Original Article

The Perioperative and Anesthetic Adverse Events in Thailand (PAAd Thai) Study of Endobronchial Intubation: An Analysis of 2,000 Incident Reports

Sukanya Pongruekdee, MD[1], Chuthamat Somchat, MD[2], Krairerk Sintavanuruk, MD[1], Sasikaan Nimmaanrat, MD[3], Nopadon Chernsirikasem, MD[4], Somrat Charuluxananan, MD[5], Sunthiti Morakul, MD[6], Somchai Agprudyakul, MD[7]

[1] Department of Anesthesiology, Charoenkrung Pracharak Hospital, Bangkok, Thailand

[2] Department of Anesthesiology, Lamphun Hospital, Lamphun, Thailand

[3] Department of Anesthesiology, Faculty of Medicine, Prince of Songkla University, Hatyai, Songkhla, Thailand

[4] Department of Anesthesiology, Phramongkutklao College of Medicine, Bangkok, Thailand

[5] Department of Anesthesiology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand

[6] Department of Anesthesiology, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

[7] Department of Anesthesiology, Buddhasothorn Hospital, Chachoengsao, Thailand

Background: The Royal College of Anesthesiologists of Thailand hosted a multicentered project, namely the Perioperative and Anesthetic Adverse Events in Thailand (PAAd Thai) Study.

Objective: The aims of the present study were to investigate incidences, contributing factors and suggested preventive strategies of anesthesia-related complications particularly the endobronchial intubation (EBI).

Materials and Methods: The PAAd Thai study was a collaborative incident report among 22 hospitals across Thailand. After approval by the Institutional Ethical Committee, the structured incident report together with open ended data record form of anesthesia-related complications such as cardiac arrest, death within 24 hours, and respiratory complications including EBI were requested to be sent to the data management center together with monthly statistics of anesthesia service in each hospital for 12 months (between January 2015 and December 2015) on an anonymous and voluntary basis. The EBI reports were reviewed by three anesthesiologists. Any discretion was discussed to achieve a consensus. Descriptive statistics were used.

Results: Among the first 2,000 incident reports, there were 23 EBIs, at the rate of 1.06:10,000 (95% CI 0.62 to 1.49) or 1.15% of all reports. Two-thirds of the incidents occurred in patients with age less than 5 years old and more than 60 years old, and in elective cases. The common sites of surgery were trunk, head and neck, and laparoscopic procedures. EBIs were diagnosed by pulse oximeter (13 cases, 54.0%), increased airway pressure (four cases, 17.2%) and clinical monitoring (four cases 17.2%). Common phases of detection were pre-induction (one case, 4.3%), induction (nine cases, 39.2%), maintenance (12 cases, 52.2%), and emergence (one case, 4.3%). Contributing factors were lack of knowledge, inexperience, and haste, while factors minimizing the incidents were having experience and vigilance. Suggested preventive strategies were additional training, including simulation, practice guidelines, improvement of supervision, and communication.

Conclusion: The authors have found that EBI was uncommon, but it is one of the serious anesthesia-related adverse events. It can happen anytime during the entire course of anesthesia. Under these circumstances, careful monitoring and vigilance of the anesthesiologists is essential.

Keywords: Anesthesia, Complication, Endobronchial intubation, Intubation, Hypoxia

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Correspondence to:

Pongruekdee S.

Department of Anesthesiology, Charoenkrung Pracharak Hospital, Bangkok 10120, Thailand.

Phone: +66-2-2897265, **Fax**: +66-2-2897863

Email: spongruekdee@yahoo.com

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Endobronchial intubation (EBI) is a major adverse event associated with endotracheal intubation. Serious complications can occur in many forms such as an inadvertent placement of the endotracheal tube in a main stem bronchus may lead to hypoxemia caused by atelectasis of the unventilated lung, hyperinflation, and barotrauma resulting in pneumothorax of the ventilated lung[1-3]. It can lead to secondary complications such as cardiac arrhythmias, hypotension, or tension pneumothorax[1-3]. Right EBI, or main-stem intubation has been shown to occur in up to 3.7% to 10.7% of intubation attempts[4,5],

and accounts for 2% of adverse respiratory claims in adults and 4% in children[6,7]. In 2015, the Royal College of Anesthesiologists of Thailand launched a project called "the Perioperative and Anesthetic Adverse Events in Thailand (PAAd Thai) Study" by sentinel incident reports. The adverse outcomes such as cardiac arrest within 24 hours, cardiac arrhythmia, suspected pulmonary aspiration, and other respiratory events were reported. The present study aimed to investigate the incidence, contributing factors, minimizing factors, and suggested corrective measures of unexpected EBI.

