that MV practice did not follow current recommendations for lung protection in patients undergoing cardiac and thoracic surgery[5, 6]. In addition, little is known about current practice regarding intraoperative ventilation management among anesthesiologists in China.

Accordingly, we conducted a nationwide survey to describe the current status in practicing intraoperative ventilation management in non-cardiothoracic surgical setting among Chinese anesthesiologists working in tertiary/university hospitals. We also collect the opinions of anesthesiologists regarding LPV at both practical and theoretical levels.

Methods

This cross-sectional, self-administered, anonymized, voluntary survey was performed in adhere to the applicable guideline: the strengthening the reporting of observational studies in epidemiology (STROBE) [7] and American Association for Public Opinion Research (AAPOR) reporting guidelines for survey studies [8]. The study was approved by Ethics Committee of West China Hospital of Sichuan University and prospectively registered on Chictr.org.cn (ChiCTR2100047653) on June 21, 2021. The informed consent was obtained from all participants by the recruitment email, available as Additional file 1.

Questionnaire Design

This survey was developed by an expert panel consisting of 3 members of the Anesthesiology Committee of Sichuan Medical Association (ACSMA). The draft survey was pretested among professors working at the department of anesthesiology in West China Hospital of Sichuan University. We consulted them about the questionnaire logic and the items' clarity and comprehension. As the final step to assess validity, the revised survey was sent to the second group of 10 experts in the field of LPV from the ACSMA. Again, their comments were used to further modify the survey to assure the validity among the target population. Subsequently, the survey was pilot tested with 44 clinicians to establish administration procedures. Eventually, we developed a 25-item questionnaire, available as Additional file 2, that assessed 3 domains: (1) basic characteristics; (2) MV strategies implemented for adult patients undergoing non-cardiothoracic surgery; (3) understanding and application of the LPV strategy. LPV was defined as low V_T ventilation of 6-8 ml kg^{-1} predicted body weight $(PBW)^{-1}$, application of PEEP and ARM[9]. The web-based platform Tencent survey was used.

Population

The target population of this survey were anesthesiologists working in tertiary general hospitals. The top 100 Chinese hospitals on the ranking list of Fudan were included and special hospitals were excluded. To improve sample representativeness, teaching hospitals were included in the regions where there is no top 100 hospital. Finally, 81 hospitals were eligible, showed in the Additional file 3.

Study Procedure

On August 11, 2021, recruitment emails were sent to the directors of the department of anesthesiology in the eligible hospitals. The recruitment email, available as Additional file 1, contains survey purpose, voluntary statement, participation anonymity, and online questionnaire link. Participants gave consent by participating in the survey. To indicate this, the following statement was included in the recruitment email: “By completing the survey, you are agreeing to participate in this research.” After the initial e-mail, 2 reminder e-mails were sent to non-responders one week later and telephone calls were made two weeks later. Eventually, 57 directors agreed (institution response rate 70%) to participate. The recruitment email was then distributed to anesthesiologists in these enrolled hospitals. It was required to recycle at least 16 questionnaires including at least 8 questionnaires from attendings or professors and at least 8 questionnaires from residents in each hospital. All surveys were distributed between August 11th and September 14th of 2021.

Sample Size Calculation

In our survey, the response rate of the target population was estimated to be 40%[10], with a 95% confidence interval (CI) and 5% margin of error. This formula was used to calculate sample size[11]: $N = Z^2_{\alpha/2}\ p\ (1-p)\ /d^2$ (N: minimum sample size; $Z_{\alpha/2}$: standard normal variable value at 95% CI, 1.96; p: 0.05; d: margin of error, 5%), which was N=387 for our study. Considering the 40% response rate, the sample size was identified as 968 after being adjusted.

Statistical Analysis

Responses were summarized using descriptive statistics. We summarized continuous variables as either mean and standard deviation (SD) or median and interquartile range (IQR), and categorical data were displayed as frequency and the proportion of total number (%). Responses to each questionnaire were recorded in a Microsoft Excel database and all statistical analyses were performed using SPSS Statistics 23 (IBM SPSS Statistics for Windows, IBM Corp, Armonk, NY, USA).

