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Original Article

# Perioperative and Anesthetic Adverse Events in Thailand (PAAd THAI) Incident Reporting Study: Perioperative Oxygen Desaturation

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## ABSTRACT

**Background:** The occurrence of hypoxemia in patients undergoing anesthesia is extremely varied. The objective of this study was to report the incidence, explore the causes, and report the outcomes of oxygen desaturation in a large surgical population.

**Methods:** We performed a retrospective study using electronically extracted anesthetic records obtained from 22 academic medical centers across Thailand. All surgical patients under anesthesia during a one-year period were included in the analysis. Hypoxemia was defined as oxygen saturation < 90% for 3 minutes. Any episode of oxygen saturation ⩽ 85% was defined as severe hypoxemia. The contributory factors, the factors minimizing incidence and suggested corrective strategies were examined.

**Results:** There were 2,000 incident cases from all centers. Four hundred sixteen of these patients developed oxygen desaturation. The incidence of oxygen desaturation among all incident cases was 0.2. 50.2% of these patients experienced the episode of severe hypoxia. Oxygen desaturation occurred during the intubation period 26.7%. Upper airway obstruction was the leading cause of oxygen desaturation in the induction, intubation, and recovery periods. Circulatory failure concomitant with oxygen desaturation was found mainly during the maintenance period and at the ward. Haste, lack of knowledge, and inadequate patient preparation were considered as major contributory factors. Improved communication skill and more manpower were the most frequently suggested corrective strategies.

**Conclusion:** Hypoxemia is common during the perioperative period despite the widespread availability of oxygen saturation monitors. This study highlighted strategies that will help to reduce the clinical impact of oxygen desaturation. These strategies are improving communication skill and providing adequate manpower. (Funded by the Faculty of Medicine, Chiang Mai University.)

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Oxygen desaturation is one of the most common "Perioperative Adverse Respiratory Events". It is considered a life-threatening condition if left untreated. The incidence reported by previous studies varies from 0.3% to 53% (1-4). Oxygen saturation can be measured by a pulse oximetry, a non-invasive, standard monitor used in all patients during anesthesia service. Normal pulse oximeter readings (SpO2) range from 95% to 100%. This range represents the normal oxygen partial pressure in arterial blood (PaO2) approximately 85 mmHg and above. Oxygen desaturation is defined as a pulse oximetry reading less than 90% (1, 2). When the value falls below 85%, it is referred to as severe desaturation (3, 4). PaO2 can also be measured from arterial blood gas analysis, which requires invasive arterial catheter insertion. A PaO2 level of 60 mmHg and below is called "hypoxemia" (1-4). The early detection of oxygen desaturation is a crucial warning sign indicating the potential subsequent progression to tissue hypoxia and functional organ damage in the patient. Therefore, prevention of severe oxygen desaturation and prompt treatment if it does occur are necessary.

We conducted this study as a part of the Perioperative and Anesthetic Adverse Events in Thailand (PAAd THAI) incident reporting study. Perioperative oxygen desaturation has been identified as a specific complication, a complication which needs clarification in terms of cause, severity, risk over time, and outcome. To comply with the quality assurance plan and anesthesia patient safety improvement, the contributory factors, the factors minimizing the incidence and suggested corrective strategies are also reported.

## METHODS

The study was multicenter and was of a retrospective nature. The data being collected from 22 hospitals across Thailand, during the period 1 January to 31 December 2015. Of the participating hospitals, 8 were university, academic service-directed institutions. The other 14 centers were community service-based hospital. The exclusion criterion was the medical records that deficient of important information to be analyzed. The Ethical Review Board approved the study protocol. An incident report form was standardized and approved by expert members of The Royal College of Anesthesiologists of Thailand (RCAT). A standardized form (Form I, in the Supplementary Appendix) was used to record the preoperative patient condition (including demographic data, such as age, sex, body weight, height, American Society of Anesthesiologists physical status), surgical factors (types of surgery, official hour, emergency or elective, duration), and anesthetic factors (choice of anesthesia, airway management, anesthetic drugs). Systematic factors, such as level and experience of anesthesia care providers, academic or non-academic medical service, surgical safety checklist and clinical details regarding oxygen desaturation were collected on a second record form (Form II, in the Supplementary Appendix). Other co-incidents, if any, were recorded on Form II. A list of contributory factors, factors minimizing the possibility of incident, suggested corrective strategies, and preventability, as well as outcomes (immediate and long-term) were recorded on the incident reporting form (Form III, in the Supplementary Appendix). Form I and Form II were distributed to participating hospitals. Anesthesiologists and anesthetist nurses were encouraged to discover all incident cases and complete these forms. These forms were deposited at the data management center in each hospital at regular intervals. The central data management was carried out at the Faculty of Medicine, Chulalongkorn University. Data from the total reported in the year, 2,206 incident cases were verified. Perioperative oxygen desaturation incidents were extracted. The Form I and II of all oxygen desaturation incidents were delivered to the authors.

Three independent peer reviewers assessed the details surrounding each event and identified the most likely cause or causes of perioperative oxygen desaturation. Each peer reviewer summarized the events on the incident report forms (Form III). A consensus was made case by case between the three reviewers. Any disagreement was discussed and concluded. Oxygen desaturation was defined as a pulse oximetry reading (SpO2) less than 90% for 3 minutes or any episode of an SpO2 reading less than 85% (1, 2).

Demographic data included age, sex, ASA physical status, weight, height, obesity (identified by body mass index, BMI, greater than 30),

pregnancy, pre-existing respiratory abnormalities, and expected difficult airway. Details of events included the lowest oxygen desaturation, duration of oxygen desaturation, type of operation, type of anesthesia, period of anesthesia (induction, intubation, maintenance, extubation, or recovery) in which the incident occurred, and most likely causes. The immediate outcome (within the first 24 hours) and long-term outcome (within 7 days after surgery) were recorded. Contributory factors, factors minimizing the possibility of incident and suggested corrective strategies were obtained by a consensus among the three peer reviewers. The descriptive statistics were used to summarize the data and were presented as frequency and percentage.