Materials and Methods

The present study was a part of the PAAd Thai study. It was a multi-center prospective observational study that included 22 hospitals across Thailand between January and December 2015[8,9]. The data of the first 2,000 incident reports were analyzed. The protocol of the present study was approved by each institutional ethics committee. All EBI incident record forms were reviewed by three anesthesiologists for completeness and to identify mechanism, contributory factors, minimizing factors, and suggested corrective strategies. Any controversy was discussed to achieve a consensus[8].

EBI was defined as unintentional insertion of endotracheal tube, which its tip was placed far beyond the carina into the right or left main bronchus. Detection of EBI would be by clinical observation (chest auscultation, equal chest movement, 20/22 rule) or other devices (pulse oximetry, capnography, or fiberoptic bronchoscopy).

The data were analyzed by descriptive statistic using IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, NY, USA).

Results

Among the first 2,000 incident reports in the PAAd Thai Study database, there were 23 cases (1.15%) of EBI. It occurred in 17 female (73.9%) and six male (26.1%) patients, with age ranging from less than 5 to more than 60 years old as shown in Table 1. Fifteen cases (65.2%) of EBI patients were classified as the American Society of Anesthesiologists classification 2 and 3. The details of patients, surgical, and anesthetic characteristics are shown in Table 1.

EBI was detected in one patient (4.3%) during pre-induction, nine patients (39.2%) during induction-intubation, 12 patients (52.2%) during maintenance, and in one patient (4.3%) during emergence. Among 23 EBI incidents, five incidents were detected

Table 1. Demographic, surgical and anesthetic characteristics (n=23)

Characteristics	n (%)
Age group (year)	
<5	7 (30.4)
5 to 15	1 (4.3)
16 to 60	7 (30.4)
>60	8 (34.9)
ASA classification	
I	5 (21.8)
II	9 (39.1)
III	6 (26.1)
IV	3 (13.0)
Emergency	8 (34.8)
Site of surgery	
Trunk	15 (65.2)
Head and neck	5 (21.7)
Extremities	2 (8.6)
Endoscopy	2 (8.6)
Laparoscopic surgery*	4 (17.2)
Type of hospitals	
Academic directed	12 (52.2)
Non- academic directed	11 (47.8)
Type of performers	
Trainee - nurse anesthetist	2 (8.6)
Trainee - resident	6 (26.1)
Staff - nurse anesthetist	9 (39.1)
Staff - anesthesiologist	4 (17.2)
Staff - others	2 (8.6)
Type of detection	
Detected by the performer	6 (26.1)
Detected by more experienced staff	17 (73.9)
Mean of detection	
Clinical detection (auscultation)	4 (17.2)
Device detection	
• Pulse oxymeter	13 (54.0)
• Airway pressure	4 (17.2)
• End-tidal capnogram	1 (4.3)
Incapable of detection (fluorocope)	1 (4.3)
Phase of detection	
Preinduction	1 (4.3)
Induction	9 (39.2)
Maintenance	12 (52.2)
Emergence	1 (4.3)
None	6 (26.1)

ASA=American Society of Anesthesiologists

* Data are not mutually exclusive

Table 2. Factors related to endobronchial intubation (n=23)

Related factors	Number of incidents n (%)
Patient factor only	0 (0.0)
Anesthetic factor only	11 (47.8)
Surgical factor only	2 (8.7)
Systematic factor only	1 (4.3)
Combined anesthetic and patient factor	4 (17.4)
Combined anesthetic and surgical factor	3 (13.0)
Combined anesthetic, patient, and surgical factor	1 (4.3)
Combined anesthetic, patient, surgical, and systematic factor	1 (4.3)
Preventable	21 (91.3)

Table 3. Contributing factors, minimizing factors and suggested preventive strategies (n=23)

