The Thai Anesthesia Incidents Study (THAI Study) of Oxygen Desaturation

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Objectives : *To examine incidents , contributory factors, treatment and outcomes associated with oxygen desaturation during anesthesia practice in Thailand.*
Material and Method : *Relevant data were extracted from the Thai Anesthesia Incidents Study (THAI Study) database between February 1, 2003 and January 31, 2004 and analyzed by using mainly descriptive statistics.*
Results : *Four hundred and ninety seven incidents of oxygen desaturation (SpO2 <90 for at least 3min or £ 85%) were reported. The incidents were widely distributed throughout anesthesia phases. Most of the incidents (92.2%) occurred during general anesthesia, while 23 (4.6%) occurred after regional anesthesia. Anesthesia was the sole contributory factor in 280 patients (56.8%) and a combination of that with other factors in 126 (25.4%). The majority of the incidents (88.4%) was related to respiratory adverse events, whereas, 8% was related to circulatory ones. Sixteen incidents (3.2%) were related to anesthetic machine and equipment failure. Most of the incidents (60.0%) caused minor physiologic changes and were correctable. The management was considered adequate in the majority of patients. As a result, 77.5 % of the patients recovered completely, whereas, death ensued in 5.8%. The cases of death were associated with co-morbidity (ASA class 4 and 5) with an Odds ratio of 12.9 (95% CI:5.4,31.0). The common contributory factors were inexperience, wrong decision, inadequate knowledge and lack of supervision. The proposed corrective strategies included improvement in supervision, care improvement, additional training, clinical practice guideline and quality assurance activity.*
Conclusion : *Incidents associated with oxygen desaturation were distributed throughout all phases of anesthesia. Most of them were preventable and correctable. Therefore, anesthesia care providers should be alert in looking for incidents, and manage them promptly before they were in serious adverse events.*

Keywords : *Oxygen desaturation, Hypoxemia, Anesthesia, Incidents, Complications*

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The occurrence of perioperative oxygen desaturation has been documented in several studies with the incidence varying from 16.7 % to 53 % [1-7]. During anesthesia, the occurrence of oxygen desaturation can be related to many incidents or respiratory problems [8,9] , which can lead to serious adverse events or complications unless they are detected early and corrected promptly. We conducted this study to

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find out the incidents or problems associated with oxygen desaturation during anesthesia practice in 20 hospitals across Thailand during the period of February 1, 2003 to January 31, 2004. Furthermore, as a part of quality assurance activity, we determined the appropriateness of the episode management, the contributory factors, outcomes and corrective strategies.

Material and Method

During the period, February 1, 2003 to January 31, 2004, the Thai Anesthesia Incidents Study (THAI Study) conducted a multi-centered research to find out the adverse events during anesthesia practice across Thailand. Twenty hospitals, comprising seven university , five tertiary , four secondary care , and four district hospitals participated in this study. The institutional Ethical Review Board approved the protocol. Details of preanesthetic conditions, anesthetic management, intraoperative events and perioperative complication of consecutive patients within 24 hours were recorded on a standardized form (form I).

Oxygen desaturation was an interesting event measured by pulse oximetry and defined as a fall in oxygen saturation to lower than 90% for at least 3 minutes; or equal to or lower than 85%.

The attending anesthesiologist or nurse anesthetist described clinical details of oxygen desaturation in another record form (form II). Then that record form was reviewed by 3 peer reviewers to determine incidents or problems most likely relating to oxygen desaturation and assess the level of anesthesia attributable to the event, contributory factors, appropriate management and preventive strategies. Data from form I and II were reviewed independently by at least two reviewers. Any disagreement was discussed and judged in order to achieve a consensus.

Relevant data were extracted and recorded twice and analyzed by the SPSS for Windows. Demographic data included age, sex, ASA status, weight, height, history of smoking, preexisting respiratory diseases and other co-morbidities. Details of events included sites of operation, types of anesthesia, period of anesthesia (induction, maintenance and recovery), and most likely causes (gas supply problems, problems related to anesthetic machine / equipment, airway problems, endotracheal tube problems, inadequate ventilation and pulmonary problems). The appropriateness of the episode management was classified as inadequate and hazardous, inadequate and not hazardous, maybe adequate, and adequate. The outcome was classified as immediate outcome (≤ 24 hours) or long-term outcome (>24 hours). Contributory factors were classified as human (wrong decision, inadequate knowledge, inexperience and haste), system failure (inadequate care, lack of or inadequate supervision, and lack of or inadequate communication) and organizational failure. The descriptive statistics were used to summarize the data in terms of frequency and percentage.

