Incidence of hypoxemia in a post-anaesthesia care unit and relevant risk factors: a retrospective study of 14604 patients with general anaesthesia

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Research article

Abstract

Background This article is aim to investigate the incidence and risk factors for postoperative hypoxemia in a post-anaesthesia care unit (PACU). Methods The retrospective cohort assessed 14604 postoperative patients who were admitted to PACU between January 2015 and December 2015. A pulse oximeter was used to monitor and record pulse oxygen saturation (SpO2) every 5 minutes. Clinical data were collected for all these patients, and the incidence of and risk factors for postoperative hypoxemia were analysed. Results The total incidence of hypoxemia was 21.83% (SpO2 ≤ 95%) and 2.79% (SpO2 ≤ 90%). Multiple regression analysis indicated that the risk factors were age ≥50-year old, body mass index (BMI) ≥25kg/m2, American Society of Anaesthesiologists (ASA) II and III, limb surgery, and thoracic surgery. Conclusions Therefore, hypoxemia was common in postoperative patients in the PACU. Age, BMI, ASA classification, and surgical site are associated with postoperative hypoxemia. More attention should be paid to these patients to prevent hypoxemia in the PACU.

Background

Hypoxemia is a major complication in the post-anaesthesia care unit (PACU) which is also the leading cause of anaesthesia-associated mortality and morbidity[1][2]. Hypoxemia may lead to serious consequences[3][4], such as arrhythmias and abnormal blood pressure. For the central nervous system, even mild hypoxemia can cause neurological damage[3], acute severe hypoxemia may cause a sudden loss of consciousness. Monitoring pulse oxygen saturation (SpO_2) enables anaesthesiologists to better detect hypoxemia and hypoxia-related events[3]; however, the overall incidence of hypoxemia remains largely unchanged.[5][6]

Many perioperative factors may induce the development and progression of hypoxemia, such as preoperative underlying diseases, surgical injury, anaesthetics, and postoperative respiratory events. Early detection and timely treatment of hypoxemia plays a key role in reducing hypoxemia-induced serious complications. At present, it is difficult to detect hypoxemia early, and most cases of hypoxemia are not detected or treated in a timely manner.[7][8] Thus, attention must be paid to monitoring hypoxemia in PACU patients, identifying patients at risk for hypoxemia, and keeping risk stratification methods up to date. In this study, we analysed the incidence and relevant risk factors of hypoxemia in PACU patients to explore strategies and methods to improve postoperative hypoxemia.

Methods

Subjects

This was a retrospective study approved by the Ethics Committee and Institutional Review Board of Peking Union Medical College Hospital (PUMCH; ethical approval number S-K198).Written informed consent was obtained from all subjects. All adult postoperative patients after general anaesthesia who had been admitted into the PACU from January 1, 2015 to December 31, 2015 were consecutively

included in this study, and all data were collected from medical records and operating room information system. Surgical sites are categorized as abdomen, pelvis, chest, spine, limbs, head and neck, and superficial sites.

After surgery, the patients were transferred to an appropriate unit on the basis of their physical and surgical conditions. Patients with severe conditions or major surgical wounds were more likely to be transferred to the intensive care unit(ICU)for further treatment, other patients were typically transferred to the PACU under the supervision of an anaesthesiologist. The PACU was close to the operating room; thus, no supplementary oxygen was given during patient transfer unless required by special circumstances. Upon patient arrival at the PACU, all patients were given supplementary oxygen (via a nasal tube, 3–4L/min). Aanaesthesiologist may give mechanical ventilation as warranted by the patient condition. A pulse oximeter (probe: Nellcor DS–100A, Shanghai, China; monitor: Philips Intelli Vue MP70, Boeblingen, Germany) would monitor and record SpO_2 of each patient after their arrival in the PACU. All monitor data were uploaded to the operating room information system in real time, the system will record every five minutes until the patient left the PACU.

Patients with key data missing were excluded (including SpO_2 and age). Finally, a total of 14,604 patients were enrolled in this study.

