# Adverse Respiratory Events Increase Post-anesthesia Care Unit Stay in China: A 2-year Retrospective Matched Cohort Study

Shang-kun LIU[1], Gang CHEN[1], Bi YAN[1], Jiao HUANG[2], Hui XU[1#]

[1]*Department of Anesthesiology, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430030, China*
[2]*School of Public Health, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430030, China*

**Summary**: Despite growing attention to patients' safety worldwide, no data were available on the impact of adverse respiratory events (AREs) on post-anesthesia care and post-operation care in China. This study evaluated the occurrence of AREs, the impact of AREs on length of stay (LOS) in post-anesthesia care unit (PACU) and postoperative time in hospital, and PACU cost and inpatient healthcare costs. A retrospective, matched-cohort study was conducted by prospectively collecting the data of 159 AREs in PACU during 2016–2017 in an university hospital in China. Records were reviewed by pre-trained, qualified nurses and/or anesthesiologists. The incidence and the impact of AREs were analyzed. The LOS in PACU and postoperative time in hospital and the costs in PACU and inpatient healthcare costs were also obtained. Results showed that there were 253 AREs involving 156 patients. Hypoxia (*n*=141, 55.73%) and respiratory depression (*n*=70, 27.67%) were the most common AREs. Measurement data including body mass index (BMI) (22.85±4.36 *vs*. 22.32±3.83), duration of procedure (138.47±77.33 min *vs*. 137.44±72.33 min), duration of anesthesia (176.35±82.66 min *vs*. 174.61±78.08 min), LOS (16.53±10.65 days *vs*. 16.57±9.56 days), inpatient healthcare costs ($9465.57±9416.33 *vs*. $8166.51±5762.01), and postoperative LOS (11.26±8.77 days *vs*. 11.19±8.30 days) showed no significant differences between ARE and matched groups (*P*>0.05). Duration (81.65±54.79 min *vs*. 38.89±26.09 min) and costs ($31.99±17.80 *vs*. $18.72±8.39) in PACU were significantly different in ARE group from those in matched group (*P*<0.001). Proportion of patients with prolonged stay in PACU was significantly higher in ARE group than in matched group (18.59% *vs*. 1.28%), with an odds ratio (after matching) of 17.58 (95% CI=4.11 to 75.10; *P*<0.001). The AREs that occurred during the immediate postoperative period in PACU increased the incidence rate of prolonged stay, delayed the PACU stay, and increased the costs in PACU, resulting in the need of higher levels of postoperative care than anticipated, but the postoperative LOS and inpatient healthcare costs were unchanged.
**Key words**: adverse respiratory events; post-anesthesia care unit; postoperative complications

Post-anesthesia care unit (PACU) is critical for patients' postoperative emergency and recovery after the operation and/or procedure. This maintains stable physiological status and helps in early detection of critical incidents that result from the anesthetic and surgical intervention, and remains to be an important place during anesthesia recovery.

One of the major critical events in PACU includes adverse respiratory events (AREs)[1]. The incidence of AREs ranged from 6% to 55% of all complications in the PACU. Hypoxemia is an independent risk factor of post-operative length of stay (LOS). Patients suffering from pneumonia after surgery have a 55% increase in hospital costs and 89% increase in LOS in hospital[2–6].

However, there is lack of robust evaluation on the impact of AREs on patients that occurred postoperatively and the positive treatment in patients who are in PACU. Hence, this retrospective review of PACU AREs from the database was conducted and the occurrence of AREs was investigated, to evaluate the impact of AREs on LOS in PACU and postoperatively in the hospital, and the cost in PACU and inpatient healthcare costs at Tongji Hospital, China. We conducted a retrospective matched cohort study with prospectively collected data on AREs from a university tertiary general hospital for 2 years i.e., from January 1, 2016 to December 31, 2017.

Shang-kun LIU, E-mail: 13971586990@163.com
#Corresponding author, E-mail: sophia_wh@hotmail.com

# 1 MATERIALS AND METHODS

## 1.1 Methods

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist for observational studies was followed to conduct the methods as well as in drafting this manuscript. The study was approved by the Hospital Ethics Committee (TJ-IRB20170501). The critical incidents of 81 875 patients in PACU were recorded by pre-trained, qualified nurses and/or anesthesiologists in our hospital from January 1, 2016 to December 31, 2017. The study was carried out in the university hospital of Hubei province in China. It is a general public university hospital, and included 62 clinical departments. The total number of operations performed was 58 000/year, and it has 99 surgical rooms in 5 surgical areas and 38 beds in PACU. This study was designed to describe the occurrence of AREs in patients who underwent general anesthesia extubation, and then were transferred from the operating room (OR) to the PACU. The data, such as demographics, consciousness, respiratory amplitude, respiratory frequency, airway patency, oxygen saturation changes, treatment, blood pressure (BP) and heart rate (HR), and fast-track criteria scores were recorded for all identified patients. A minimal score of 12 (with no score less than 1 in any individual category) would be required for a patient to move to the general ward[7, 8].