Results

There were 497 records completed for this study. Characteristics of patients with oxygen desaturation are presented in Table 1. Details regarding surgery and anesthesia are described in Table 2 and Table 3. Oxygen desaturation occurred in both sexes and all age groups. The incidents were reported in all types of operations including airway (19.7%), extremities (14.5%), lower abdomen (12.1%), upper

Table1. Patient characteristics and potential risk factors (N = 497)

	n	%
Sex		
Male	276	55.3
Female	218	43.9
Unknown	3	0.6
ASA		
Class 1	115	23.14
Class 2	235	47.28
Class 3	109	21.93
Class 4	28	5.63
Class 5	7	1.40
Unknown	3	0.60
Age group		
0 - < 1	105	21.1
1 - < 5	53	10.7
5 - < 10	21	4.2
10 - < 15	11	2.2
15 - < 20	20	4
20 - < 40	91	18.3
40 - < 60	95	19.1
≥ 60	101	20
BMI > 28	14	2.8
Smoking (> 10 pack-years)	38	7.6
Pregnancy	19	3.82
Respiratory abnormality	129	25.95
Difficult airway	74	14.68

Table 2. Type of surgery (N=497)

	n	%
Emergency		
Yes	190	38.2
No	305	61.4
Unknown	2	0.4
Official hours		
Yes	346	69.6
No	146	29.4
Unknown	5	1.0
Sites of operation		
Intrathoracic	30	6.0
Airway (intraoral)	98	19.7
Upper abdomen	58	11.7
Lower abdomem	60	12.1
Cardiac	8	1.6
Major vascular	4	0.8
Casearean section	22	4.4
Intracranial	22	4.4
Extremities	72	14.5
Others	123	24.8

Table 3. Type of anesthesia and techniques and duration of anesthesia

	n	%
Types of anesthesia		
GA and endotracheal tube	388	78.1
GA and mask	21	4.2
GA and LMA	16	3.2
GA via tracheostomy	6	1.2
GA via endoscope	22	4.2
Total IV. Anesthesia	10	2.0
Spinal	15	3.0
Spinal with sedation	6	1.2
Epidural	1	0.2
Brachial plexus block	1	0.2
MAC	10	2.0
Unknown	1	0.2
Anesthesia outside OR		
Yes	9	1.8
No	488	98.2
Rapid sequence induction		
Yes	16	3.2
No	481	96.8
One lung		
Yes	13	2.6
No	484	97.4
Duration of anesthesia (min)		
<30	45	9.2
30-150	358	73.1
>150	87	17.8
Missing	7	1.4

Table 4. Severity of oxygen desaturation, place and period of anesthesia

	n	%
Place		
Operating room	357	71.8
Recovery room	91	18.3
ICU	16	3.2
Ward	27	5.4
Others:x-ray 2, dental room 1, cardiac cath room1, during transfer 1 and unknown 1	6	1.2
Period		
Induction	53	10.7
Intubation	104	20.9
Maintenance	154	31.0
Emergence and extubation	60	12.0
Recovery	78	15.7
Postoperative period	46	9.2
Unknown	2	0.4
Severity		
SpO2 < 90 for 3 min	135	27.2
SpO2 £ 85	361	72.6
Unknown	1	0.2

Tables 5. Factors related to the event

	n	%
Anesthesia related	288	57.9
Surgical related	16	3.2
Patient related	25	5.0
Combination factors	163	32.8
Others (not stated)	5	1.0

abdomen (11.7%), intrathoracic (6.0%) and other superficial sites (24.8%). Most of the incidents (92.2%) occurred during general anesthesia, whereas, 23 (4.6%) occurred after regional anesthesia (Table 3). Three hundred and fifty seven incidents took place in the operating room, 91 in the recovery room, 27 in the ward, 16 in the intensive care unit (ICU), and 6 at other

Table 6. Events related to oxygen desaturation

	n	%
Problems during airway management	**93**	**18.71**
- Difficult/failed intubations	58	
- Difficult mask ventilation	12	
- Delayed or prolonged intubation time	8	
- Problems during LMA insertion	6	
- Problems during fiberoptic bronchoscope	2	
- Problems during the change of endotracheal tube	1	
- Problem during tracheostomy	3	
- Others	3	
Inadequate ventilation	**104**	**20.93**
- During induction and intubation	24	
- During maintenance	16	
- During recovery (emegence + extubation + recovery)	52	
- During post operative period in the ward	11	
Problems with the endotracheal tube	**109**	**21.93**
- Occlusion (kinking 1,occlusion 6,biting 8, secretion 11, compression 1)	27	
- Endobronchial intubation	23	
- Esophageal intubation	31	
- Accidental extubation	12	
- Leakage	4	
- Others	12	
Upper airway obstruction	**122**	**24.54**
- laryngeal spasm	32	
- Tongue and soft tissue obstruction	34	
- Secretion	21	
- Blood and foreign bodies	13	
- Airway edema	7	
- Airway pathology (tumour 5)	9	
- Others	6	
Problems in lungs	**83**	**16.70**
- Pulmonary edema (high pressure 14, negative pressure 2, neurogenic 3, permeability 4)	23	
- Pulmonary aspiration	8	
- Pulmonary aspiration - blood	3	
- Pneumothorax	10	
- Pleural effusion	9	
- Pulmonary embolism (air 1)	5	
- Atelectasis	9	
- Pulmonary infection (pneumonia)	12	
- Lung compression during surgery	4	
Problems in lower airways	**83**	**16.70**
- Bronchoconstriction	41	
- Bronchial secretion	39	
- Bronchial blood	2	
- Other	1	