## RESULTS

Of over 200,000 patients who underwent anesthesia from all 22 hospitals during the one-year period, 2,000 cases were identified where there was any incidence in line with the guidelines already given. Among these number, 465 records were the oxygen desaturation cases. Forty-nine patients were excluded because they did not meet the definition of perioperative oxygen desaturation. The incident rate of perioperative oxygen desaturation among all incident cases was 0.20%. The characteristics of the patients are presented in Table 1. Types of surgery are presented in Table 2.

**Table 1. Patient Characteristics and Pre-Operative Risk Factors (n = 416).**

| | n | % |
|---|---|---|
| Sex | | |
| Male | 201 | 48.4 |
| Female | 214 | 51.4 |
| Non-stated | 1 | 0.2 |
| ASA classification | | |
| I | 49 | 11.8 |
| II | 134 | 32.2 |
| III | 170 | 40.9 |
| IV | 36 | 8.7 |
| V | 15 | 3.5 |
| Age group (years) | | |
| 0-10 | 116 | 27.8 |
| 11-20 | 30 | 7.2 |
| 21-40 | 79 | 19 |
| 41-60 | 101 | 24.2 |
| ⩾ 60 | 90 | 21.8 |
| BMI > 35 | 30 | 7.2 |
| Smoking (> 10 pack-years) | 42 | 10 |
| Pregnancy | 9 | 2.2 |
| Respiratory abnormality | 134 | 32.2 |
| Expected difficult airway | 22 | 5.3 |

**Table 2. Types of Surgery (n = 416).**

| | n | % |
|---|---|---|
| Emergency | 128 | 30.8 |
| Official hours | 292 | 70.2 |
| Site of operation | | |
| General surgery | 114 | 27.4 |
| Cardiovascular surgery | 30 | 7.2 |
| Thoracic surgery | 26 | 6.2 |
| Obstetric and gynecologic surgery | 34 | 8.1 |
| Urologic surgery | 13 | 3.1 |
| Plastic surgery | 21 | 5.0 |
| Orthopedic surgery | 38 | 9.1 |
| Ophthalmologic surgery | 17 | 4.1 |
| Othorhinolaryngologic surgery | 44 | 10.6 |
| Radiologic diagnosis and intervention | 9 | 2.1 |
| Endoscopic and minimally invasive surgery | 20 | 4.8 |
| Others | 23 | 5.5 |

### Preoperative Airway Assessment

Over 60% of oxygen desaturation incidents were categorized as normal airway parameters indicated by Mallampati classification grade 1-2 and thyromental distance equal or greater than 5 cm. Laryngoscopic view grade 1-2 were identified in over 50% (Table 3).

### Choice of Anesthesia and Type of Airway Management

Ninety percent of oxygen desaturation occurred during the patients were under general anesthesia as shown in table 3. Endotracheal tubes and a laryngeal mask airway (LMA) were used as the airway equipment in most incident cases. Among patients who developed oxygen desaturation during LMA placement, improper positioning (10 out of 14) and laryngospasm (8 out of 14) were

**Table 3. Airway Parameters, Type of Anesthesia and Techniques and Duration of Anesthesia.**

| | n | % |
|---|---|---|
| Mallampati classification | | |
| Grade 1 | 131 | 31.5 |
| Grade 2 | 133 | 32.0 |
| Grade 3 | 32 | 7.7 |
| Grade 4 | 8 | 2.1 |
| Grade 5 | 2 | 0.5 |
| Missing | 109 | 26.2 |
| Thyromental distance | | |
| > 5 cm | 248 | 59.6 |
| ⩽ 5 cm | 27 | 6.5 |
| Missing | 140 | 33.9 |
| Laryngoscopic view | | |
| Grade 1 | 197 | 47.3 |
| Grade 2 | 53 | 12.7 |
| Grade 3 | 19 | 4.8 |
| Grade 4 | 7 | 2.2 |
| Grade 5 | 96 | 23.0 |
| Missing | 42 | 10.0 |
| Type of anesthesia | | |
| General anesthesia (GA) | 375 | 90.1 |
| Volatile-based GA | 360 | |
| Total intravenous anesthesia (TIVA) | 15 | |
| Spinal block | 2 | 0.5 |
| Epidural block | 1 | 0.2 |
| Monitor anesthesia care (MAC) | 15 | 3.6 |
| Nerve block | 3 | 0.7 |
| Missing | 5 | 1.2 |
| Airway equipment | | |
| Endotracheal intubation | 242 | 58.2 |
| Nasotracheal intubation | 7 | 1.7 |
| Tracheostomy | 18 | 4.3 |
| Laryngeal mask airway (LMA) | 27 | 6.5 |
| Double lumen intubation | 16 | 3.8 |
| Spontaneous mask ventilation | 16 | 3.8 |
| Bronchoscope and jet ventilation | 3 | 0.7 |
| $O_2$ supplement | 7 | 1.7 |
| Nasal airway | 7 | 1.7 |
| Duration of anesthesia (min) | | |
| < 30 | 19 | 4.6 |
| 30-150 | 269 | 64.7 |
| > 150 | 125 | 30 |
| Missing | 3 | 0.7 |

Missing indicates the data that were not recorded from the original case record form.

the primary causes. For the patients with double lumen tube placement, improper positioning (9 out of 14), bronchospasm (10 out of 14), and secretion obstruction (5 out of 14) were the causes of oxygen desaturation (Table 5). Five patients needed a nasal airway placement with oxygen supplement during MAC because of deep sedation and development of an upper airway obstruction. Two patients needed a nasal airway in the recovery room due to residual anesthetic effect and upper airway obstruction. Most of the events occurred under care of anesthesiologists, anesthetic nurses, and residents in training. (Table 4) The first-year anesthesiology resident in training, just graduated anesthetic nurse, and anesthesiologist who had working experience less than 2 years were confronted greater incident of oxygen desaturation.