Observation indexes

We defined hypoxemia with two criteria ($SpO_2 \leq 95\%$ and $SpO_2 \leq 90\%$) and analysed the data respectively. The primary observation indexes and clinical data were (1) SpO_2; (2) gender; (3) age; (4) body mass index (BMI); (5) ASA classification; (6) preoperative respiratory disease; (7) intraoperative airway management; (8) surgical site; (9) intraoperative position; (10) operating time; (11) infusion quantity; (12) opioid dose; (13) red blood cell transfusion quantity; (14) the use of postoperative patient-controlled analgesia (PCA).

Statistical analysis

Continuous variables are expressed as the mean ± standard deviation, and the incidence is expressed as a percentage (%). t-tests or Mann–Whitney U tests for continuous measures and the χ2 test and Fisher's exact test were used to analyse the relationship among categorical variables. Associations between risk factors with hypoxemia were estimated using generalized estimating equation analyses, with an exchangeable correlation structure. The generalized estimating equation (GEE) analyses can include all available SpO2 measurement information at each observation point for specific patient. The Huber-White sandwich estimator was used to compute robust standard errors. Quasi-likelihood information criterion was used for correlation structure and variable selection in GEE modelling process. All analysis was conducted with the use of SAS 9.4 Version (Institute, Inc, Cary, NC, USA.). P<0.05 was considered statistically significant.

Results

Figure 1 shows the enrollment, exclusions and patients available for analysis among 16316 patients admitted into the PACU from January 1, 2015 to December 31, 2015. Finally, 14,604 patients were analysed whose basic data are shown in Table1. Of all the patients, 40.6% were males, and 59.4% were females, with ages of 50.1 ± 14.6 years. Their BMI averaged 24.2± 3.7 kg/m^2. Patients with a high ASA grade were usually transferred to the ICU for further treatment after surgery; in this study, a higher proportion of patients had ASA grades of I (45.7%) or II (50.8%). All patients were given general anaesthesia using inhaled anaesthetics, intravenous anaesthetics, opioids, neuromuscular blocker and muscle relaxant antagonist. Tracheal intubation was the main method of airway management (78.27%), followed by laryngeal mask airway (20.93%). The three most common surgical sites are the head and neck (34.4%), abdomen (28%), and pelvis (9.1%). A few patients had preoperative respiratory disease (2.61%), such as chronic obstructive pulmonary disease (COPD), asthma, obstructive sleep apnea hypopnea syndrome(OSAHS), lung infection, interstitial lung disease, pleural effusion, and pulmonary bullae.

When hypoxemia was defined as $SpO_2 \leq 95\%$, the overall incidence of hypoxemia was 21.83% (3188 patients). When hypoxemia was defined as $SpO_2 \leq 90\%$, the overall incidence of hypoxemia was 2.79% (408 patients). Patients were divided into a hypoxemia group and a non-hypoxemia group for between-group comparison.

We performed multivariate regression analysis of the risk factors in hypoxemia and non-hypoxemia patients as $SpO_2 \leq 95\%$ and $SpO_2 \leq 90\%$ respectively. For this analysis, age, BMI, ASA classification, surgical site, and intraoperative position were multivariate categorical variables; and the reference group for each variable was 18–34-year old (age), BMI<25 kg/m^2 (BMI), ASA I (ASA classification), superficial site (surgical site), and supine (intraoperative position). The results are shown in Table2 and Table3.

When hypoxemia was defined as $SpO_2 \leq 95\%$, multivariate regression analysis showed that age and BMI were closely related to the incidence of hypoxemia, especially in elderly patients over 50-year old (50–64 years old, OR = 1.63, 95%CI:1.43–1.87; ≥65 years old, OR = 1.92, 95%CI:1.65–2.23) and people with BMI ≥25kg/m^2(25≤BMI<28, OR = 1,75, 95%CI:1.59–1.92; BMI≥28, OR = 2.48, 95%CI:2.24–2.75). Other risk factors were ASA grades of II (OR = 1.2, 95%CI:1.09–1.31) and III (OR = 1.32, 95%CI:1.07–1.63), thoracic surgery (OR = 1.37, 95%CI:1.10–1.71). No significant correlation was observed between the incidence of hypoxemia and intraoperative position.