	n	%
Problems with the anesthetic machine/equipment	**16**	**3.2**
- Disconnection of common gas outlet	5	
- Problem of breathing circuit (disconnection 2, wrong connection 1)	3	
- Vaporizer leakage	2	
- Leakage through end tidal CO2 catheter port	1	
- Malposition of jet	2	
- Laryngoscope-inadequate light (1), improper size (1)	2	
- Lack of gas supply	1	
Circulation failure	40	**8.0**
Vasoconstriction	2	**0.4**

locations (Table 4). Oxygen desaturation of ≤ 85% was noted in 360 incidents (72.4%). Anesthesia was considered to be the sole contributory factor in 280 patients (56.8%) and a combination of that with other factors in 126 (25.4%). (Table 5) The majority of the incidents (88.4%) was related to respiratory adverse events, whereas, 8% was related to circulatory adverse ones. Sixteen incidents (3.2%) were related to anesthetic machine and equipment failure (Table 6).

During induction and intubation

During induction and intubation, 157 incidents occurred. Most of the events (66.2%) were related to problems with airway management including inadequate ventilation, difficult mask ventilation, difficult or failed intubation and improper laryngeal mask insertion. The respiratory events relating to oxygen desaturation during induction were upper airway obstruction (laryngeal spasm 11, tongue/soft tissue 8, secretion/blood 13 and airway pathology 8), esophageal intubation (28), and pulmonary aspiration (4). Eleven events were related to problems with the anesthetic machine and equipment, i.e. disconnection of the common gas outlet (5), wrong or disconnected breathing circuit (2), breathing bag leakage (1), disconnection of the end tidal CO2 catheter (1), vaporizer leakage (1) and laryngoscope problems (3). The majority of the patients (76.4%) were managed adequately and completely recovered (90%). Six operations were cancelled.

During maintenance of anesthesia

During maintenance of anesthesia, 154 incidents occurred. The major respiratory causes of oxygen desaturation during maintenance included endotracheal tube problems (endobronchial intubation 16, accidental extubation 9, secretion obstruction 7, kinking 5, leakage 4 and esophageal intubation 3), upper airway obstruction (laryngeal spasm 8, tongue/sot tissues 5, secretion 6 and blood 1), bronchial obstruction (secretion 14, blood 1 and bronchospasm 15), inadequate ventilation (16), lung compression (4), atelectasis (5), pulmonary edema (high pressure 5, neurogenic 2 and permeability types 1), pneumonia (4), pneumothorax(3), pulmonary effusion(2), pulmonary embolism (fat 2 and air 1) and pulmonary aspiration (4). Problems with anesthetic machine and equipment were responsible for 5 events during the maintenance of anesthesia, i.e. malposition of the jet needle (2), vaporizer leakage (1), disconnection of the breathing circuit (1) and lack of oxygen supply (1). About 70% of the patients were considered to have had adequate management, and 74.7 % of them recovered completely. Cardiac arrest occurred in 15 patients. Two operations were cancelled. Fourteen patients needed prolonged ventilation support in the ICU.

During the emergence period

During the emergence period, 49 patients developed oxygen desaturation. The major causes of oxygen desaturation were problems with the upper airways (laryngospam 13, tongue/soft tissue obstruction 5, and secretion obstruction 4), inadequate ventilation (respiratory depression 10, breath-holding 2 and residual curarization 3), problems with endotracheal tubes (biting 4, secretion 1 and accidental extubation 2), bronchial obstruction (secretion 1 and bronchospasm 1), pulmonary congestion (1), and problems with airway management (during the change of endotracheal tubes 1 and suction 1). Management of these events was considered perfectly adequate in 69.4% of the patients. The majority of them (83.7%) recovered completely within 24 hours. Other ten patients needed emergency intubation and seven needed prolonged ventilatory

supporting and ICU admission.