Results

A total of 1089 anesthesiologists from 57 institutions responded to the survey. Detailed information about sample characteristics is listed in Table 1. Among respondents, over 2/5 were residents (469/1089; 43.1%) or attendings (457/1089; 41.9%), while 15% (163/1089) of the respondents were professors.

Nearly 2/5 (418/1089; 38.4%) had been practicing anesthesia for 0-4 years, 31.2% (340/1089) had been engaged in clinical anesthesia for 5-9 years, and 30.3% (331/1089) for over 10 years. The vast majority of the respondents worked in the teaching hospital (1035/1089; 95%) and practiced in flexible subspecialties (929/1089; 85.3%).

V_T, PEEP, and ARM

The large proportion (1010/1089; 92.7%) of anesthesiologists used low V_T ventilation (6-8 ml kg $^{-1}$) which was calculated referring to the PBW (376/1089; 34.5%), actual body weight (ABW) (340/1089; 31.2%) or corrected body weight (347/1089; 31.9%).

About three quarters (840/1089; 77.1%) of the respondents applied PEEP. Most of the respondents ventilated patients with a PEEP of 1–5 cmH_2O in either laparoscopic (639/840; 76.1%) or non-laparoscopic surgery (736/840; 87.6%) **(table 2)**. Nearly 80% of the anesthesiologists (584/840; 69.5%) set PEEP based on lung compliance **(figure 1A)**. A total of 84.6% (921/1089) applied intraoperative ARM. The manual ARM was most commonly utilized to recruit the lungs (843/921; 91.5%) **(table 2)**. 72.5% of the respondents (668/921) applied ARM with oxygen/air mixture, while 22.8% (210/921) and 4.7% (43/921) used pure oxygen and air respectively. ARM was performed regularly at fixed time interval (385/921; 41.8%), when saturation of pulse oxygen (SpO_2) dropped (437/921; 47.4%) or before tracheal extubation (623/921; 67.6%) **(figure 1B)**.

LPV practice

There were only 208 of 1089 (19.1%) respondents who routinely performed bundles of low V_T, PEEP, and ARM **(table 2)**. Regarding the respondents' opinions on LPV, they preferred to perform LPV in specific patients **(figure 1C)** and laparoscopic surgery **(figure 1D)**. The first three most important lung protective ventilatory parameters considered by the respondents were V_T (94.7%), PEEP (92.1%), and fraction of inspired oxygen (FiO_2) (76.4%) **(figure 1E)**. The vast majority of respondents (1066/1089; 97.9%) considered bundles of “low V_T, PEEP, and ARM” as LPV strategy **(figure 1F)**.

Other ventilatory settings

A total of 59.2% (645/1089) respondents in laparoscopic surgery and 81.6% (889/1089) in non-laparoscopic surgery preferred volume-controlled ventilation (VCV) **(figure 2A)**. It was commonly applied with intraoperative FiO_2 of 40%-60% (485/1089;44.5%) or 60-80% (418/1089; 38.4%) **(figure 2B)**. Most of the respondents (798/1089; 73.3%) set the inspiratory-to-expiratory ratio (I: E) to 1:2 **(figure 2C)**. RR was set at 9-12 breaths/min in 66.2% (721/1089) of the respondents and was adjusted to maintain normal E_TCO_2 in more than half of the respondents (583/1089; 53.5%) **(figure 2D)**. The median E_TCO_2 was reported to be 50mmHg (interquartile range 45–55) as the acceptable upper limit.

Discussion

To our knowledge, this is the first nationwide survey among Chinese anesthesiologists that demonstrate considerablely variabe practices with respect to intraoperative ventilation management in non-cardiothoracic surgical setting. The majority of respondents reported applying low V_T, PEEP, and ARM separately, while only about a fifth performed LPV with bundles of low V_T, PEEP, and ARM.

The LPV strategies

It has been well established that intraoperative LPV strategies, containing low V_T, appropriate PEEP with or without ARMs, could reduce the development of PPCs[12-14]. A retrospective study reported that approximate half of anesthesiologists at U.S. academic medical centers utilized both low V_T and PEEP[15]. Our survey showed that only 21.8% routinely applied both low V_T and PEEP, although most respondents recognized bundles of “low V_T, PEEP, and ARMs” as LPV strategy. This may explained by the knowledge-practice gap among Chinese anesthesiologists. In recent years, some studies have proposed that open-lung ventilation strategy[16], driving pressure (ΔP) guided ventilation strategy[17, 18], and mechanical power–guided ventilation strategy[19] may have lung protective effects. However, results remain equivocal regarding their ability to prevent PPCs[20-23].