When hypoxemia was defined as $SpO_2 \leq 90\%$, risk factors were age(≥65 years old, OR = 1.80, 95%CI:1.21–2.68), BMI (25≤BMI<28, OR = 1.55, 95%CI:1.22–1.9; BMI≥28, OR = 1.87, 95%CI: 1,43–2.4), limbs surgery(OR = 1.71, 95%CI:1.02–2.85), and thoracic surgery (OR = 2.69, 95%CI:1.51–4.7). No significant correlation was observed between the incidence of hypoxemia and intraoperative position.

Discussion

Hypoxemia is usually defined as $SpO_2 \leq 90\%$, but in PACU, patients with $SpO_2 \leq 95\%$ must be treated, so we defined hypoxemia with two criteria ($SpO_2 \leq 95\%$ and $SpO_2 \leq 90\%$) and analysed respectively. The incidence of hypoxemia in PACU patients varies a great deal with the study population and sample size. [5] [7] [9] [10]. In this study, we included 14604 adult patients admitted to the PACU over a period of one year and found that the overall incidence of hypoxemia was approximately 21.83% ($SpO_2 \leq 95\%$) and 2.79%($SpO_2 \leq 90\%$). In our study, patients with a high ASA grade were usually in more serious condition and thus were transferred to the ICU for further treatment after surgery. PACU patients had fewer comorbidities, better preoperative condition, a higher cardiopulmonary reserve and all of them received muscle relaxant antagonist, but hypoxemia still occurs in some high-risk patients. We must pay more attention to potential hypoxemia in PACU patients to prevent it.

To accurately predict the risk of postoperative hypoxemia, many factors, such as patient condition, anaesthesia, and surgery factors before, during, and after operation must be taken into account, thus complicating the prediction of hypoxemia. At present, researchers are still debating the risk factors for hypoxemia. According to literature reports, potential risk factors include age,[6] obesity,[11] [12] ASA classification,[10] [12] OSAS,[13] [14] operating time,[10] [12] type of muscle relaxant,[15] [16] and intraoperative position.[17] However, researchers reached different conclusions about these factors.

This study showed that hypoxemia may be closely related to age, BMI, ASA classification, and surgical site, but may be unrelated to intraoperative position.

Previous studies have reported the relationship between the surgical site and postoperative hypoxemia. This study showed that thoracic surgery may be a probable risk factor which was consistent with literature reports. Xue[6] included 944 patients undergoing superficial plastic surgery, abdominal surgery, and thoracic surgery; the results showed that the incidence of postoperative hypoxemia was highest in patients undergoing thoracic surgery (52%; incidence of severe hypoxemia: 20%), followed by upper abdominal surgery (38%) and superficial surgery (approximately 7%; incidence of severe hypoxemia: 0.7%).The factors associated with hypoxemia may include direct compression of the lungs during operation, incomplete pulmonary re-expansion, postoperative pain-related weak chest wall and diaphragm movement, atelectasis, and increased pulmonary shunting.[18]

The risk of hypoxemia varies a great deal with age. This study showed that age was a sensitive indicator for predicting the risk of hypoxemia. The incidence of hypoxemia was generally low in patients aged 18 to 34 but was much higher in elderly patients, especially in elderly patients over 50-year-old.

Elderly patients were susceptible to hypoxemia.[17] [19] When patients were transferred from the operating room to the PACU without supplementary oxygen, the SpO_2 was lower in patients aged 60 or over upon approval at the PACU.[20] This reasons may be that elderly patients are more likely than younger patients to have residual postoperative muscle relaxation,[21] which affects the hypoxic ventilatory response and respiratory muscle strength, increasing the risk of airway obstruction and hypoxemia. Moreover,

respiratory reserve decreases with age for elderly patients[22]; low lung capacity, high residual volume, low ventilatory efficiency, low blood vessel elasticity, and low lung perfusion lead to an imbalance in the pulmonary ventilation/blood flow ratio, further increasing the risk of hypoxemia in cases with surgical and anaesthesia stress.