## Location of Oxygen Desaturation

Oxygen desaturation occurred in the operating room in 62.7% of cases and in recovery 20.0%. The remainder of the cases occurred in the intensive care unit, ward, and radiologic suit in 5.0%, 2.4%, and 0.5% of cases respectively.

During Induction and Intubation

The most common causes of oxygen desaturation in the induction and intubation period were airway management and ventilation problems including difficult / failed intubation, laryngospasm, tongue and soft tissue obstruction and pulmonary aspiration. All of the esophageal intubation cases were detected and the tubes were re-positioned prior to the maintenance phase. Two patients with improper LMA insertion were converted to endotracheal intubation. Oxygen desaturation caused as a result of cardiovascular collapse was found in 10 patients. Disconnection of the breathing circuit and improper positioning of carbon dioxide absorbers were the causes of equipment malfunction.

During Maintenance of Anesthesia

The airway-associated oxygen desaturation in the maintenance period came from improper positioning of the LMA and DLT and secretion obstruction. In cases of circulation-related oxygen desaturation, cardiac arrest was the major cause.

During the Emergence and Recovery Period

Upper airway obstruction, re-intubation, and lung pathology were the major causes of oxygen de-

saturation in the emergence and recovery period.

### During the Transfer Period

Oxygen desaturation was suspected in the case of 4 patients diagnosed due to clinical manifestations. The condition was confirmed by pulse oximetry on arrival in the recovery room.

### Postoperative within 24 Hours

Of the 27 patients who developed oxygen desaturation in the postoperative period, re-intubation from lung pathology and cardiac arrest were the concomitant events.

### Event Consequences

Most incidences of perioperative oxygen desaturation were treatable without postoperative consequences. Three hundred and seventy patients (88.9%) out of the patients who suffered desaturation, had complete recovery after the oxygen desaturation event. In the patients who developed major physiologic derangement both the respiratory and cardiovascular system were usually involved. With regard to the consequences of oxygen desaturation within 24 hours, unplanned ICU admission occurred in 37 patients, unplanned hospital admission occurred in 3 patients, prolonged emergence occurred in 9 patients, and cancelled operations due to oxygen desaturation occurred in 5 patients.

### Event Analysis

The associated factors are summarized as shown in Table 7. More than one factor is involved in each analysed event. Human error was classified into three groups: rule-based, knowledge-based, and skill-based. Lack of skill was the main cause of human error (233 events out of 272, 85.6%). System (management) factor that was found to be related to desaturation event included anesthesiologist staff consultation after the office hour, unavailable of special airway equipment after the office hour, and very low rate of preoperative surgical safety checklist (13.2%). Table 8 summarizes the contributing factors, factors minimizing the possibility of incident, and suggested corrective strategies. Of all possible contributory factors, haste, lack of knowledge, and inadequate patient preparation were considered to be the most significant. Improved communication skills and increased manpower including more staff training were the corrective strategies most frequently suggested for enhancement.

**Table 4. Supervising Professional, Severity of Oxygen Desaturation, and Period of Anesthesia Related to the Event.**

| | n | % |
|---|---|---|
| Supervising Professional | | |
| Anesthesiologist | 238 | 57.2 |
| Anesthetic nurse | 180 | 43.3 |
| Resident of Anesthesiology | 155 | 37.3 |
| Resident from other departments | 5 | 1.2 |
| Surgeon | 2 | 0.5 |
| Medical student | 6 | 1.4 |
| Nursing student | 25 | 6.0 |
| Missing | 4 | 1.0 |
| Severity | | |
| SpO2 < 90% for 3 minutes | 139 | 33.4 |
| SpO2 ⩽ 85% | 209 | 50.2 |
| SpO2 < 90% without duration recorded | 68 | 16.4 |
| Period | | |
| Induction | 39 | 9.4 |
| Intubation | 111 | 26.7 |
| Maintenance | 99 | 23.8 |
| Emergence and extubation | 60 | 14.4 |
| Transfer to recovery room | 4 | 1.0 |
| Recovery | 90 | 21.6 |
| Postoperative within 24 hours | 27 | 6.5 |

Missing indicates the data that were not recorded from the original case record form.

## DISCUSSION

Oxygen desaturation is a common adverse event which occurs during anesthesia. It arises from many causes including factors associated with anesthesia, the patients, and surgery. Pulse oximetry had been introduced for use as a standard monitor, and this relatively simple procedure facilitates early detection and correction of this potentially catastrophic event. The level of oxygen desaturation was derived using this monitor and the data used for this study, the defining parameters as de-

**Table 5. Events-Related to Oxygen Desaturation: Number of Incidents by Cause and Phase of Anesthesia.**

| Associated Cause | Induction | Maintenance | Emergence and Recovery | Ward | Total |
|---|---|---|---|---|---|
| A = Airway | | | | | |
| Difficult/ Failed intubation (22/7) | 21/6 | 0 | 1/1 | 0 | 29 |
| Improper LMA/ DLT (14/14) | 10 | 18 | 0 | 0 | 28 |
| Esophageal intubation | 20 | 0 | 4 | 0 | 24 |
| Re-intubation | 0 | 0 | 61 | 9 | 70 |
| Laryngospasm | 32 | 8 | 7 | 0 | 47 |
| Tongue and soft tissue obstruction | 24 | 0 | 19 | 0 | 43 |
| Unable to ventilate | 12 | 0 | 4 | 0 | 16 |
| Accidental extubation | 0 | 2 | 3 | 0 | 5 |
| Secretion obstruction | 2 | 12 | 19 | 0 | 33 |
| B = Breathing | | | | | |
| Pulmonary aspiration | 5 | 0 | 0 | 1 | 6 |
| Pulmonary embolism | 0 | 2 | 0 | 1 | 3 |
| Pulmonary edema | 0 | 0 | 3 | 1 | 4 |
| Hypoventilation | 0 | 0 | 9 | 0 | 9 |
| Pneumothorax | 0 | 1 | 1 | 0 | 2 |
| Atelectasis | 0 | 0 | 5 | 0 | 5 |
| C = Circulation | | | | | |
| Myocardial infarction | 0 | 1 | 0 | 1 | 2 |
| Cardiac arrest | 2 | 22 | 2 | 14 | 40 |
| Death | 0 | 8 | 16 | 0 | 24 |
| Ardiopulmonary resuscitation from ER | 8 | 0 | 0 | 0 | 8 |
| D = Drugs | | | | | |
| Anaphylactic reaction, anaphylaxis | 3 | 0 | 0 | 0 | 3 |
| Residual anesthetic effect | 0 | 0 | 9 | 0 | 9 |
| Drug error | 0 | 1 | 0 | 0 | 1 |
| E = Equipment malfunction | 2 | 0 | 0 | 0 | 2 |