Recovery room

In the recovery room, 91 patients developed oxygen desaturation. The major causes of these incidents were problems with inadequate ventilation (residual curarization 8, respiratory depression 9, and inadequate awakening 10), upper airway obstruction (tongue/soft tissues 12, secretion 4, blood 1, and airway edema 6), bronchial obstruction (secretion 6 and bronchospasm 17), pulmonary edema (high pressure 3, negeative pressure 2 and permeability 3), pulmonary aspiration (3), pneumonia (4), pneumothorax (2), pleural effusion (3), problems with the endotracheal tube (secretion obstruction 5 and endobronchial intubation 3) , and problems with circulatory failure (6) and vasoconstriction (1). Management of these events was considered perfectly adequate in 61.5% of the events. Emergency intubation was performed in 23 patients (25.7%). One patient needed an emergency surgical airway. One patient had a cardiac arrest and needed cardiopulmonary resuscitation. Fifty-nine patients (64.8%) recovered completely within 24 hours. Twenty-one patients required respiratory support. Twenty-eight patients needed unplanned ICU admission and 8 patients died.

In the ward

In the ward, 27 patients developed oxygen destauration during 24 hours post operation (Table 4). The respiratory problems related to oxygen desaturation were pulmonary problems (high pressure pulmonary edema 4, atetectasis 2, pneumothorax 2, pneumonia 1, pleural effusion 1 and suspected pulmonary emboli 1), lower airway problems (secretion 4 and bronchospasm 5), upper airway obstruction (secretion 4 and tongue/soft tissues 1), inadequate ventilation (central respiratory depression 1 and, not awakening 2, intrathecal morphine 1 and post extubation 1), and endotracheal obstruction (secretion 1). The event management was considered perfectly adequate in 51.9% of the patients and inadequate in 18.5%. The events were preventable in 66.7%. Eleven patients (40.7%) required reintubation, while nine (33.3%) required unplanned ICU admission. Cardiac arrest occurred in 4 patients. Thirteen patients (48.1%) recovered completely within 24 hours post operation. One patient developed convulsion and three patients died.

In the ICU

In the ICU, 16 incidents of oxygen desaturation occurred. The main causes were endotracheal problems (endobronchial intubation 2, occlusion 2 and accidental extubation 1), inadequate ventilaton (central respiratory depression 1, inadequate coughing due to pain 1 and post extubation 1), pulmonary problems (atelectasis 1, high pressure pulmonary edema 1, and neurogenic pulmonary edema 1), problems with the lower airway (bronchial secretion 1), problems with airway management (difficult reintubation due to airway edema 1), and problems with circulatory failure (1). Management of these events were considered perfectly adequate in 50% of the patients. Only 6 patients (37.5%) recovered completely within 24 hours. Five patients needed prolonged respiratory support. One patient was disabled and three patients died.

Event management and consequence

Event management was evaluated. Three hundred and thirty nine patients (68.2%) received adequate treatment and 12 (2.4%) were treated inadequately without hazard, whereas, 49 patients (9.9%) received inadequate and hazardous treatment (Table 8).

Regarding the consequences of oxygen desaturation within 24 hours, transient physiological changes occurred in 298 patients (60.0%), while major physiologic disturbance occurred in 80 (16.1%). Seventy patients (14.1%) received emergency intubation. Four patients required a surgical airway. Twenty-two patients (4.4%) developed cardiac arrest and two of them died. One patient had myocardial infarction. Twenty-four hours after the event, 385 patients (77.5%) had recovered completely, whereas, death ensued in 29 cases (5.8%). Fifty-six patients needed prolonged respiratory support. Four patients had convulsion (2), disability (1), and vegetative state or brain death (1). Moreover, from the case-control analysis, the deaths

Table 7. Events management and preventability

	n	%
Adequacy of event management		
Inadequate and hazardous	49	9.9
Inadequate and not hazardous	12	2.4
Maybe adequate	91	18.3
Adequate	339	68.2
Not clearly stated	6	1.2
Preventability		
Preventable	361	72.6
Partially preventable	99	19.9
Unpreventable	34	6.8
Inconclusive	3	0.6

Table 8. Consequence after the events

	n	%
Immediate outcome (< 24 hours)		
Minor physiological change	298	60.0
Major physiological change	80	16.1
- Emergency intubation	70	14.1
- Surgical airway	4	0.8
- Cardiac arrest	22	4.4
- Death	2	0.4
- MI	1	0.2
Cancelled operation		
Yes	8	1.6
No	489	98.4
Long term outcome (>24 hours)		
Complete recovery	385	77.5
Prolonged ventilatory support	56	11.3
Unplanned ICU admission	12	2.4
Vegetative and brain death	2	0.4
Convulsion	2	0.4
Disability	1	0.2
Cardiac arrest	1	0.2
Death	29	5.8
Unknown	9	1.8

were associated with co-morbidity (ASA class 4 and 5), with an Odds ratio of 12.9 (95% CI:5.4,31.0).