Conclusion

This study included a large data set and reflected the overall incidence of hypoxemia in PACU patients. The results showed that age, BMI, ASA classification, and surgical site were the main risk factors for hypoxemia in PACU patients, thus providing a valuable reference for predicting hypoxemia in clinical practice. In the future, we will conduct in-depth studies on individual factors or populations to further validate the predictive value of these factors. We believe that clinicians should carefully monitor at-risk patients before, during, and after operation and assess airway condition in a timely manner for supplementary oxygen or mechanical ventilation. Detailed knowledge on the mechanism of hypoxemia and relevant predictive factors will help clinicians make better clinical decisions to ensure patient safety and postoperative recovery.

Declaration Section

Ethics approval and consent to participate

This was a retrospective study approved by the Ethics Committee and Institutional Review Board of Peking Union Medical College Hospital (PUMCH; ethical approval number S-K198). Written informed consent was obtained from all subjects.

Consent to publish

All authors agree to publish

Availability of data and materials

Data and materials were collected from electronic patient system of Peking Union Medical College Hospital

Competing interests

The authors declare no competing interests.

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Authors' Contributions

Study design/planning: Tang Shuai, Zhang Liangyan, Zhang Xiuhua

Study conduct: Tang Shuai, Zhang Liangyan, Xue Yang

Data analysis: Zhang Liangyan, Han Wei, Tang Shuai, Yi Tian

Writing the manuscript: Tang Shuai, Zhang Liangyan, Han Wei

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Statistics proofreading: Han Wei, Zhang Xiuhua, Huang Yuguang

All authors read and approved the final manuscript.

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Tables

Table 1. Clinical data of patients

Patient Data	n = 14604
Gender (M/F)	5926(40.6%)/8678(59.4%)
Age (years)	50.1 ± 14.6
BMI (kg/m^2)	24.2 ± 3.7
ASA classification	
Grade I	6677(45.7%)
Grade II	7415(50.8%)
Grade III	505(3.5%)
Grade IV	7(0.1%)
Preoperative respiratory disease	
COPD	24(0.2%)
Asthma	98(0.7%)
OSAHS	51(0.31%)
Lung infection	91(0.6%)
Pleural effusion	12(0.1%)
Pulmonary bullae	68 (0.5%)
Interstitial lung disease	31 (0.2%)
Intraoperative airway management	
Tracheal intubation	12893(78.27%)
Laryngeal mask	3448(20.93%)

Other	132(0.90%)

Surgical site

Major vessels	85 (0.6%)
Abdomen	4093(28.0%)
Spine	785 (5.4%)
Superficial site	1232 (8.4%)
Limbs	928 (6.4%)
Head and neck	5028 (34.4%)
Peripheral vessels	178 (1.2%)
Chest	906 (6.2%)
Pelvis	1331 (9.1%)
Others	38 (0.3%)

Intraoperative position

Lithotomy position	1711 (11.7)
Lateral position	1971 (13.5)
Trendelenburg's position	470 (3.2)
Prone position	717 (4.9)
Supine position	9661 (66.2)
Others	74 (0.5)
Infusion quantity(mL)	1317.3 ± 661.0

Postoperative PCA (Yes/No)	2403(14.59%)/ 14070(85.41%)
Blood plasma transfusion(Yes/No)	161（1.10%）/14443（98.90）
Red blood cell transfusion(Yes/No)	200（1.37%）/14404（98.63%）

Continuous variables are expressed as the mean ± standard deviation; categorical variables are expressed as n (%).

Table 2. Multivariate regression analysis of the risk factors for hypoxemia (hypoxemia was defined as $SpO_2 \leq$ 95%)