scribed above. The wide range of previously reported oxygen desaturation incidence came from different diagnostic criteria, different reported periods of the events, and differing age groups.

## Comparison with Previous Studies

The incidence of perioperative oxygen desaturation among all incident cases in this study was 0.20%, which is lower than in comparison to that previously reported (1-5). Raksakietisak et al. showed an incidence of 0.37% (3). Uakritdathikarn et al. showed the incidence of 2.74% (2). Tamdee et al. reported the oxygen desaturation incidence of 0.236% in geriatric patients (5). Ehrenfeld et al. reported the incidence of hypoxemia at 6.8% (6). The reported incidence of oxygen desaturation varied depending on the definition and severity of hypoxemia in each study. Raksakietisak et al. defined desaturation as a Sp02<90% which lasted longer than 3 minutes. Uakritdathikarn et al. defined desaturation Sp02 as < 95% for > 10 seconds. Ehrenfeld et al. used SpO2 < 90 for hypoxemia and SpO2 ≤ 85 for severe hypoxemia. Furthermore, the choice of anesthesia and the period over which events occurred differed in previous studies.

Oxygen desaturation was found during the intubation period in one fourth of all events (26.7%). This is consistent with the findings reported by Oofuvong et al. (7, 8). Szekely et al. suggested that difficult intubation, laryngospasm, and pulmonary aspiration occurring during intubation were the main causes of oxygen desaturation (9). In this study, the incidence of oxygen desaturation in patients aged less than 10 and over 60 years old were 27.8% and 21.8%, respectively. These findings were consistent with those reported by Charuluxananan et al. They found that an age less than 5 significantly predicted desaturation, OR 9.3 (95% CI 5.416.0) (4). Age was one of the patient-related factors reported to predict oxygen desaturation (4-8). Oxygen desaturation suspected during the transfer period and later confirmed in the recovery room was consistent with the results reported by Maity et al., emphasizing the importance of oxygen supplementation and continuous pulse oximetry monitoring during the transfer period (10, 11). A previous study mentioned that ventilation with 100% oxygen for 5 minutes before transport did not prevent desaturation during the transfer period. This event was closely related to the duration of anesthesia (12). Hypoventilation in the recovery period was caused by the residual anesthetic effect in all patients. This finding is consistent with the study of Misal et al. (11).

The association between airway equipment and oxygen desaturation has been studied. Interestingly, improper LMA positioning led to desaturation occurring in 10 out of 14 patients (71.4%). This finding was lower than those reported by Haynes et al (12). In that study, the authors reported 11 out of 12 patients developed desaturation during LMA insertion and all those patients did not receive supplementary oxygen prior to LMA insertion (12, 13). One of the limitations of this study is the type of LMA and the techniques used for LMA insertion were not recorded. Improper DLT positioning leading to desaturation during one-lung ventilation occurred in 9 out of 14 patients (64.3%). The safety margin of correct DLT positioning is very narrow. A change of more than 1 cm from the correct position confirmed by fiberoptic bronchoscope will necessitate immediate correction (14, 15). In 10 out of 14 patients DLT deviation was detected after positioning to lateral decubitus. In 4 cases it was difficult to adjust the DLT to the proper site during the intubation period.

Interestingly, desaturation occurred in 15 patients under monitored anesthesia care (MAC). Two of them developed desaturation in the radiologic suite. A previous study mentioned that the type of invasive procedure was an important factor in estimating the risk of hypoxemia in procedural sedation (16). We explored the possible causes of hypoxemia in these patients and found that extreme age, propofol sedation in combination with an opioid, and a pre-existing respiratory abnormality were the predictors of oxygen desaturation in MAC. These findings are consistent with previously reports (16-18).

**Table 6. Consequences after the Event.**

| | n | % |
|---|---|---|
| Immediate outcome (within 24 hours) | | |
| Minor physiological change | 68 | 16.3 |
| Major physiological change | 88 | 21.2 |
| Respiratory system | 84 | |
| Cardiovascular system | 13 | |
| Neurological system | 3 | |
| Long term outcome (7 days) | | |
| Prolonged ventilator support | 28 | 6.7 |
| Prolonged hospital stays | 20 | 4.8 |
| Psychic trauma | 1 | 0.2 |
| Disability | 2 | 0.5 |
| Vegetative / brain death | 2 | 0.5 |
| Death | 25 | 6.0 |

**Table 7. Associated Factors.**

| | n | % |
|---|---|---|
| Patient factors | 319 | 76.7 |
| Surgical factors | 119 | 28.6 |
| Anesthetic factors | 328 | 78.8 |
| System (management) factors | 74 | 17.8 |
| Spontaneously incidentally unpreventable | 50 | 12.0 |
| Preventable | 322 | 77.4 |
| Complete surgical safety checklist | 55 | 13.2 |
| Human error | 272 | 65.4 |

