Anesthesia-Related Airway Patient Safety Incidents Correlated with Major Adverse Cardiac Events: A Single-Center Retrospective Case-Control Analysis from 2009 to 2019

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Research

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Abstract

Background: Airway-related patient safety incidents (PSIs) have always been the top concern of anesthesiologists because this type of incident could severely threaten patient safety if not treated immediately and properly. This study aimed to reveal the composition and outcomes of and to identify risk factors related to airway incidents reported by anesthesiologists.

Methods: All airway-related PSIs reported by anesthesiologists at a Chinese academic hospital between September 2009 and August 2019 were collected from the PSI reporting system. Patients with reported airway incidents were matched 1:1 with controls based on sex and type of surgery. Univariate and multivariate analyses were performed to identify risk factors associated with airway incident occurrence and to evaluate the influence of airway PSIs on the prognosis.

Results: Among 773 PSIs voluntarily reported by anesthesiologists during the study period, 208 (26.9%) were airway-related incidents, with an overall reporting incidence of 4.59 per 10,000. In patients with reported airway PSIs, postoperative major adverse cardiac events (MACEs) were more likely (7 vs 1 case, odds ratio: 7.37 [95% confidence interval (CI): 0.89 to 60.83], p=0.031) and the extubation time (0.82±1.63 d vs 0.21±0.89 d, mean difference: 0.61 d [95% CI: 0.28 to 0.95 d], p<0.001) and ICU length of stay (LOS) (2.03±6.66 d vs 0.22±0.96 d, mean difference 1.81 d [95% CI: 0.60 to 3.02 d], p=0.004) were longer. Only the American Society of Anesthesiologists (ASA) physical status was found to be a significant independent predictor of these airway PSIs.

Conclusions: This single-institutional retrospective case-control study describes the composition of airway-related PSIs reported by anesthesiologists within eleven years. Airway incidents influence the prognosis by increasing the incidence of postoperative MACEs and prolonging both the extubation time and ICU LOS. Airway PSI data are worth analyzing to improve patient safety.

Background

A patient safety incident (PSI) is an event or circumstance that could have resulted, or did result, in unnecessary harm to a patient according to the World Health Organization (WHO) classification for patient safety [1]. Airway incidents are the most common type of anesthesia-related PSI [2, 3], and an intensive care unit (ICU) incident analysis revealed that airway incidents were more harmful for patients than other types of incidents [4]. Therefore, airway incidents have always been the top concern of anesthesiologists because this type of incident could severely threaten patient safety if not treated immediately and properly.

A PSI reporting system was established at Peking Union Medical College (PUCM) Hospital in 2009, and all anesthesia-related PSIs are encouraged to be reported voluntarily using the system. In this study, we collected all airway incidents reported by anesthesiologists at our hospital during an eleven-year period to evaluate the composition of and identify risk factors related to airway incidents, with the aim of providing suggestions for improving airway-related patient safety from the anesthesiologist's perspective.

Methods

Data collection

With the approval of the PUMC Hospital Institutional Review Board (S-K1107, 25 March 2020), all airway incident data from September 2009 to August 2019 were collected from the PSI reporting system. To determine the relationship between incident occurrence, patient prognosis and incident reporting, patients with reported airway incidents were matched 1:1 with controls based on sex and type of surgery. Under the premise of blinding of the reviewers to whether the patient had a reported incident, we searched our anesthesia record system for patients with the same sex and exact surgery type who underwent their procedures in the same month, and the first matched patient was chosen as the matched control. If there was no eligible control that met the criteria for matching during that month, we expanded the search by one month until we found a suitable case.

We considered several potential predictors of airway incidents, including patient-related factors and anesthesia-related factors. The patient-related factors included age, height, weight, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status, preoperative comorbidities, smoking and drinking history and preoperative laboratory test results. We evaluated the time of extubation, ICU length of stay (LOS), postoperative LOS, and total in-hospital LOS by reviewing patient records for prognostic analysis. Moreover, we evaluated some special events that might be related to anesthesia procedures and could be extremely harmful to patients, including death, postoperative pulmonary infection, and postoperative major adverse cardiac events (MACEs).