	Number of incidents (%)*
Contributing factors	
Lack of knowledge	87.0
Inexperience	87.0
Haste	17.4
Inappropriate decision	4.3
Minimizing factors	
Having experience	95.6
Vigilance	65.2
Experienced assistant	26.1
Comply to practice guidelines	26.1
Improvement of training	13.0
Effective consultation system	8.7
Effective communication	4.3
Suggested corrective strategies	
Additional training	47.8
Comply to practice guidelines	34.7
Improvement of supervision	30.4
Improvement of communication	21.7
Quality assurance activity	21.7
More equipment	8.7
Equipment maintenance	4.3

* Data are not mutually exclusive

by clinical diagnosis (chest auscultation) before monitoring, while 17 incidents (73.9%) were detected using pulse oximeter only (seven cases, 41.2%), airway pressure only (three cases, 17.6%), pulse oximeter and airway pressure (four cases, 23.5%), pulse oximeter and capnography (two case, 11.0%), pulse oximeter and airway pressure and capnography (one case, 5.9%). One case could not be detected by clinical observation and device monitoring but was diagnosed intraoperatively by chest X-ray during an operation. There were 16 reports (69.5%) of oxygen desaturation, three reports (13.0%), and one report (4.3%) of hypertension as immediate outcomes while six cases (26.1%) had no immediate adverse outcome.

After three anesthesiologists have reviewed the 23 cases, 21 cases (91.3%) were considered as preventable. Eleven incidents (47.8%), two incidents (8.7%), and one incident (4.3%) were considered as anesthesia factor only, surgical factor only, and systematic factors only, respectively. Another nine incidents of EBI were considered as combination of anesthetic and other factors as shown in Table 2. Regarding human error that was considered as preventable, there were 12 incidents (52.1%), 16 incidents (69.6%), and seven incidents (30.4%) considered as rule-based, knowledge based, and skill-based, respectively. Three anesthesiologists divided the model of anesthesia-related adverse event of EBI into contributing factors, minimizing factors, and suggested corrective strategies as shown in Table 3.

Discussion

During general anesthesia, to get a proper position of the endotracheal tube is one of the key factors to ensure patient safety. Endotracheal intubation requires two critical steps. The first step is insertion of the endotracheal tube into the trachea, and the second step is its depth adjustment. An endotracheal tube that is advanced too deep into the bronchus can result in EBI. This is a common cause of oxygen desaturation and increased airway pressure. Unrecognized EBI can lead to atelectasis and hypoxemia, as well as potential hyperinflation and barotrauma of intubating lung, cardiac arrest, and death[1,2,4,10,11]. Many studies reported various EBI incidences. The Australian Incident Monitoring Study (AIMS) assessed complications related to endotracheal intubation in 2,000 adults and found that the occurrence of EBI was 42% of all adverse events[12]. McCoy et al had published an EBI incidence as 3.7% of the first 3,974 incident reports between 1988 and 1994[4]. The Thai Anesthesia Incident Monitoring Study (Thai AIMS) in 2008 accounted EBI rate for 1.6% from overall 1,996 incidents[10]. The present study reported 23 (1.15%) EBI-incident reports from the first 2,000 incidents of PAAd Thai study[6]. Compared to total amount of 216,179 cases

of general anesthesia, the incidence of EBI was 1.06:10,000 (95% CI 0.62 to 1.49).

Three-fourths of patients with EBI occurred in female, while two-thirds of incidents occurred in elderly and pediatric patients. The present study revealed that one-third of EBI cases were children younger than 5 years. Difficulty in intubation in pediatric patients might mean that more than one attempt intubation was done, and appropriate depth of endotracheal intubation was poorly evaluated. EBI did not commonly occur in emergency setting as two-thirds of the incidents occurred in elective setting. The EBI incidents distribution was not confined to academic directed or non-academic directed hospitals. Anesthesiologists and nurse anesthetists were performers of intubation in more than half of the incidents. This was different from PAAd Thai Study in regard to esophageal intubation, which was mainly unintentionally performed by trainees[13].

Most of the EBI incidents occurred in the operating theatre. One case of EBI was detected by its depth of 24 cm at patient's lip upon arrival to the operating theatre. After checking with chest auscultation, the endotracheal tube was adjusted by withdrawal of the tube until equal bilateral lung sound was detected.