This was a retrospective, matched-cohort study (one ARE group, one matched group) conducted using a prospectively collected database. Patients discharged with no AREs from PACU was designated into the matched group, while patients with AREs during PACU stay were designated into the ARE group. The patients were matched according to the type of procedure performed, surgical characteristics, duration of anesthesia (±0.5 h), duration of operation (±0.5 h), ASA classification, and age (±3 years). Data of surgical and anesthesia parameters including ASA classification, age, height, weight, sex, start time of operation, end time of operation, start time of anesthesia, end time of anesthesia, time in and discharge from PACU, procedure performed, emergency/selective operation were obtained from the anesthesia information system. Admission time and discharge time were obtained from the Hospital Information System (HIS). Inpatient healthcare costs and PACU costs were obtained from the price system. Data were extracted by structured query language questioning of the database. The necessary data were retrieved from the medical records at the time of hospital admission during the year 2016–2017. The LOS in PACU and the management of critical incidents were also documented. We started the study in February 2018. Data collection was accomplished when the patients left the hospital, and the time of last patient discharge was, i.e., on January 4, 2018.

## 1.2 Inclusion and Exclusion Criteria

Patients with AREs after general anesthesia extubation and who were transferred to PACU from OR were included. Cases that did not match the criteria or AREs after the first 5 min in PACU following OR extubation were not considered.

## 1.3 Definitions

In our study, the following definitions were used:

Critical incident was defined as any incident in which the safety margin of the patient was decreased or could have decreased under anesthetic care[9]. So, AREs in PACU were defined as any incident in which the life safety of patients was compromised or could have been compromised under anesthetic care during the first 5 min in PACU because of breathing or airway problems such as hypoxemia, airway obstruction, respiratory depression, and intubation, excluding the preoperative AREs.

Post-operative hypoxemia was defined as patients with two or more episodes of $SpO_2 < 94\%$ on room air or nasal cannula supplemented with oxygen of 1–2 liters per minute, or <98% with greater supplementation of oxygen, or post-operative $SpO_2$ of ≥5% reduction as compared to their pre-operative value[6].

Prolonged stay in PACU was defined as the duration of stay that lasts for more than 2 h[10].

Admission date, operation date and discharge date were calculated as one day when we collected LOS and LOS of postoperation.

## 1.4 Samples

Before initiation of the study, we conducted a retrospective cohort study. The necessary data were retrieved from the medical records of hospital admissions during the year 2015. A power analysis was performed based on the duration of PACU in patients with AREs. The mean total patient care minutes were 34.8 and 81.5 in matched group and ARE group, respectively, with a standard deviation of 53. To detect a 30-min difference in patient care minute time between the 2 groups, 125 study subjects were required in each group (α=0.05 and β=0.2, two-sided test). We estimated that 20% of the eligible patients might not complete the study as our sample size has been inflated to reduce the error, and so we finally enrolled 312 patients.

## 1.5 Quality Control

We implemented a standardized form to collect the data regarding complications in the PACU. All patients were assessed and AREs were recorded after rigorous uniform training and examination through Microsoft Excel® 2010 spreadsheet by the nursing staff. ARE data were part of the quality control in the department of anesthesiology. Every day quality control nursing staff checked, tracked and supplied the data. Data integrity measures are regularly performed to safeguard the reliability and validity of the system's

data. Missing data were replaced by the mean values during the retrospective study.

### 1.6 Statistical Analysis

Data were entered into Microsoft Excel® 2010 spreadsheet and imported into SPSS System for Windows. Statistical analysis was carried out by Statistical Package of the Social Sciences version 18.0 (SPSS Inc., USA). All data were described as mean±standard deviation. The chi-square test or nonparametric two-independent sample test was used to analyze the categorical data, and student's $t$ test used to analyze continuous variables. A two-tailed $P$ value less than 0.05 ($P<0.05$) was considered to be statistically significant. We calculated the relative risk (RR) for prolonged stay in PACU with a 95% confidence interval (CI).

## 2 RESULTS

During the 2-year study period, 137 625 patients underwent procedures under general anesthesia for the major operation area. Of these 137 625 patients, 81 875 extubation patients stayed in PACU from OR. Although AREs were recorded for 159 patients in the PACU database, 1 patient was excluded due to lack of matched patient reasons, and 2 patients were excluded due to unavailable records. In total, 156 matched patients with 253 incidents were included in the analyses. A flow diagram describing the process of patients recorded is shown in fig. 1, and their demographics and clinical characteristics are shown in table 1.