Risk Factors	Crude OR	95% CI	P value	Adjusted OR	95% CI	P value
Age (years)						
18-34	1	1		1	1	
35-49	1.19	1.04-1.3	0.02	1.11	0.97-1.28	0.13
50-64	1.84	1.62-2.09	<0.01	1.63	1.43-1.87	<0.01
≥65	2.01	1.75-2.31	<0.01	1.92	1.65-2.23	<0.01
BMI (kg/m^2)						
<25	1	1		1	1	
≥25 and <28	1.84	1.68-2.0	<0.01	1.75	1.59-1.92	<0.01
≥28	2.30	2.36-2.87	<0.01	2.48	2.24-2.75	<0.01
ASA classification						
I	1	1		1	1	
II	1.56	1.44-1.6	<0.01	1.2	1.09-1.31	<0.01
≥III	1.75	1.44-2.13	<0.01	1.32	1.07-1.63	<0.01
Surgical site						
Superficial site	1	1		1	1	
Major vessels	1.19	0.74-1.9	0.48	0.76	0.47-1.21	0.24
Abdomen	0.87	0.74-1.03	0.10	0.87	0.74-1.03	0.1
Spine	0.97	0.79-1.19	0.76	0.95	0.71-1.28	0.73
Limbs	1.27	1.04-1.54	0.02	0.93	0.76-1.13	0.46
Head and neck	0.98	0.84-1.15	0.8	0.94	0.8-1.1	0.43
Peripheral vessels	0.91	0.65-1.29	0.61	0.63	0.45-0.9	0.01
Chest	1.21	1.0-1.47	0.05	1.37	1.10-1.71	<0.01

	OR	95% CI	P	OR	95% CI	P
Pelvis	0.47	0.37-0.5	<0.01	0.46	0.35-0.62	<0.01
Others	0.74	0.21-2.6	0.63	0.88	0.25-3.11	0.84
Intraoperative position						
Supine position	1	1		1	1	
Lithotomy position	0.6	0.50-0.71	<0.01	0.78	0.64-0.96	0.02
Lateral position	0.91	0.81-1.02	0.09	0.69	0.6-0.8	<0.01
Trendelenburg's position	1.04	0.84-1.29	0.71	1.1	0.89-1.36	0.37
Prone position	0.855	0.719-1.017	0.08	0.7	0.53-0.93	0.01
Others	0.43	0.22-0.81	0.01	0.4	0.21-0.76	<0.01

OR: odds ratio

CI: confidence interval

Table 3. Multivariate regression analysis of the risk factors for hypoxemia (hypoxemia was defined as $SpO_2 \leq 90\%$)

Risk Factors	Crude OR	95% CI	P value	Adjusted OR	95% CI	P value
Age (years)						
18-34	1	1		1	1	
35-49	0.83	0.56-1.22	0.33	0.75	0.51-1.11	0.15
50-64	1.45	1.03-2.04	0.03	1.14	0.79-1.63	0.49
≥65	2.41	1.7-3.43	<0.01	1.8	1.21-2.68	<0.01
BMI (kg/m^2)						
<25	1	1		1	1	
≥25 and <28	1.61	1.27-2.05	<0.01	1.55	1.22-1.98	<0.01
≥28	2.0	1.54-2.59	<0.01	1.87	1.43-2.45	<0.01
ASA classification						
I	1	1		1	1	
II	1.85	1.47-2.33	<0.01	1.29	1.0-1.68	0.05
≥III	2.39	1.47-3.89	<0.01	1.56	0.9-2.71	0.11
Surgical site						
Superficial site	1	1		1	1	
Major vessels	1.80	0.63-5.16	0.27	0.97	0.32-2.91	0.96
Abdomen	1.12	0.71-1.78	0.63	1.03	0.64-1.65	0.9
Spine	1.26	0.72-2.21	0.42	0.88	0.46-1.7	0.71
Limbs	2.5	1.51-4.13	<0.01	1.71	1.02-2.85	0.04
Head and neck	0.9	0.57-1.43	0.66	0.82	0.51-1.30	0.4
Peripheral vessels	0.81	0.28-2.35	0.7	0.49	0.17-1.41	0.18
Chest	2.39	1.45-3.96	<0.01	2.69	1.51-4.78	<0.01

	OR	CI	p	OR	CI	p
Pelvis	0.47	0.23-0.97	0.04	0.38	0.15-0.95	0.04
Others	4.23	0.94-18.96	0.06	4.01	0.83-19.4	0.08
Intraoperative position						
Supine position	1	1		1	1	
Lithotomy position	0.65	0.43-0.96	0.03	0.92	0.52-1.61	0.77
Lateral position	1.32	1.0-1.74	0.05	0.67	0.46-0.96	0.03
Trendelenburg's position	1.58	0.97-2.58	0.07	2.1	1.26-3.48	<0.01
Prone position	1.12	0.74-1.69	0.61	1.01	0.58-1.77	0.97
Others	1.07	0.34-3.34	0.91	0.86	0.29-2.63	0.8