**Table 8. Contributing Factors, Factors Minimizing Incident, and Suggested Corrective Strategies.**

| | n | % |
|---|---|---|
| Contributing factors | | |
| Haste | 237 | 57 |
| Lack of knowledge | 159 | 38.2 |
| Inadequate patient preparation | 133 | 32 |
| Improper patient assessment | 86 | 20.7 |
| Tired from prolonged work | 59 | 14.2 |
| Inadequate equipment | 48 | 11.5 |
| Lack of experience | 30 | 7.2 |
| Ineffective equipment and monitor | 28 | 6.7 |
| Unfamiliar with place and environment | 27 | 6.5 |
| No monitors | 9 | 2.2 |
| Unavailable ICU | 4 | 1.0 |
| Factors minimizing incident | | |
| Adequate working personal, enough to change a work shift | 324 | 77.9 |
| Expertise assistance | 275 | 66.1 |
| Highly surveillance | 249 | 59.9 |
| Improve training system | 44 | 10.6 |
| Enough equipment and monitoring | 32 | 7.7 |
| Strictly following guidelines | 30 | 7.2 |
| Good communication | 28 | 6.7 |
| Continuing maintenance of equipment and monitors | 26 | 6.3 |
| Enough diagnostic monitors | 18 | 4.3 |
| Suggested corrective strategies | | |
| Improved communication | 242 | 58.2 |
| More manpower | 222 | 53.4 |
| Additional training | 114 | 27.4 |
| Good referral system | 113 | 27.2 |
| More equipment | 65 | 15.6 |
| Equipment maintenance | 40 | 9.6 |
| Improved supervision | 24 | 5.8 |
| Quality assurance activity (morbidity and mortality conference) | 6 | 1.4 |
| Guideline practice | 2 | 0.5 |

Oxygen desaturation occurrence during the maintenance period was co-incident with circulatory failure and cardiac arrest. The degree of hypoxia during cardiac arrest was reported as a significant factor in the determination of the sequelae and outcomes (19). High oxygen concentration during cardiopulmonary resuscitation is recommended while hyperoxemia should be avoided in a post cardiac-arrest period (20).

In this study, the complete surgical safety checklist including sign-in, time-out, and sign-out, was done in 55 of 416 event cases (13.2%). This number demonstrated the inconsistency in compliance and attitudes of surgical team members, surgical circulators, scrub practitioners, and attending anesthetic team. The finding is consistent with previous reports (21, 22). The root-cause analysis of this study pointed out that improved communication among the working teams was highly recommended. More manpower was suggested to correct the most ranked contributing factors, which were haste and inadequate patient preparation. Additional training was suggested to correct the contributory factor of lack of knowledge.

## Clinical Implications

Preoperative airway assessment, which indicates that easy airway management does not guarantee the safety of patients as regards oxygen desaturation, should be a high priority. Intravenous sedation MAC should be conducted under supervision by senior anesthesiologist or attending staff, and end-tidal CO2 and oxygen saturation monitoring should be carried out. Level of sedation should be closely monitored to avoid loss of airway control. Upper airway obstruction during the induction period arises from improper mask ventilation. This was considered to be a resident-training risk. Staff training and supervision needs to be improved to address this. During the transfer period, all patients should receive oxygen supplementation via nasal cannula or face mask. Surgical team members, surgical circulators, scrub practitioners, and the attending anesthetic team should be encouraged to complete the surgical safety checklist. The suggested corrective strategies should be implemented in clinical practice to reduce the number of critical incidents and increase perioperative safety for the patients.

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# Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

Supplement to: Pathomporn Pin-on, Krit Panjasawatwong, Anantachote Vimuktanandana, Wimonrat Sriraj, Chuthamat Somchat, Dujduen Sriramatr. Perioperative and Anesthetic Adverse Events in Thailand (PAAd THAI) Incident Reporting Study: Perioperative Oxygen Desaturation. *J Anesth Perioper Med* 2018;5:101-13. doi: 10.24015/JAPM.2018.0051

# Form I

กรุณาระบุหมายเลขทั้งสองแผ่น เนื่องจากอาจหลุดจากกัน

**ราชวิทยาลัยวิสัญญีแพทย์แห่งประเทศไทย**
**สถาบันพัฒนาและรับรองคุณภาพโรงพยาบาล**
**Multicenter Study การเฝ้าระวังภาวะแทรกซ้อนทางวิสัญญี**

(เฉพาะเจ้าหน้าที่ รพ.) ☐☐☐-☐☐-☐☐-☐☐-☐☐☐ DATA CODE
สถาบัน วันที่ เดือน พ.ศ. รายที่...ของเดือน

คำแนะนำ 1.เติมข้อมูลในช่องว่าง 2.ทำเครื่องหมาย ✓ ใน ☐ หรือเขียนวง ◯ ล้อมรอบข้อความที่เลือก (อาจมีได้ > 1คำตอบ) 3.ถ้าแก้ไขให้ระบายทึบ ■

| อายุ | ปี เดือน วัน | เพศ | ☐ หญิง | ☐ ชาย | น้ำหนักตัว | ก.ก. | ส่วนสูง* | ซ.ม. |
|---|---|---|---|---|---|---|---|---|

| ASA | 1 | 2 | 3 | 4 | 5 | 6 | E | ในเวลา | นอกเวลา | แผนกผู้ป่วย | นอก | ใน | ANES.DURATION * | ชั่วโมง นาที |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Operation / Site ระบุได้มากกว่า 1

- ☐ Cardiac
- ☐ Thoracic
- ☐ C-section
- ☐ Dental
- ☐ Diagnostic (Image, biopsy)
- ☐ Intervention Rx
- ☐ Radiotherapy
- ☐ Electroconvulsive
- ☐ Endoscopic (ส่องเข้ารู)
- ☐ General surgery
- ☐ Gynecological S.
- ☐ Obstetric
- ☐ Minimally invasive S.(Lap...)
- ☐ Neurosurgery
- ☐ Opthalmological
- ☐ Orthopaedic
- ☐ Otorhinolaryngological
- ☐ Plastic
- ☐ Urological (รวมทั้ง TUR)
- ☐ Vascular
- ☐ Other ระบุ.....