All incidents occurred in patients who underwent general surgical, orthopedic procedures, obstetrics and gynecology procedures, ophthalmology and otorhinolaryngology procedures, urinary procedures, pediatric procedures, or general chest procedures.

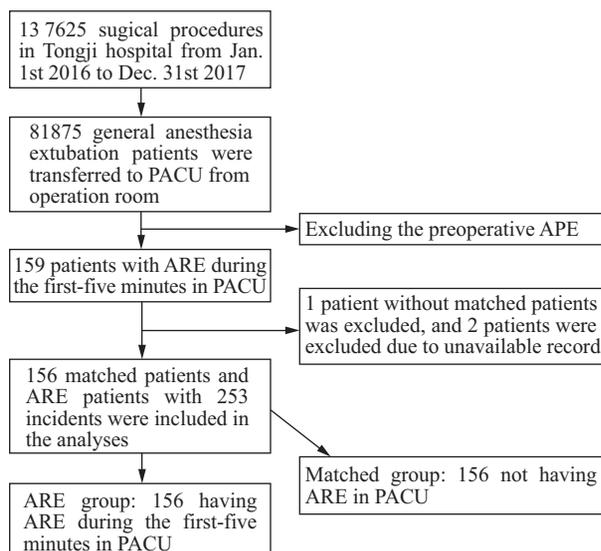There were 156 AREs (0.19%) in the PACU.



**Fig. 1** Schematic demonstration of study samples

**Table 1 Patient demographics in 2 groups**

| | Matched group ($n$=156, %) | ARE group ($n$=156, %) | $\chi^2$ | $P$ |
|---|---|---|---|---|
| Gender | | | | |
| Male | 65 (41.67) | 70 (44.87) | 0.326 | 0.568 |
| Female | 91 (58.33) | 86 (55.13) | | |
| Procedure | | | | |
| Emergency | 15 (9.62) | 19 (12.18) | 0.528 | 0.467 |
| Elective | 141 (90.38) | 137 (87.82) | | |
| ASA physical status | | | | |
| I–II | 143 (91.67) | 133 (85.26) | 3.140 | 0.076 |
| III–IV | 13 (8.33) | 23 (14.74) | | |
| Age (year) | | | | |
| 0–17 | 14 (8.97) | 17 (10.90) | 0.322 | 0.570 |
| ≥18 | 142 (91.03) | 139 (89.10) | | |

ASA: American Society of Anesthesiologists

**Table 2 Respiratory critical incidents in PACU**

| Respiratory incidents | $n$ | % |
|---|---|---|
| Hypoxia | 141 | 55.73 |
| Respiratory depression | 70 | 27.67 |
| Obstruction | 41 | 16.21 |
| Reintubation | 1 | 0.40 |

Hypoxia ($n$=141, 55.73%) and respiratory depression ($n$=70, 27.67%) were the most common AREs (table 2). There were patients with $SPO_2$ <90% ($n$=34, 21.79%) and <85% ($n$=62, 39.74%) in the ARE group, respectively. Of these, 54 (34.62%) patients were under assisted ventilation, 19 (12.18%) were under opened airway, and 1 (0.64%) under reintubation in the PACU. Six patients were included as unplanned admissions to the intensive care unit (ICU), while the others were admitted to the ward through correct treatment and observation.

Patients' demographics and clinical characteristics are presented in table 1. Complications are associated with increased costs and prolonged LOS, measurement data in the 2 groups including BMI, duration of procedure, duration of anesthesia, LOS, inpatient healthcare costs, length of postoperative stay were analyzed using $t$ test (all $P>0.05$). Duration of PACU and costs in PACU are presented in table 3.

Proportion of patients with prolonged stay in PACU was significantly higher in the ARE group than in matched group (18.59% *vs.* 1.28%), with an odds ratio (after matching) of 17.58 (95% CI=4.11 to 75.10; $P<0.001$) (table 4).

One patient had choking sensation in the chest in the matched group and 2 had desaturation in the ARE group, when the patients were transferred to the ward from PACU.

## 3 DISCUSSION

The immediate postoperative period, during which

**Table 3 Costs and duration in PACU**

|  | Matched group ($\bar{x}\pm s$) ($n$=156) | ARE group ($\bar{x}\pm s$) ($n$=156) | $t$ | $P$ |
|---|---|---|---|---|
| BMI | 22.32±3.83 | 22.85±4.36 | 1.145 | 0.894 |
| Duration of procedure (min) | 137.44±72.33 | 138.47±77.33 | 0.122 | 0.903 |
| Duration of anaesthesia (min) | 174.61±78.08 | 176.35±82.66 | 0.192 | 0.848 |
| Length of stay (day) | 16.57±9.56 | 16.53±10.65 | 0.035 | 0.972 |
| Inpatient healthcare costs ($) | 8166.51±5762.01 | 9465.57±9416.33 | 1.470 | 0.143 |
| Length of postoperative stay (day) | 11.19±8.30 | 11.26±8.77 | 0.070 | 0.944 |
| Costs in PACU ($) | 18.72±8.39 | 31.99±17.80 | 8.426 | <0.001 |
| Duration of PACU (min) | 38.89±26.09 | 81.65±54.79 | 8.802 | <0.001 |