Low V_T and PEEP

In our survey, the majority of respondents performed low V_T ventilation. The finding was in line with existing literature, which described that the use of low V_T had been significantly increased[24, 25]. However, less than half of respondents calculated V_T using PBW in accordance with expert recommendation[26]. Two studies found that compared to PBW, calculating V_T with ABW would overestimate the target V_T and that may expose patients to harmful volutrauma and barotrauma, especially to obese patients[27, 28]. In addition, our survey suggested more than 3/5 respondents set PEEP. While an observational study noted that 80% of patients still were ventilated without PEEP[29]. Reasons for not using PEEP included concerns about potential hemodynamic fluctuations [30] and PEEP not included in the default settings of ventilators[31]. Besides, we found most participants preferred PEEP level at 0-5 cmH_2O, which was consistent with prior studies [32, 33]. However, a network meta-analysis found that moderate-to-high PEEP (≥5 cmH_2O) combined with low V_T ventilation could reduced the risk of PPCs in surgical patients[14]. By far, there was no consensus on optimal PEEP level, and individualized PEEP according to patients’ lung compliance or ΔP was suggested by several studies [18, 34]. Our findings suggested that most anesthesiologists preferred to set PEEP based on lung compliance.

ARMs

Our survey showed that more than 60% of anesthesiologists performed ARMs during MV. The results differed from a large observational study, in which less than 1/5 patients received intraoperative ARMs [33]. The implementation of ARMs after intubation was suggested to alleviate the deterioration of functional residual capacity following anesthesia[26]. However, it remains inconsistent regarding the role of ARMs after intubation to prevent PPCs. In our study, only a small number of respondents performed ARMs after tracheal intubation. This might be the result of detrimental effects of ARMs on cardiac output which could aggravate the instability of hemodynamics after induction[35]. Our survey showed that respondents preferred to perform manual ARMs, while ventilator-driven ARMs recommended in the expert consensus were rarely utilized[26].

Other ventilatory settings

Our survey suggested that VCV was most commonly used among respondents, which was consistent with the results of two observational studies[36, 37]. Most anesthesiologists preferred FiO_2 at 40%-60%. Until now, the optimal level of FiO_2 remains unknow. Two randomized controlled trials comparing the use of high (80%) versus low (30%) FiO_2 showed no difference in reducing the incidence of PPCs[38, 39]. Expert consensus recommended FiO_2 should be set to ≤ 0.4 with the goal of using the lowest possible FiO_2 to achieve normoxia (or $SpO_2 \geq 94\%$) and reduce the occurrence of resorption atelectasis[26]. In our survey, a small number of anesthesiologists applied high FiO_2 (>80%) during operation.

Limitation

Our study has several limitations. Firstly, our survey was only distributed to anesthesiologists of some tertiary/university hospitals in China, and selection bias may exist, which restricts external validity. The results cannot be easily extrapolated to other medical centers in China and other countries. Secondly, our investigation had a 70% institution response rate, possibly introducing nonresponse bias. Nonetheless, a higher response rate does not necessarily improve nonresponse bias regarding demographic and practice variables[40]. Thirdly, as a general limitation of the survey, we cannot verify whether the statement of respondents was truly correct and reflected the current practice in their center. Fourthly, our study remained an observational research. It can only provide limited information about intraoperative ventilator management. It cannot be regarded as a reliable source to make definitive statements.

Conclusions

In China, intraoperative ventilation management in the setting of non-cardiothoracic surgery varies widely among anesthesiologists. The LPV strategy including low V_T, PEEP, and ARMs is generally acknowledged by anesthesiologists, while the implementation rate was low. A knowledge-practice gap may exist among Chinese anesthesia providers, which could be narrowed and further eliminated by interpretation of relevant expert consensus and continuing education.