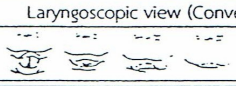
Operation ระบุทุกราย*

| Tech - nique | Main | GA | GA(TIVA) | MAC | Spinal | Epidural | CSE | Caudal | Brachial block | Nerve block | Bier block |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Additional | ☐Epidural | ☐Spinal | ☐Caudal | ☐Brachial block | ☐Nerve block | ☐Local Topical | ☐IV suppl. | GA/TIVA due to RA | ☐fail/Inadequate | ☐wear off |

| Monitors | NIBP | Invasive BP | $SpO_2$ | EKG | $EtCO_2$ | Et gas | CVP | Chest piece | Esophageal steth | Temperature | Other ระบุ ..... |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Peripheral nerve stimulator | Airway pressure | PAP | Cardiac output | EEG / BIS / Entropy | Doppler | Echo | Oxygen analyzer | | | |

| Anesthetic Agents | Pentothal | Propofol | Ketamine | Midazolam | Diazepam | Succinylcholine | Pancuronium | Atracurium | Cisatracurium |
|---|---|---|---|---|---|---|---|---|---|
| | Vecuronium | Rocuronium | Nitrous oxide | Isoflurane | Sevoflurane | Desflurane | Morphine | Pethidine | Remifentanil |
| | Fentanyl | Lidocaine | Bupivacaine | Levobupivacaine | Prostigmine | Atropine | Glycopyrrolate | Other ระบุ ..... | |

| | | |
|---|---|---|
| Anesthesia Performer | ☐ วิสัญญีแพทย์ ☐ วิสัญญีพยาบาล ☐ แพทย์ประจำบ้าน/ทุนวิสัญญี ☐ แพทย์ประจำบ้าน/ใช้ทุนอื่นๆ ☐ แพทย์ผ่าตัด ☐ นักศึกษาแพทย์ ☐ นักเรียนพยาบาล ☐ อื่นๆ ระบุ ..... | ประสบการณ์วิสัญญี.....ปี, เดือน |
| ผู้พบอุบัติการณ์ | ☐ วิสัญญีแพทย์ ☐ วิสัญญีพยาบาล ☐ แพทย์ประจำบ้าน/ทุนวิสัญญี ☐ แพทย์ประจำบ้าน/ใช้ทุนอื่นๆ ☐ แพทย์ผ่าตัด ☐ นักศึกษาแพทย์ ☐ นักเรียนพยาบาล ☐ อื่นๆ ระบุ ..... | ประสบการณ์วิสัญญี.....ปี, เดือน |

| Mallampati | ☐ ประเมินไม่ได้ | Thyro-mental Distance ในรายที่อายุ > 15 ปี | Laryngoscopic view (Conventional) |
|---|---|---|---|
|  | ☐ ไม่ได้ตรวจ | Distance ☐ < 5 ซ.ม. หรือ < 3 finger breadth ☐ > 5 ซ.ม. หรือ > 3 finger breadth ☐ ไม่ได้ตรวจ |  ☐ N/A |

| Airway | Oro-tracheal | Naso-tracheal | Oral airway | Nasal airway | Tracheostomy | LMA | Under Mask | Double lumen | Bronchoscope | Jet | $O_2$supplement | Other ระบุ ..... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

| ภาวะแทรกซ้อนทางวิสัญญี (วงได้มากกว่า 1 ที่) 1=ระหว่างผ่าตัด 2=ในห้องพักฟื้น 3=ภายใน 24 ชั่วโมงหลังผ่าตัด | | | | | ☐ ไม่มีใน 1 | ☐ ไม่มีใน 2 | ☐ ไม่มีใน RR | ☐ ไม่มีใน 3 | | | | | *☐ มี(กรอกเหตุการณ์หน้า 2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pulmonary Aspiration | 1 | 2 | 3 | Failed Intubation | 1 | 2 | | | Cardiac Arrest | 1 | 2 | 3 | |
| Pulmonary embolism (Suspected) | 1 | 2 | 3 | Total Spinal Block | 1 | 2 | | | Death (all causes) | 1 | 2 | 3 | |
| Esophageal Intubate(early+late) | 1 | 2 | | Awareness (during GA) | 1 | 2 | 3 | | Suspected Malignant Hyperthemia | 1 | 2 | 3 | |
| Endobronchial intubate(early+late) | 1 | 2 | | Coma / CVA / Convulsion | 1 | 2 | 3 | | Anaphylaxis / Anaphylactoid Reaction/Allergy | 1 | 2 | 3 | |
| Desaturation (<85 หรือ <90...3min) | 1 | 2 | 3 | Nerve Injuries | 1 | 2 | 3 | | Drug Error | 1 | 2 | | |
| Re-Intubation | 1 | 2 | 3 | Transfusion Mismatch | 1 | 2 | 3 | | Equipment Malfunction / Failure | 1 | 2 | | |
| Difficult Intubation (>3 ครั้ง/> 10 นาที) | 1 | 2 | | Suspected MI / Ischemia | 1 | 2 | 3 | | Suspected Emergence Delirium | 1 | 2 | | |
| severe arrhythmia : AF c RVR, 2 or 3 AV block, VT, VF, HR < 40 | | | | | 1 | | | | wrong patient, site, surgery | 1 | | | |