OR: odds ratio

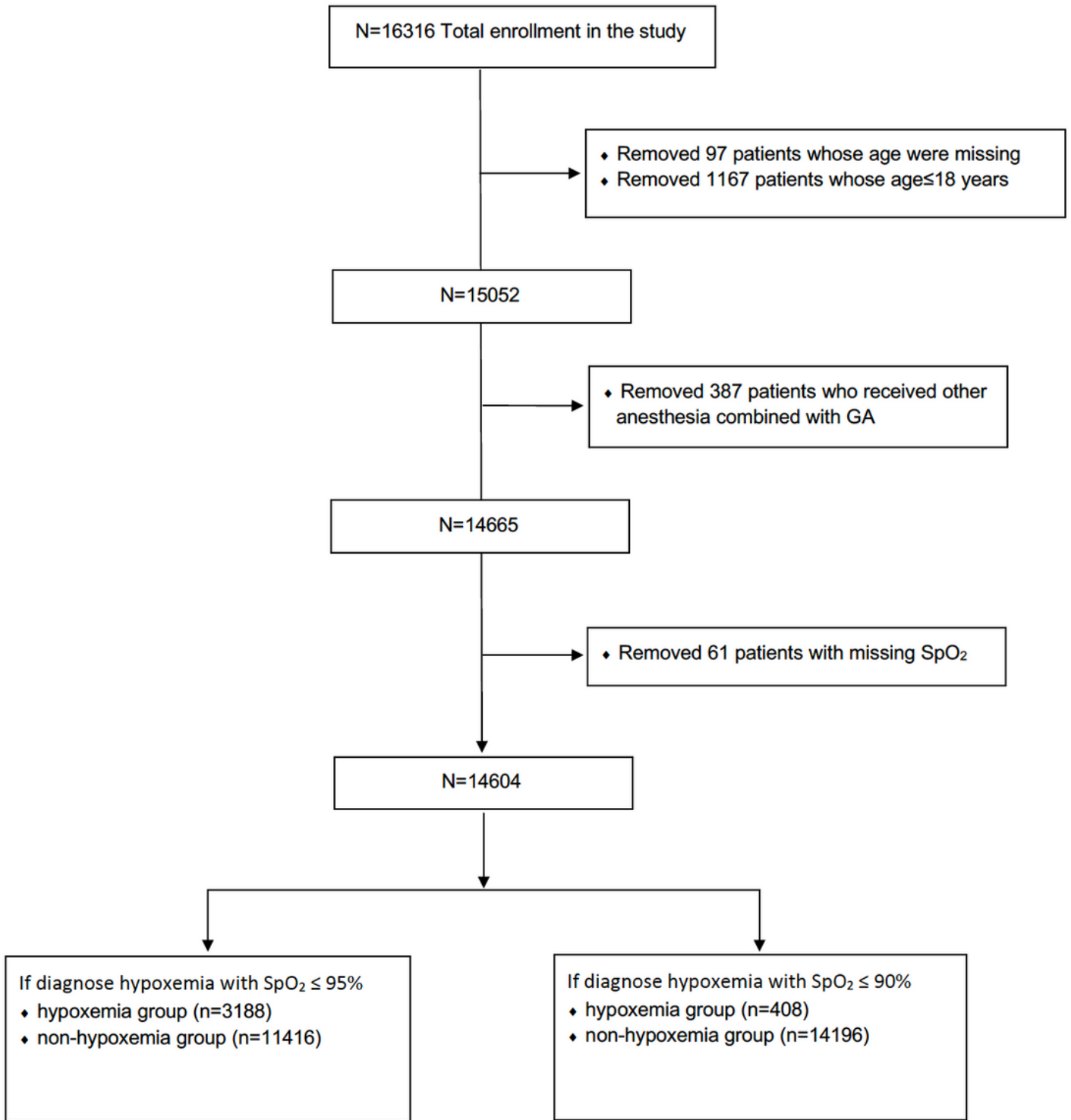CI: confidence interval

Figures

Figure 1

Study diagram, showing enrollment, exclusions and patients available for analysis.