Abbreviations

ACSMA, Anesthesiology Committee of Sichuan Medical Association; ARM, alveolar recruitment maneuver; AAPOR, American Association for Public Opinion Research; ABW, actual body weight; BMI, body mass index; CI, confidence interval; $EtCO_2$, end-tidal carbon dioxide; FiO_2, fraction of inspired oxygen; I: E, inspiratory to expiratory ratio; LPV, lung-protective ventilation; MV, mechanical ventilation; OLS, open lung strategy; PBW, predicted body weight; PEEP, positive end-expiratory pressure; PCV, pressure-controlled ventilation; PCV-VG, pressure-controlled-volume guaranteed ventilation; PPCs, postoperative pulmonary complications; QR Code, quick response code; RR, respiratory rate; SpO_2, saturation of pulse oxygen; STROBE, the strengthening the reporting of observational studies in epidemiology; V_T, tidal volume; VCV, volume-controlled ventilation; VILI, ventilator-induced lung injury; ΔP, driving pressure.

Declarations

Ethics approval and consent to participate

The study was approved by Ethics Committee of West China Hospital of Sichuan University and the informed consent was obtained from all participants by the recruitment email.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no competing interests.

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None

Authors' contributions

Qian-Qian Rao designed the study, analyzed the data, and prepared the manuscript. Hong Yu designed the study, analyzed the data, and prepared the manuscript. Si-Yang Wang analyzed the data and prepared the manuscript. Jia-Xin He collected the data and prepared the manuscript. Xue-Fei Li analyzed the data and prepared the manuscript. Fei Fei collected the data and prepared the manuscript. Kai-Xi Shang collected the data and prepared the manuscript. Hai Yu designed the study and prepared the manuscript. All authors read and approved the final manuscript.

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Tables

Table1 Sample Characteristics in this survey.

Charastiristic		N (%)
Academic position	Resident	469 (43.1)
	Attending	457 (41.9)
	Professor	163 (15.0)
Years of practice	0-4	418 (38.4)
	5-9	340 (31.2)
	10-14	195 (17.9)
	15-19	68 (6.2)
	≥20	68 (6.2)
Primary type of practice	Flexible subspecialties	929 (85.3)
	General sugery	41 (3.8)
	Orthopedics	39 (3.6)
	Neurosurgery	19 (1.7)
	Obstetrics and Gynecology	16 (1.5)
	Otorhinolaryngology	10 (0.9)
	Urology	8 (0.7)
	Stomatology	4 (0.4)
	Ophthalmology	0 (0)
	Others	23 (2.1)
Type of hospital	Teaching hospital	1035 (95.0)
	Non-teaching hospital	54 (5.0)

Data are presented as number (percentage).

Table 2 Respondents' Practice Details of LPV Strategy

Item	Practice	N(%)
V_T	<6	28 (2.6)
	6-8 (low V_T)	1010 (92.7)
	9-10	46 (4.2)
	others	5 (0.5)
PEEP	1-5	639 (58.7) */736 (67.6) †
	6-10	198 (18.2) */102 (9.4) †
	11-15	3 (0.3) */2 (0.2) †
	No PEEP	249 (22.9)
ARM	Manual method	843 (77.4)
	Progressively increase PEEP	42 (3.9)
	Progressively increase tidal volume	28 (2.6)
	Control vital capacity by ventilator	6 (0.6)
	No ARM	168 (15.4)
Low V_T +PEEP+ARM	Yes	208 (19.1)
Low V_T +PEEP	Yes	237 (21.8)

Data are presented as number (percentage).

Abbreviations: ARM, Alveolar recruitment maneuvers; LPV, Lung-protective ventilation; PEEP, Positive end-expiratory pressure; V_T, Tidal volume.

* For laparoscopic surgery; † For non-laparoscopic surgery.