There are usual practices among anesthesiologists to prevent and detect accidental EBI. Auscultation of bilateral sides of chest is considered a standard practice to detect proper placement after intubation[2,14]. For confirmation of bilateral breath sounds, there are 5 foci: bilateral axilla, bilateral fifth intercostal spaces, and the epigastrium[15]. However, endotracheal tube designed with a Murphy eye can result in bilateral breath sound in 60% of cases who have EBI[7,16,17]. The 20/22 rule relate when the endotracheal tube is taped at 20 cm at the incisors of the female patients and 22 cm for the male patients[2]. There were only four incidents (17.2%) detected by clinical auscultation in the present study, while 13 incidents (54.0%) and four incidents (17.2%) were detected by pulse oximeter and increased airway pressure, respectively. In the AIMS, there were 154 cases (3.7%) of the 3,947 cases[4]. The AIMS also showed that chest auscultation might be clinically difficult to detect EBI and there was no change in capnography in most cases[4]. In the present study, there was only one EBI that went undetected by clinical and monitoring means, but accidentally diagnosed with intraoperative fluoroscopy.

Anatomical variation of airways, placing the patient in the Trendelenburg position or laparoscopic surgery might also be factors affecting the position of endotracheal tube[18,19].

Study of model of anesthesia-related adverse events involves contributing factors and minimizing factors. Lack of knowledge and inexperience were considered as contributing factors of EBI, while haste was considered in 17% of incidents. These factors lead to suggest corrective strategies involving compliance to the practice guidelines and providing simulation training of diagnosis and management of EBI. These were in accordance to having experience, vigilance, experienced assistant, and compliance to guidelines as minimizing factors. Other suggested corrective strategies considered were improvement of supervision and improvement of communication. Effective communication within anesthesia team and between the team and other health care providers is essential in preventing and solving patients' problems[20]. For EBI incidents in the PAAd Thai Study, factors related to adequate monitoring such as availability of equipment and equipment maintenance were also suggested. The Royal College of Anesthesiologists of Thailand modified the guidelines for monitoring during general endotracheal anesthesia and the use of capnography was recommended as a mandatory monitoring in 2015.

There were several limitations of the present study. 1) This was not a randomized controlled trial, but a retrospective analysis of the prospective collection of incident reports. 2) The sentinel event was reported on a voluntary basis, which might be underreported. However, the participating hospitals were familiar with this reporting system and that it was in an anonymous basis. 3) During data collection (between January and December 2015), the RCAT had launched the new regulation that changed the usage of capnography during general endotracheal anesthesia from recommended to mandatory. Therefore, the rate of using capnography in that period of time might be inconstant. However, case record forms were voluntary sent from all 22 hospitals across the country, these could represent data from big government hospitals in Thailand.

Conclusion

The incidence of EBI in the PAAd Thai study was 1.06:10,000 (95% CI 0.62 to 1.49) or 1.15% of the first 2,000 incident reports. It more commonly occurred in pediatric and elderly patients, and in some types of surgery such as laparoscopic surgery and operation of upper part of body. Despite that it was a common adverse event, EBI was generally diagnosed

by monitoring equipment such as pulse oximeter and airway pressure measurement, more than clinical detection. The occurrence of EBI was caused by a sole or combined factor of anesthesia, surgery, and system. Most events were considered as preventable (91.3%). Model of occurrence of EBI showed that the contributing factors were lack of knowledge, inexperience, and haste, while minimizing factors were having experience, vigilance, and adherence to the practice guidelines. The suggested preventive strategies of the present study were to comply to the guidelines, having additional training, particularly simulation training regarding EBI, as well as improvement of supervision and communication.

What is already known on this topic?

EBI was a common adverse event and mostly preventable. Clinical detection by the provider of endotracheal intubation included bilateral chest auscultation, use of the 22/20 rule and the palpation of inflated endotracheal tube cuff. Oxygen desaturation was the most common warning sign while most cases showed no change of capnography.

What this study adds?

Incidence of anesthesia related EBI in Thailand was 1.06:10,000 (95% CI 0.62 to 1.49) and most of the incidents were preventable. Most incidents were detected in the operating theatre. The diagnosis of EBI was detected by clinical chest auscultation, using 22/20 cm rules, and unexplained oxygen desaturation or increased airway pressure. Contributing factors of EBI were lack of knowledge, inexperience, and haste, while minimizing factors were having experience and vigilance. Suggested preventive measures were compliance to the guidelines and additional training, particularly simulation training regarding EBI.

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Conflicts of interest

The authors declare no conflict of interest.

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