Three anesthesiologists (Xue Zhang, Lingeer Wu, and Huizhen Huang) from the Department of Anesthesiology, PUMC Hospital, collected the data. They had received training in data extraction to ensure validity and reliability during data collection and signed a confidentiality agreement before receiving the data. The data we chose for our study were all objective indices to avoid subjective bias in the data collection procedure.

Statistical analysis

Data analysis was conducted using SPSS (version 26, IBM SPSS statistics, Chicago, IL, USA). Patient characteristics are summarized using descriptive statistics. The incidence of airway-related PSIs was calculated by the number of airway incidents divided by the total number of surgeries, and the confidence interval (CI) of the incidence rate was estimated using the likelihood method. Potential risk factors were first checked using univariate analysis. Statistically significant risk factors in this analysis were further checked with clinical experience and previous relevant studies, and clinically relevant risk factors were included in the multivariate logistic regression model, in which stepwise selection was used to identify the final model. A two-sided P value less than 0.05 was regarded as statistically significant.

Results

Among the 773 PSIs voluntarily reported by anesthesiologists from September 2009 to August 2019, 208 (26.9%) were airway-related incidents, with an overall reporting incidence of 4.59 per 10,000 among 452,974 anesthesia care episodes. We excluded several cases and finally enrolled 121 cases for further analysis. Details regarding the classification of enrolled cases and reasons for exclusion are illustrated in Fig. 1.

Significant differences were found via univariate analysis between patients with airway-related PSI reported and controls with regard to the ASA physical status, history of hypertension and diabetes, patient BMI and preoperative albumin level, as shown in Table 1. On multivariate analysis, only the ASA physical status was found to be a significant independent predictor of airway PSIs.

Table 1
Risk factors associated with airway-related PSIs on univariate analysis

Risk factor		Airway PSI group	Control group	Mean difference/OR (95% CI)	P value
Age (mean ± SD)		55.45 ± 15.22	52.35 ± 13.26	3.11 (-0.51 to 6.72)	0.092
Height (cm)		165.09 ± 7.64	165.71 ± 7.64	-0.62 (-2.69 to 1.46)	0.558
Weight (kg)		67.55 ± 12.88	64.64 ± 12.25	2.91 (-0.28 to 6.10)	0.073
BMI (kg/m^2)		24.67 ± 4.09	23.55 ± 3.60	1.12 (0.11 to 2.13)	0.029*
ASA PS	Grade I	15	36	Reference	–
	Grade II	82	75	2.62 (1.33 to 5.17)	0.005*
	Grade III	24	10	5.76 (2.22 to 14.93)	< 0.001*
Preoperative comorbidities	Hypertension	40	24	2.00 (1.11 to 3.59)	0.020*
	Diabetes	23	12	2.13 (1.01 to 4.51)	0.044*
Smoking history		30	32	0.92 (0.52 to 1.63)	0.768
Drinking history		16	19	0.82 (0.40 to 1.68)	0.583
Preoperative laboratory test indices (mean ± SD)	WBC (*10^9/L)	6.70 ± 1.98	6.51 ± 2.58	0.19 (-0.39 to 0.78)	0.518
	NEUT% (%)	62.87 ± 10.14	61.10 ± 10.65	1.78 (-0.86 to 4.42)	0.186
	LY% (%)	27.37 ± 9.09	29.23 ± 9.34	-1.85 (-4.19 to 0.49)	0.120
	HGB (g/L)	131.09 ± 27.10	135.15 ± 18.95	-4.06 (-10.00 to 1.88)	0.180

PSI: patient safety incident; OR: odds ratio; CI: confidence interval; SD: standard deviation; BMI: body mass index; ASA PS: American Society of Anesthesiologists physical status; WBC: white blood cell count; NEUT%: neutrophil granulocyte percentage; LY%: lymphocyte percentage; HGB: hemoglobin; Hct: hematocrit; PLT: platelet count; ALT: alanine aminotransferase; Alb: albumin; Cr: creatinine; PT: prothrombin time; APTT: activated partial thromboplastin time.