Figures

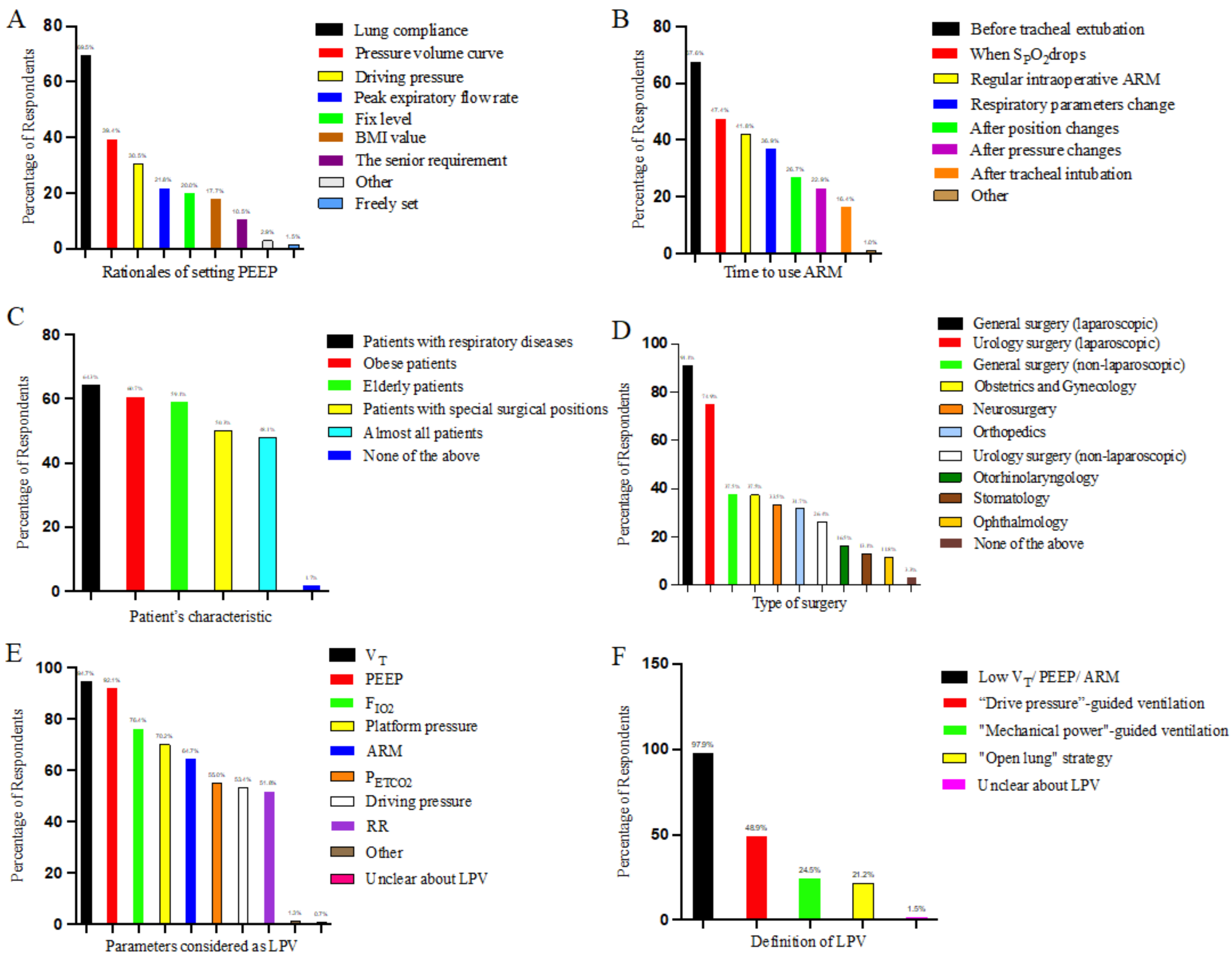

Figure 1

The implementation of LPV in non-cardiothoracic surgery.

A, Rationale of setting PEEP

B, Time to use ARMs

C, Patient's characteristic

D, Type of surgery

E, Parameters considered as LPV

F, Definition of LPV

Numbers in the brackets indicate the percentage of the respondents. Because multiple answers are accepted, percentages do not equal 100%. Abbreviations: ARMs, Alveolar Recruitment Maneuvers; BMI, Body Mass Index; E_TCO_2, End-Tidal Carbon Dioxide

; FiO_2, Fraction of inspired oxygen; LPV, Lung protective ventilation; PEEP, Positive End-Expiratory Pressure; RR, Respiratory rate; SpO_2, Saturation of Pulse Oxygen; V_T, Tidal volume.