System analysis

Considering the system analysis, the common contributory factors were inadequate care from inexperience (68%), haste (32.2%), wrong decision (27%), inadequate knowledge (25.4%) and lack of supervision (38.2%). (Table 9). The proposed corrective strategies included improvement in supervision (70.8%), care improvement (62.7%) additional training (56.7%), and quality assurance activity (81.3%) (Table 9).

Discussion

The introduction of pulse oximetry has made early detection of incidents associated with oxygen desaturation possible during anesthesia and the perioperative period [9]. A randomized controlled study by Moller et al. confirmed that pulse oximetry could detect early hypoxemia and related events, which therefore facilitated early correction. In Thailand, pulse oximetry has been accepted as a standard practice of anesthesia in many hospitals [10].. Recently, we used

Table 9. Contributory factors and suggested corrective strategy (N = 497)

Contributory factors	n	%
Inexperience	338	68.0
Inadequate care	297	60.5
Lack of supervision	191	38.2
Haste (hurry)	160	32.2
Wrong decision	136	27.0
Inadequate knowledge	125	25.4
Communication failure	90	18.1
Poor patient condition	70	14.1
Organization failure	41	8.2
Nonfunctioning equipment	21	4.2
Recovery room care failure	10	2.0
Unavailable equipment	9	1.8
ICU care failure	6	1.2

Suggested corrective strategy	n	%
Improving supervision	352	70.8
Care improvement	312	62.7
Additional training	282	56.7
Quality assurance activity	404	81.3
Guideline practice	149	30.0
Improving communication	129	26.0
Good referral system	46	9.3
More manpower	44	8.9
More equipment provided	13	2.6
Equipment maintenance	12	2.4

the criteria described by a previous study [7] , of SpO2 < 90 % lasting for at least 3 min or SpO2 85 %, to identify cases with oxygen desaturation. We found that 521 incidents out of 163,403 anesthetics (0.32%) developed oxygen desaturation during a one-year study period. The incidence rate (0.32%) was consistent with the finding reported from an earlier study at Siriraj Hospital in Thailand [7] and extremely low when compared to the incidence from other previous studies [1-6] . From an observation study by Moller et al. [4] , the incidence of hypoxemia depended on the severity of hypoxemia, as follows: mild hypoxemia (SpO_2 86-90%) 53% and severe hypoxemia (SpO_2 < 81%) 20%. According to a current study by Raksakietisak M [7] , we modified the definition of oxygen desaturation in order to detect clinically relevant incidents relating to oxygen desaturation in terms of its severity (SpO_2 < 90) and duration (at least 3 min). Hence, patients with milder form of oxygen desaturation were not included in our survey. On the other hand, the continu-

ous monitoring of arterial oxygen desaturation with pulse oximetry would enable the anesthesia providers to detect and promptly treat milder form of oxygen desaturation (SpO_2 90-92 %). Provided that there was no under reporting, this extremely low incidence could reflect the quality of anesthesia management. Further study is still needed to verify this figure as one of indices in determining the quality of anesthesia care in Thailand.

Of 521 incidents of oxygen desaturation, 497 incidents (95.39%) provided adequate clinical information for analysis. We found that the occurrence of oxygen desaturation was widely distributed throughout all phases of anesthesia, i.e. from induction to post operative periods. Our aim of this study was to describe the incidents relating to severe form of oxygen desaturation. Hence, the nature of this study design was descriptive. The limitation of our study was that we were not able to find the strength of association between the potential risk factors and the occurrence of oxygen desaturation. However, from the database of the Thai Anesthesia Incidents Study (THAI Study) we performed our preliminary analysis and found the potential risk factors significantly associated with the perioperative oxygen destauration, , as follows : ASA class 3 , 4, 5 (RR = 2.74 , 95%CI:2.26-3.32), age < 10 years (RR 4.37 , 95% CI : 3.65,5.23) , Age > 60 yrs (RR 1.72, 95% CI : 1.37,2.16), preoperative upper airway obstruction (RR = 4.78 , 95% CI : 2.99,7.64)), preoperative lower respiratory tract infection (3.65, 95%CI : 2.33,5.70) , preoperative difficult airway (RR = 6.23 , 95%CI : 4.38,8.86), intraoral surgery (RR = 3.26, CI : 2.22,4.9%), intrathoracic surgery (RR = 4.37, 95%CI : 2.9,6.56) and general anesthesia (RR = 5.38, 95% CI : 3.8,7.62). This quantitative analysis is still ongoing.