*$p < 0.05$

Risk factor		Airway PSI group	Control group	Mean difference/OR (95% CI)	P value
	Hct (%)	39.75 ± 5.57	40.23 ± 5.11	-0.48 (-1.84 to 0.87)	0.483
	PLT	239.16 ± 79.71	242.87 ± 76.97	-3.71 (-23.60 to 16.18)	0.714
	ALT	32.22 ± 56.77	28.41 ± 54.79	3.80 (-10.36 to 17.96)	0.597
	Alb (g/L)	41.45 ± 5.09	42.79 ± 4.03	-1.34 (-2.52 to -0.17)	0.025*
	Serum Cr (μmol/L)	71.14 ± 22.58	66.45 ± 13.57	4.70 (-0.04 to 9.43)	0.052
	PT (s)	11.84 ± 1.10	11.59 ± 1.26	0.26 (-0.04 to 0.56)	0.092
	APTT (s)	28.29 ± 4.45	27.26 ± 3.66	1.03 (-0.01 to 2.07)	0.051
	Fibrinogen (g/L)	3.34 ± 1.29	3.05 ± 0.98	0.29 (0.00 to 0.58)	0.005
	Glucose (mmol/L)	5.70 ± 1.31	5.71 ± 1.68	-0.01 (-0.39 to 0.37)	0.955

PSI: patient safety incident; OR: odds ratio; CI: confidence interval; SD: standard deviation; BMI: body mass index; ASA PS: American Society of Anesthesiologists physical status; WBC: white blood cell count; NEUT%: neutrophil granulocyte percentage; LY%: lymphocyte percentage; HGB: hemoglobin; Hct: hematocrit; PLT: platelet count; ALT: alanine aminotransferase; Alb: albumin; Cr: creatinine; PT: prothrombin time; APTT: activated partial thromboplastin time.

*$p < 0.05$

We further compared the two groups in terms of prognosis. The extubation time and ICU LOS were significantly prolonged in patients with airway PSIs. However, the differences in the postoperative LOS and total in-hospital LOS between the two groups were not statistically significant. Seven patients with an airway PSI and one patient without an airway PSI suffered from a postoperative MACE (three with postoperative myocardial infarction and four with postoperative heart failure), and the difference between the two groups was significant, but the incidence of postoperative pulmonary infection was not significantly different between the two groups, as illustrated in Table 2.

Table 2
Prognostic data analysis for airway incidents

Time	Airway PSI group	Control group	Mean difference (95% CI)	P value
Extubation	0.82 ± 1.63	0.21 ± 0.89	0.61 (0.28 to 0.95)	< 0.001*
ICU LOS (days)	2.03 ± 6.66	0.22 ± 0.96	1.81 (0.60 to 3.02)	0.004*
Postoperative LOS (days)	11.46 ± 14.71	8.59 ± 12.46	2.88 (-0.58 to 6.33)	0.102
In-hospital LOS (days)	16.14 ± 16.96	12.88 ± 13.52	3.26 (-0.62 to 7.15)	0.099
Complications	Airway PSI group	Control group	OR (95% CI)	P value
Pulmonary infection	7	4	1.80 (0.51 to 6.30)	0.355
MACE	7	1	7.37 (0.89 to 60.83)	0.031*
CI: confidence interval; ICU: intensive care unit; LOS: length of stay; MACE: major adverse cardiac event.				
*p < 0.05				

Discussion

PSI reporting has been widely accepted to be an important quality control method for improving patient safety. Airway incidents should always be taken seriously by anesthesiologists because they may have catastrophic consequences if not treated properly [5, 6]. Most airway-related PSI research originates from the ICU. Thomas and colleagues reported that only 2.1% of ICU incidents described more than temporary harm, of which 13.5% were airway-related incidents [4]. Similar patterns were reported in a previous review of airway incidents in critical care [5]. Only a few studies focusing on anesthesia-related incidents, especially airway incidents, are available in the literature. One study from Singapore by Saito and colleagues reported that the incidence of airway PSIs was 0.46%, including cases of airway spasm, dental trauma, difficult airway, reintubation and pulmonary aspiration [3]. The types of incidents in our research are similar to those reported by Saito; nevertheless, the overall reporting incidence is much lower. Other than the heterogeneity caused by regional differences, underreporting should not be ignored. Many near-miss incidents or incidents that only cause minor or even moderate harm to patients might not be reported if PSI reporting is not mandatory. Moreover, poor data processing and organizational support, as well as inadequate doctor engagement and feedback, are always related to underreporting [7–9].