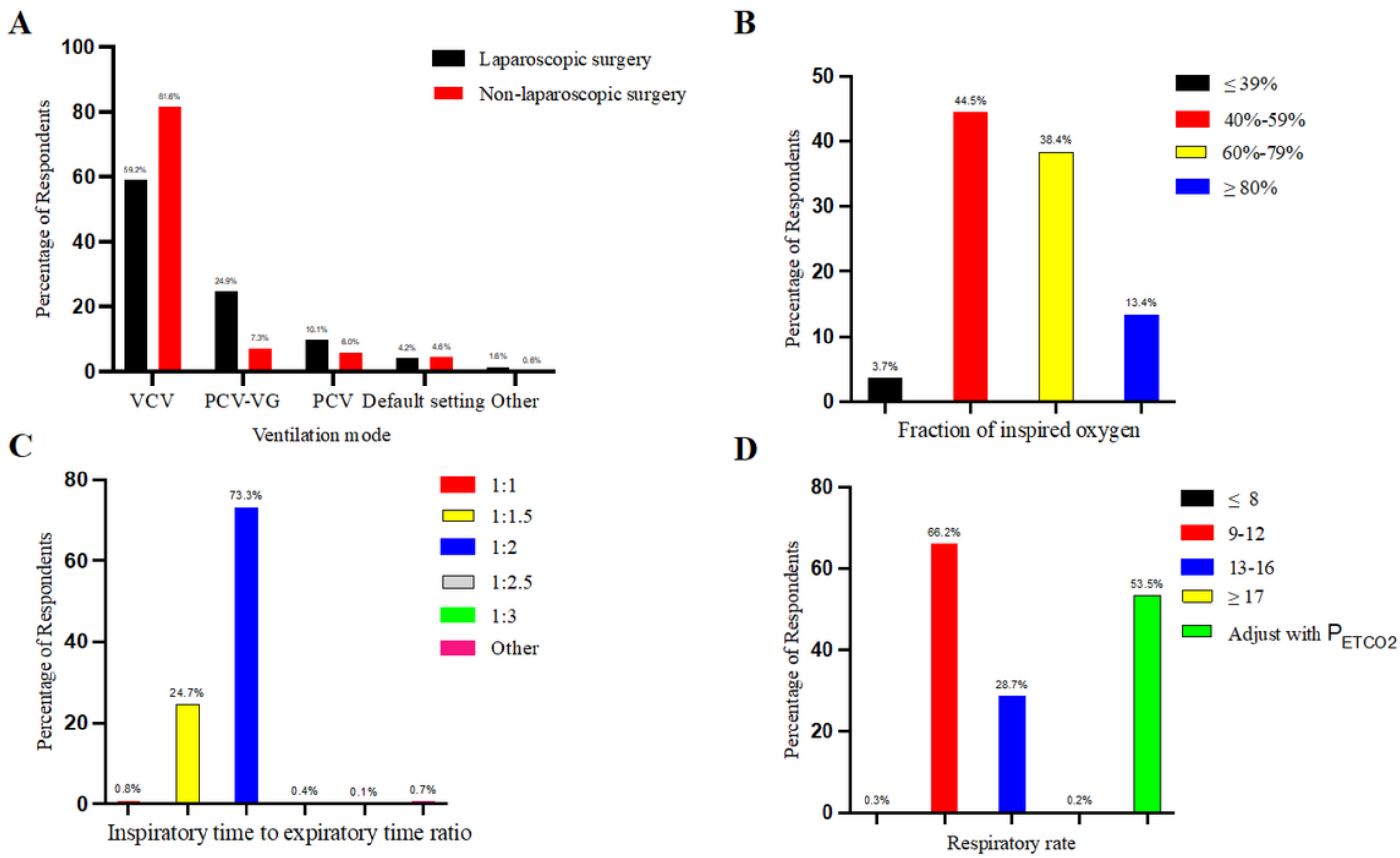

Figure 2

The implementation of other ventilatory settings in non-cardiothoracic surgery.

A, Ventilation mode

B, Fraction of inspired oxygen

C, Inspiratory to expiratory ratio

D, Respiratory rate

Numbers in the brackets indicate the percentage of the respondent. Because multiple answers are accepted, percentages do not equal 100%. Abbreviations: E_TCO_2, End-Tidal Carbon Dioxide; PCV-VG:

Pressure-Controlled-Volume Guaranteed Ventilation; PCV, Pressure-Controlled Ventilation; VCV: Volume-Controlled Ventilation.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1Recruitmentemail..docx
- Additionalfile2Questionnaireitems.docx
- Additionalfile3Listofcollaborators.docx