Age could be one of the patient-related risk factors for hypoxemia during anesthesia and recovery [4, 5] . Although the occurrence of oxygen desaturation was distributed in all age groups in our study, about 41% of the incidents occurred in patients of extreme age, i.e. < one year and ≥ 60 years. Young children under one year of age are prone to oxygen desaturation during induction of anesthesia [15]. Laycock et al also reported that the incidence of oxygen desaturation significantly increased in children who were anxious or crying before intravenous induction [15]. Uncooperative children always refuse mask or oxygen prior to intravenous induction. Hence, the time margin before unacceptable oxygen desaturation is very short for them during apnea or airway obstruction after induction. We also found other potential respiratory-related risk factors including respiratory abnormalities (26%) and difficult airways (16%). Other potential patient-related risk factors, i.e. heavy smoking[32]; BMI > 28 kg/m^2 [33]; and pregnancy [34], were infrequently identified in our study.

The association between anesthetic technique (general versus regional) and oxygen desaturation has been documented [4] . In our study, the majority of oxygen desaturation happened in patients receiving general anesthesia. Despite less frequency associated with oxygen desaturation when compared to general anesthesia, spinal anesthesia was a predominant technique used over other regional methods. From our data base, we found that the majority of oxygen desaturation incidents after spinal anesthesia were related to problems with inadequate ventilation and upper airway obstruction (45.6%), and perfusion failure (22.7%). Furthermore, we found that 27.3% of oxygen desaturation after spinal anesthesia occurred in patients receiving sedation. Heavy sedation during spinal anesthesia can be a precipitating factor, which leads to upper airway obstruction and inadequate ventilation and results.in oxygen desaturation. Thus, monitoring arterial blood oxygen saturation and adequate respiratory care with supplemental oxygen is mandatory in patients with a high spinal anesthetic level and/or drowsiness during surgery [11].

We found sixteen events of oxygen desaturation related to problems of the anesthetic machine and equipment (Table 6), which occurred during induction [11] and maintenance anesthesia [5]. Ranchman et al. [8] reported seven out of 46 disconnections at the common gas outlet were first detected by pulse oximetry. We found four out of five disconnections at the common gas outlet which occurred during attempted intubation. This indicated that the patients were preoxygenated with disconnected circuits before intubations. A factor contributing to this incident was failure to check the anesthetic machine and breathing circuit (rule-based error), due to the inattention or haste of the attending anesthesiologist. Hence, corrective strategies suggested to prevent this incident should include equipment checking discipline, improved environment and fatigue alleviation routine [12]. Other issues regarding the anesthetic machine and equipment failure have also been discussed elsewhere in this symposium [13].

After induction of anesthesia, many respiratory events such as airway obstruction, hypoventilation

and apnea can result in oxygen desaturation [14, 15]. In our study, the major problems responsible for oxygen desaturation after induction were problems in airway management due to inadequate ventilation, upper airway obstruction, difficult mask ventilation and difficult/failed intubations. Other problems included aspiration, esophageal intubation, and anesthetic machine / equipment failure. Strategies to prevent oxygen desaturation during induction would include proper airway management, adequate preoxygenation, adequate preparation for difficult intubation, measures to prevent pulmonary aspiration, early detection of esophageal intubation (e.g. end-tidal carbon dioxide or the esophageal detector device), and maintaining and checking the anesthetic machine/ equipment before induction. So far, preoxygenation has been used to prevent oxygen desaturation during induction and intubation. [14] Recently, routine preoxygenation, as a new minimal standard of care, has been discussed [16-19]. Despite its effectiveness in the prevention of oxygen desaturation during induction and intubation, the administration of 100% oxygen can result in ateletasis [20] and late detection of esophageal intubation[22]. Edmark et. al. [21] conducted a randomized controlled trial to determine the optimal oxygen concentration during induction of general anesthesia, and concluded that 80% oxygen for preoxygenation for 5 minutes during induction of general anesthesia caused minimal atelectasis, but the time margin before unacceptable oxygen desaturation occurred was significantly shorter when compared with 100% oxygen (303 – 59 vs. 411 – 84 sec.) in healthy adults. This evidence indicates that, whichever method used for preoxygenation before induction of anesthesia, anesthesia providers should keep in mind about time margin before unaccepatable oxygen desaturation during intubation.

Late detection of esophageal intubation can result in severe hypoxemia[22] . From our study, esophageal intubation with severe oxygen desaturation occurred in 28 patients during induction. Nearly half of them had the problem of difficult intubation. Hence, end-tidal carbon dioxide (ET CO_2) or the esophageal detector device [23] should be available for early detection of esophageal intubations, particularly in high-risk patients.