**Table 4 Recovery time in 2 groups**

|  | Recovery time <120 min | Recovery time ≥120 min | OR (95% CI) | $\chi^2$ | $P$ |
|---|---|---|---|---|---|
| Matched group ($n$=156, %) | 154 (98.72) | 2 (1.28) | 1.00 | 26.11 | <0.001 |
| ARE group ($n$=156, %) | 127 (81.41) | 29 (18.59) | 17.58 (4.11–75.10) | | |

the patient recovers from the insults of surgery and anesthesia, is the time of significant physiologic flux. The incidence of complications in the PACU ranged from 6% to 30%[3].

 AREs are the major adverse events affecting the morbidity and mortality rates. Desaturation is one of the major complications observed during the active period[3]. Most (55.73%) of the patients with AREs were hypoxemic[2]. A retrospective study by Hines *et al* extracted 701 incidents from the critical incidents database of Singapore General Hospital, and noted that the major ARE was hypoxemia. In our study, there were patients with $SPO_2$ <90% ($n$=34), and <85% ($n$=62) in the ARE group, respectively. Several risk factors have been identified as reasons of desaturation in the PACU. Anesthesiologist did not grasp the extubation indication or not carefully observe patients after extubation for decreasing OR stay time and increasing efficiency, and all the patients were transferred without monitoring $O_2$.

Desaturation associated respiratory/airway issues were observed in patients who were immediately transferred from the OR into the PACU during the postoperative period. Similarly, Siddiqui *et al* reported a high incidence of hypoxemia during the transfer of patients from the OR to the PACU[3]. Desaturation can be improved by taking some corresponding measures including timely observation, inspired oxygen, open airway, assisted ventilation, neuromuscular blocking agents, opioid blocking agents etc. Another reason for desaturation during patient transport from OR to PACU is physicians' lack of recognition of hypoxemia. According to a study, the benefits of PACU were seen in terms of improved surgical outcomes, and reduced postoperative morbidity and mortality[11].

The early recognition of deterioration and the start of therapy in PACU may prevent these complications and improve the patient outcomes or reduce the serious adverse events following surgery. Complications are associated with increased inpatient healthcare costs

and prolonged LOS[4]. In our study, although the AREs increased the costs and prolonged the LOS in PACU, these AREs were not associated with LOS and inpatient healthcare costs. The reason for this might be due to that the early recognition of deterioration and the start of therapy in PACU was performed through trained medical staff in our study.

PACU represents the unit where continuous patient monitoring and a higher level of nursing care are provided after anesthesia. PACU also provides early recognition of any complication[12]. PACU plays an important role in ensuring patient safety and is different from other units in the hospital with regards to duty. Its main purpose is to safely recover patients to preoperative state from surgical and interventional procedures, with concomitant anesthesia. Patients were structured and provided tight clinical observation along with continuous patient monitoring and hence were treated early in PACU. This in turn reduces the adverse outcomes and increases the efficacy.

Nurses closely watch the patients in PACU, and the implementation of careful nursing helps in providing the medical intervention as early as possible. If PACU does not have the ability to identify AREs or identifies later, this leads to patient death or prolonged LOS in the hospital. It proved that nearly 50% of post-anesthesia care deaths were preventable[13]. Considerably less healthcare resources will be consumed, if the patients do not have AREs.

AREs prolonged the LOS in the PACU, which has an impact on healthcare utilization, resulting in the need for higher levels of care postoperatively than anticipated, decreasing the operating room efficiency, and delaying the operation schedule. If the patient has AREs in PACU, early and proper treatment and care at the right time in transferring the patients to the general wards should be done. Though the scientific discharge criteria were consistent with the fast-track criteria scores, and their PACU stay had positive effects on

the outcomes, the postoperative time and inpatient healthcare costs remain unchanged.

AREs that occurred in the immediate postoperative period in PACU increased the incidence rate of prolonged stay, prolonged the PACU stay, increased the costs in PACU, resulting in the requirement for higher levels of care postoperatively than anticipated, but postoperative time and inpatient healthcare costs remained unchanged. Regular inspection and immediate response for critical incidents in the PACU is essential for the maintenance of quality of immediate postoperative care.

**Conflict of Interest Statement**

The authors had no conflicts of interest to declare in relation to this article.

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