Surgical Safety Checklists *(กรอกได้มากกว่า 1 ช่อง)

| Sign in * (กรอกทุกราย ตามจริง) | Time out * (กรอกทุกราย ตามจริง) | Sign out * (กรอกทุกราย ตามจริง) |
|---|---|---|
| ☐ Patient identification (by patient)<br>☐ Mark site (ถ้าจำเป็น)<br>☐ มีการประเมิน difficult airway<br>☐ Anticipate pulm aspiration (NPO,...)<br>☐ Anticipate blood loss > 500cc (adult) หรือ > 7cc / kg (child)<br>☐ ถามประวัติ drug allergy<br>☐ คิด Pulse oximeter ก่อนเริ่ม<br>☐ Complete anesthesia checklists (ตรวจ machine, เตรียม tube, laryngoscope, suction...) | Confirm<br>☐ Patient identification<br>☐ Operation / Site<br>Anticipate<br>☐ Anesthesia critical incident<br>☐ Surgical critical incident<br>☐ duration of surgery<br>☐ การเสียเลือดมาก<br>Antibiotics<br>☐ ให้<br>◯ ให้ก่อนลงมีด<br>◯ ให้หลังลงมีด ◯ ให้หลังเด็กคลอด<br>◯ ลืมให้<br>☐ N/A (Non applicable) | ☐ การนับเครื่องมือ ผ้าซับ ฯลฯ<br>☐ ทบทวนเหตุการณ์สำคัญระหว่างผ่าตัด<br>☐ ทบทวนแผนดูแลหลังผ่าตัด<br>☐ การประเมินเลือดที่เสีย (EBL)<br>☐ การสื่อสารปัญหาที่อาจเกิดขึ้น : Fluid, drain etc<br><br>◯ ◯ ◯ ◯<br>DMU Code (รพ. ไม่ต้องกรอก) |

# Form II

**Incidents (What happen?)**

| circuit (What) | ส่วนของ circuit ที่มีปัญหา (Where) | Airway Incidents |
|---|---|---|
| ☐ Disconnect หลุด | ☐ $CO_2$ Absorber | ☐ Endobronchial Intubation (โดยไม่ตั้งใจ) |
| ☐ Leak รั่ว | ☐ Common gas outlet | ☐ Extubation (โดยไม่ตั้งใจ) |
| ☐ Misconnect ต่อผิด | ☐ Endotracheal tube or equivalent (:LMA) | ☐ Failed Intubation |
| ☐ Overpressure | ระบุ ..... | ☐ Cannot ventilate |
| ☐ Rebreathing | ☐ Flowmeter | ☐ Obstruction |
| ☐ Dilution of gas | ☐ Gas supply | ☐ laryngospasm |
| ☐ อื่นๆ ระบุ ..... | ☐ Humidifier | ☐ bronchospasm |
| | ☐ Oxygen bypass | ☐ Esophageal Intubation(early+late) |
| | ☐ Inspire or expire valve | ☐ Airway trauma |
| | ☐ Pressure relief valve | ☐ Other ระบุอาการ ..... |
| | ☐ Scavenging systerm | **Nerve injury ระบุอาการ .....** |
| | ☐ Tubing or connection | ☐ Ulnar nerve — ○ USG Guided |
| | ☐ Vaporizer | ☐ Brachial plexus — ○ NM USG Guided |
| | ☐ Ventilator | ☐ Lumbosacral root — ○ NM Stimulator |
| | ☐ อื่นๆ ระบุ ..... | ☐ Spinal cord — ○ Conventional |
| | | ☐ Femoral |
| | | ☐ Other ระบุอาการ ..... |

**Incident alerted *(กรอกทุกราย)**

| Phase when alerted* | Location* | | Drug incident ☐ Syringe swap ☐ wrong ampule / vial | | Allergic incident |
|---|---|---|---|---|---|
| ☐ Preinduction | ☐ Induction room | ☐ Delivery | ☐ Wrong Incident | ☐ Over dose | ☐ CVS ระบุ ..... |
| ☐ Induction | ☐ Intensive care | ☐ Dental | ☐ Wrong drug | ☐ Under dose | ☐ RS ระบุ ..... |
| ☐ Maintenance | ☐ Operating room | ☐ Ward | ☐ Wrong route ผิดทาง | ☐ Omit dose ลืมให้ | ☐ Skin ระบุ ..... |
| ☐ Emergence | ☐ Recovery room | ☐ Imaging | ☐ Wrong form | ☐ Omit record ลืมบันทึก | ☐ Other ระบุ ..... |
| ☐ Recovery | ☐ Emergency unit | ☐ transfer period | ☐ Wrong label | ☐ Contaminate (chem/Infect) | |
| ☐ Post recovery(24 hr.) | ☐ Day surgery | ☐ other..... | ☐ Wrong concentration | ☐ Other ระบุ..... | |

สถานะผู้เตรียมยา..... ผู้ให้ยา..... ผู้ detect Incident.....

**Awareness**

| จำได้ | ผล |
|---|---|
| ☐ sound | ☐ temporary stress |
| ☐ pain | ☐ PTSD (posttrauma) |
| ☐ paralysis | ☐ sleep disturbance |
| ☐ Intubation | ☐ dream |
| ☐ surgery without pain | ☐ anxiety |
| ☐ panic | ☐ flashback |
| ☐ other ..... | ☐ other ระบุ..... |

**Cardiac arrest/ Death**

| Inittal condition | | | possible causes | treatment | |
|---|---|---|---|---|---|
| Conscious | ☐ yes | ☐ No | ☐ drug ระบุ..... | ☐ cardiac massage | ☐ magnesium ☐ calcium |
| breathing | ☐ yes | ☐ No | ☐ vagal | ☐ atropine | ☐ DC shock |
| pulse | ☐ yes | ☐ No | ☐ bleeding | ☐ adrenaline | ☐ other ระบุ ..... |
| | | | ☐ hypoventilation | ☐ lidocaine | CPR |
| | | | ☐ anaphylaxis | ☐ bicarbonate | ☐ no CPR ☐ CPR ..... ครั้ง |
| | | | ☐ direct cardiac | ☐ amiodarone | ครั้งที่ 1 นาน ..... |
| | | | ☐ other ระบุ ..... | ☐ adenosine | ครั้งที่ 2 นาน ..... |
| | | | | | ครั้งที่ 3 นาน ..... |

| Detail of event กรุณาเขียนให้ละเอียดที่สุดเท่าที่ทำได้ (กรอกทุกราย)* เพิ่มกระดาษได้ | Management & Results (การจัดการและผลที่เกิดกับผู้ป่วย) |
|---|---|
| **ผู้ใด (สถานภาพ) ทำ, ผู้ใดวินิจฉัยได้, Onset, Duration ฯลฯ**<br>**เกิดอะไร, อย่างไร**<br>**ทำไมจึงเกิด**<br>**วินิจฉัยด้วย Clinical หรือ Monitor ชนิดใดตามลำดับ** | |
| **หมายเลขโทรศัพท์ สำหรับติดต่อกลับ .....**<br>DMU Code (รพ. ไม่ต้องกรอก)<br>○ ○ ○ ○ | (ที่ไม่พอเพิ่มกระดาษได้) |

# Form III

FORM 3

Incident code ○○○○ Specific code [ ]

(เฉพาะเจ้าหน้าที่ รพ.) DATA CODE

□□□-□□-□□-□□-□□□
สถาบัน วันที่ เดือน พ.ศ.