In this study, we proved by case-control analysis that patients with airway-related incidents were more vulnerable to postoperative MACEs and experienced a longer extubation time and ICU LOS than patients with no reported incidents. These results show that airway PSI reporting is indeed related to the patient

prognosis. Many existing airway abnormalities, such as asthma and airway obstruction, have been proven to be associated with MACEs [10, 11]. We considered two reasons why airway incidents could result in more MACEs. First, airway-related PSIs are always accompanied by severe hypoxia, which might result in heart ischemia and myocardial cell damage. Second, some drugs used for controlling preexisting airway diseases, such as [12, 13] long-acting beta2-agonists (LABAs), are correlated with MACEs. Recommendations to improve airway safety in the ICU, such as implementing capnography monitoring, reviewing checklists for recognizing tube displacement, and providing staff with the skills to manage the problem, have been made based on related studies [4, 5, 14]. There are many guidelines available in the literature focusing on anesthesia-related airway management [15, 16], but anesthesia-related airway PSIs have not gained enough attention. This has resulted in a major waste of precious clinical airway PSI data. Analyzing airway incident data and entering the PDCA (plan-do-check-act) cycle should be closely considered because these are important patient safety quality control steps for improving the patient prognosis.

A worse ASA physical status has been proven to be correlated with increased mortality as well as a higher perioperative cardiac arrest rate [17]. Our results further demonstrate that the ASA physical status is also an independent risk factor for airway-related PSIs. It is also worth mentioning that the patient BMI showed significance on univariate analysis. It has been demonstrated that obese patients show an increased incidence of difficult mask ventilation, difficult laryngoscopy and difficult intubation [18–20], and these factors might result in more airway incidents. Although the ASA physical status and BMI are not intervenable before surgery, anesthesiologists should pay more attention to patients with a worse ASA physical status and higher BMI. A more detailed airway evaluation, better preparation of airway management equipment, and preparation of good backup plans in the case of ventilation or intubation failure should be carefully performed before anesthesia.

Our study has several limitations that should be considered when interpreting the results. First, this was a single-center retrospective study without regional and organizational heterogeneity; thus, the results might not be applicable in other environments. Second, underreporting may result in underestimation of the incidence of airway-related PSIs and may influence the representativeness of the results. Underreporting was unavoidable because reporting airway-related PSIs was not mandatory, and the culture of PSI reporting has not been established very well in China. Moreover, some PSIs resulting in no or minor patient harm are not always considered to be worth reporting. In fact, PUMC Hospital is one of the first hospitals to have established a PSI reporting system in China and has always made efforts to encourage PSI reporting by faculty. Therefore, we believe that our results could reflect the status of airway-related PSIs to some extent. Finally, the independent risk factors in our study were not intervenable, and large, multicenter studies are necessary to verify the results in the future.

Conclusions

This was a single-institutional retrospective case-control study in which the incidence of anesthesia airway-related PSIs was 4.59 per 10,000. The incidence of anesthesia airway-related PSIs was correlated

with a prolonged extubation time and ICU LOS and could significantly increase the incidence of postoperative MACEs. The ASA physical status was independently correlated with airway PSI occurrence. Airway PSI data are worth analyzing to improve patient safety.

Abbreviations

PSI
patient safety incident
WHO
World Health Organization
ICU
intensive care unit
PUCM
Peking Union Medical College
BMI
body mass index
ASA
American Society of Anesthesiologists
LOS
length of stay
MACEs
major adverse cardiac events
CI
confidence interval
LABAs
long-acting beta2-agonists
PDCA
plan-do-check-act

Declarations

1. Ethics approval and consent to participate

This investigation was a retrospective hospital-based study approved by Peking Union Medical College Hospital Institutianal Review Board (S-K1107, 25 March 2020). No written informed consent was obtained from participants since that it is a retrospective study without any individual person's data. All the data were collected from the patient safety incident reporting system and hospital information system in our hospital.

2. Consent for publication

Not applicable.

3. Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

4. Competing interests

The authors declare that they have no competing interests.