During maintenance, major causes of oxygen desaturation were related to endotracheal tube problems (endobronchial intubation, accidental extubation, kinking and secretion); upper airway obstruction (during mask or LMA anesthesia) and inadequate ventilation. Preventive strategies should include early detection of bronchial intubation, airway pressure monitoring, endotracheal tube care, adequate depth of anesthesia, management of laryngeal spasm, improved technique of laryngeal mask insertion, management of bronchospasm, careful fluid administration, and maintaining and checking the anesthetic machine/equipment etc.

Unrecognized endobronchial intubation can lead to oxygen desaturation during maintenance of anesthesia. The pulse oximeter has been recommended as the front-line monitor for endobronchial intubation [8] . Other signs including high airway pressure, unilateral diminished breath sounds and suddenly decreased end-tidal carbon dioxide [24] should be examined to detect endobronchial intubation.During emergence, major causes of oxygen desaturation were related to upper airway obstruction and inadequate ventilation. According to Koga et al. [25], respiratory complications could occur in a patient extubated either while deeply anesthetized or during recovery of consciousness. During or immediately after extubation, upper airway obstruction (soft tissues) is common in deeply anesthetized patients, while straining, bucking, breath-holding, coughing and laryngospasm can occur in patients recovering from anesthesia. Residual effects of anesthetics can be attributed to inadequate ventilation after extubation. The presence of an endotracheal tube may stimulate breathing and counteract the respiratory depression [26] . When the trachea is extubated, the diminished respiratory stimulation can lead to inadequate ventilation. Therefore, constant vigilance is required immediately after extubation during emergence from anesthesia.

In the recovery room, the occurrence of oxygen desaturation has been well documented from several studies [1-5] . In our survey, we found 91 cases of oxygen desaturation in the recovery room. This figure could be underestimated because continuous pulse oximetry was not performed in every case. In our study, upper airway obstruction and inadequate ventilation were the main problems responsible for oxygen desaturation. Inadequate reversal of muscle relaxants was to blame for inadequate ventilation in eleven patients, of which seven required re-intubation and postoperative respiratory support. Appropriate use of muscle relaxants can be one strategy used in the prevention of this serious respiratory event. The association between the conscious state and respiratory complications including oxygen desaturation during early recovery from general anesthesia, has been docu-

mented [5] . Thus, anesthetic techniques, which can provide patients with a better level of consciousness during recovery, can reduce the risk of hypoxemia during the early post operative period. Routine oxygen administration in the recovery room does not guarantee the absence of critical respiratory incidents and prevent episodic arterial desaturation [35]. Therefore, recovery room personnel should be alert in looking for early signs and symptoms of respiratory complications, including upper airway obstruction and inadequate ventilation, and manage these events promptly before critical respiratory events happen.

Postoperative pulmonary complications have been reported to occur in 3-11% of surgical patients [28,29] . According to our study design, we did not follow up postoperative patients uniformly for longer than 24 hours. Therefore, the true incidence of postoperative pulmonary complications has not been estimated from our survey. Although reports of oxygen desaturation in the ward are infrequent, we identified 36 cases with oxygen desaturation in the ward during 24 hours of post operation. The majority of the respiratory events were related to pulmonary problems, such as atelectasis, pulmonary edema and respiratory depression. There were four patients with cardiogenic pulmonary edema due to fluid overload. Most of these patients had preexisting lung and heart diseases. Regarding respiratory depression, there has been much attention paid to methods of opioid delivery, such as spinal opioid [30], patient-controlled analgesia (PCA) [31] , continuous intravenous injection and intramuscular injection [32] . In our study, one patient experienced respiratory depression in the ward after spinal morphine. At present, the use of epidural or intrathecal morphine has gained popularity among anesthesiologists to combat the post operative pain. [36] Although significant side effects are uncommon, pronounced respiratory depression can occur and careful observation is necessary.

From our analysis, factors attributable to the incidents relating to oxygen desaturation were anesthetic-related (25%) patient-related (22.2%), surgical-related (8.3%), combining (19.4%) and undetermined (25%). Most of the incidents associated with oxygen desaturation were correctable and preventable. We found that the contributory factors could be knowledge-based error (inadequate knowledge and/or wrong decision), ruled-based error (inattention and/or ignorance), skill-based error (haste and/orfatigue), technique-based error (wrong technique) and systemic error (no practice guideline and/or lack of supervision). This indicates that quality assurance activity, including detection, correction and prevention, should be implemented to prevent critical incidents and provide safety for all anesthetics.