**วินิจฉัยได้จาก**

อาการทางคลินิก (Clinical) ✶
- ☐ วินิจฉัยไม่ได้
- ☐ วินิจฉัยได้ก่อน monitor
- ☐ วินิจฉัยได้หลัง monitor

Monitor ✶
- ☐ วินิจฉัยไม่ได้
- ☐ วินิจฉัยได้ตามลำดับ
  1. ระบุ.....
  2. ระบุ.....
  3. ระบุ.....

**✶ ท่านคิดว่า Incident นี้อาจเกี่ยวข้องกับ**

| ☐ Patient factors | ☐ Surgical factors | ☐ Anesthetic factors | ☐ System (management) factors |
|---|---|---|---|
| 1. ..... | 1. ..... | 1. ..... | 1. ..... |
| 2. ..... | 2. ..... | 2. ..... | 2. ..... |
| 3. ..... | 3. ..... | 3. ..... | 3. ..... |

☐ เกิดขึ้นเอง (จะเกิดก็เกิด) Spontaneously incidentally unpreventable ☐ preventable ☐ human error — ○ Ruled-based ○ Knowledge-based ○ Skill-based ☐ Surgical safety checklist ป้องกันได้

| ✶ Immediate Outcome (ภายใน 24 ชม.) | | ✶ Long term Outcome (7 วัน) | |
|---|---|---|---|
| ☐ Unplanned ICU Admission | ☐ Major physiological change | ☐ Prolonged ventilator Support ..... วัน | ☐ Vegetative / Brain death |
| ☐ Unplanned hospital admission | ☐ RS (hypoxia, pulm edema) ..... | ☐ Hospital stay after event ..... วัน หรือ ☐ > 7 วัน พร้อมเหตุผล | ☐ Death |
| ☐ Prolonged emergence / apnea | ☐ CVS (:MI...)..... | ☐ เหตุผลวิสัญญี..... | ☐ Other Morbidity ระบุ..... |
| ☐ Awareness | ☐ Neuro..... | ☐ เหตุผลอื่นๆ ระบุ..... | ☐ Complete recovery |
| ☐ Cancellation / postponement of surgery | ☐ Other (renal..)..... | ☐ Psychic trauma ระบุ..... | ☐ None |
| ☐ Minor physiological change (เช่น HR BP) ระบุ..... | ☐ Cardiac arrest | ☐ Disability ระบุ..... | ☐ Others ระบุ..... |
| ☐ Others ระบุ..... | ☐ Death | | |
| | ☐ Complete recovery | | |
| | ☐ None | | |

| ✶ Contributing Factors (ปัจจัยนำ) | ✶ Factors minimizing incident (ปัจจัยลดอุบัติการณ์) | ✶ Suggested Corrective Stregies |
|---|---|---|
| ☐ ตัดสินใจไม่เหมาะสม ☐ ขาดความรู้ | ☐ เคยมีประสบการณ์ในเรื่องนั้นๆ มาก่อน | ☐ Guideline practice |
| ☐ ขาดประสบการณ์ ☐ รีบร้อน | ☐ ผู้ช่วยที่มีประสบการณ์ | ☐ Additional training |
| ☐ อ่อนล้าจากงานวิสัญญีติดต่อกัน..... ชม. | ☐ มีความระแวดระวังสูง | ☐ More manpower |
| ☐ บุคลากรป่วย ระบุ..... | ☐ บุคลากรเพียงพอที่จะเปลี่ยนให้พัก | ☐ Improved supervision |
| ☐ บุคลากรไม่เพียงพอ | ☐ มีระบบการปรึกษาทั้งในและระหว่างหน่วยงาน | ☐ Improved communication |
| ☐ ปัญหาจากการติดต่อ สื่อสาร | ☐ มีระบบการติดต่อสื่อสารที่ดี | ☐ More equipment |
| ☐ ไม่คุ้นเคยกับสถานที่และสิ่งแวดล้อม | ☐ ปรับปรุงระบบการฝึกอบรม | ☐ Equipment maintenance |
| ☐ ภาวะฉุกเฉิน | ☐ เครื่องมือมีปริมาณเพียงพอ | ☐ Quality assurance activity (M&M) |
| ☐ ประเมินผู้ป่วยไม่ดี | ☐ มีการบำรุงรักษาเครื่องมืออย่างต่อเนื่อง | ☐ Good referral system |
| ☐ เตรียมผู้ป่วยไม่พร้อม | ☐ มีการตรวจสอบเครื่องมืออย่างต่อเนื่อง | ☐ Others ระบุ..... |
| ☐ เครื่องมือมีไม่พอ ☐ เครื่องมือไม่มีประสิทธิภาพ | ☐ มี Monitor เพื่อการวินิจฉัย ระบุ..... | |
| ☐ ไม่มี monitor ☐ monitor ไม่มีประสิทธิภาพ | ☐ ปฏิบัติตาม guidelines | |
| ☐ ปัญหา Label ยา | ☐ Others ระบุ..... | |
| ☐ ไม่มีห้องพักฟื้น ☐ ไม่มี ICU | | |
| ☐ ปัญหา blood bank ☐ อื่นๆ ระบุ..... | | |