5. Funding

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6. Author's contributions

XZ collected data, did data cleaning and was the major contributor in writing the manuscript. LW, HH collected data and work on data analysis. YZ directed the study design and participated in the statistical analysis. LS and YH were project administration, directed the design of the study and gave supervision to the study. LS also modified the article.

7. Acknowledgements

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Figures

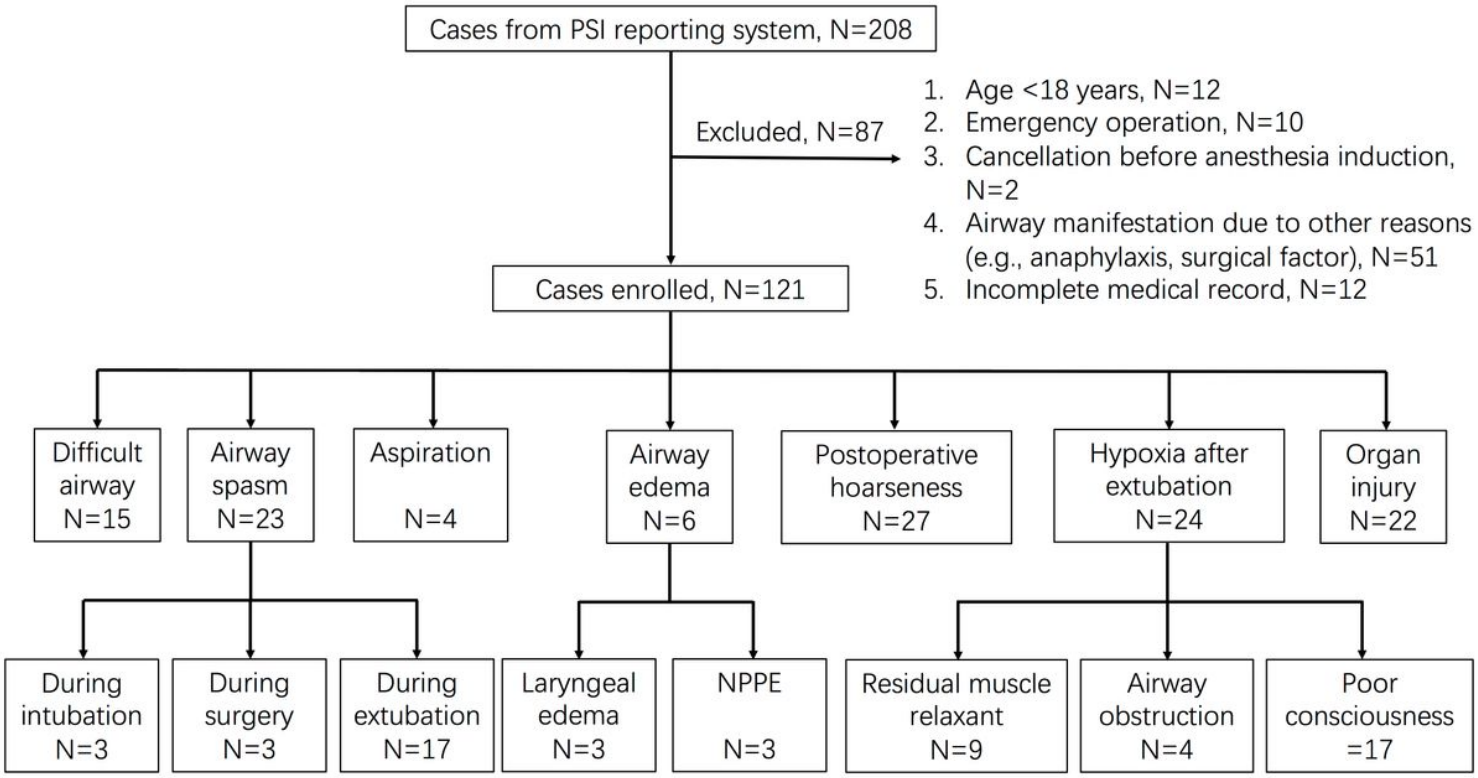

Figure 1

Airway-related PSI enrollment and classification. This figure shows the classification of airway-related PSIs reported by anesthesiologists from September 2009 to August 2019, as well as the number of cases in each category. PSI: patient safety incident; NPPE: negative-pressure pulmonary edema.