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การศึกษาอุบัติการณ์เกิดภาวะความอิ่มตัวของออกซิเจนต่ำจากการให้ยาระงับความรู้สึกในประเทศไทย

ยอดยิ่ง ปัญจสวัสดิ์วงศ์, ฐิติมา ชินะโชติ, สมรัตน์ จารุลักษณานันท์, อักษร พูลนิติพร, ศิริลักษณ์ กล้าณรงค์, วราภรณ์ เชื้ออินทร์, อรลักษณ์ รอดอนันต์

วัตถุประสงค์: *เพื่อหาการเกิดอุบัติการณ์ ปัจจัยส่งเสริม การรักษา และผลลัพธ์ ที่เกี่ยวข้องกับการเกิดภาวะออกซิเจนต่ำในเลือด ในผู้ป่วยที่ได้รับยาระงับความรู้สึกในประเทศไทย*

วัสดุและวิธีการ: *เป็นการวิจัยเชิงพรรณนาโดยการวิเคราะห์ข้อมูลที่ได้จากการลงทะเบียนการเกิดภาวะแทรกซ้อนทางวิสัญญีวิทยาจากกลุ่มวิจัยที่ติดตามการเกิดอุบัติการณ์ทางวิสัญญีวิทยาระหว่างวันที่ 1 กุมภาพันธ์ พ.ศ. 2546 ถึงวันที่ 31 มกราคม พ.ศ. 2547*

ผลการศึกษา: *จากรายงาน 497 อุบัติการณ์ที่เกิดภาวะออกซิเจนต่ำในเลือด (SpO2 ต่ำกว่า 90% นานอย่างน้อย 3 นาที หรือเท่ากับ หรือน้อยกว่า 85%) พบว่าภาวะออกซิเจนต่ำในเลือดเกิดขึ้นทุกช่วงของการให้ยาระงับความรู้สึกตั้งแต่การนำสลบจนถึง 24 ชั่วโมง หลังผ่าตัด ส่วนใหญ่ (92%) เกิดขึ้นในระหว่างการระงับความรู้สึกแบบทั้งตัวในขณะที่ส่วนน้อย 23 ราย (4.6%) เกิดในระหว่างการให้ยาระงับความรู้สึกแบบการฉีดยาชาเฉพาะส่วน โดยเกี่ยวข้องกับการให้ยาระงับความรู้สึกเป็นปัจจัยเดียวในผู้ป่วย 280 ราย. (56.8%) และร่วมกับปัจจัยอื่น 126 ราย (25.4%) อุบัติการณ์ส่วนใหญ่ (88.4%) มีความสัมพันธ์กับการเกิดภาวะแทรกซ้อนทางระบบการหายใจในขณะที่ส่วนน้อย (8%) สัมพันธ์กับการเกิดภาวะแทรกซ้อนทางระบบไหลเวียนเลือด ประมาณ 3.2% เกี่ยวข้องการความผิดพลาดในการทำงานของเครื่องดมยาสลบและอุปกรณ์ที่ใช้ในการวางยาสลบ ส่วนใหญ่ของอุบัติการณ์ (60%) มีผลต่อการเปลี่ยนแปลงทางสรีรวิทยาเพียงเล็กน้อย แก้ไขได้ และได้รับการดูแลรักษาอย่างเหมาะสม ทำให้กลับคืนมาเป็นปกติถึง 77.5% ในขณะที่มีการเสียชีวิตประมาณ 5.8% โดยที่การเสียชีวิตนั้นเกี่ยวข้องกับภาวะการเจ็บป่วยที่รุนแรงก่อนผ่าตัด (ASA class 4 และ 5) โดยมีความเข้มของการเสี่ยง (Odds ratio)อยู่ที่ 12.964 ในช่วงของความเชื่อมั่นที่ 95% ระหว่าง 5.43 กับ 31.0 ปัจจัยเชิงระบบที่ส่งเสริมการเกิดอุบัติการณ์ได้แก่ การขาดประสบการณ์ การตัดสินใจไม่ถูกต้อง ขาดการดูแล และขาดการปรึกษาที่เหมาะสม ดังนั้นแนวทางที่แก้ไขที่สำคัญได้แก่ การปรับปรุงระบบการดูแล การให้คำแนะนำปรึกษา การฝึกอบรมเพิ่มเติม การสร้างแนวทางเวชปฏิบัติ ตลอดจนการทำกิจกรรมการประกันคุณภาพ*

สรุป: *อุบัติการณ์ที่เกี่ยวข้องกับการเกิดภาวะออกซิเจนต่ำในเลือดเกิดได้ทุกช่วงของการให้ยาระงับความรู้สึกจนถึง 24 ชั่วโมงหลังผ่าตัด ส่วนใหญ่เป็นเหตุการณ์ที่ป้องกันและแก้ไขได้ ผู้ให้การวางยาสลบควรตื่นตัวในการเฝ้าติดตามและพร้อมที่จะให้การแก้ไขเพื่อป้องกันไม่ให้เกิดภาวะแทรกซ้อนที่รุนแรง*