

Original article

# Perioperative non-hypoxic bradycardia in pediatric patients: Thai anesthesia incident monitoring study (Thai AIMS)

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**Background:** The Royal College of Anesthesiologists of Thailand arranged the first national incident reports of anesthesia-related adverse events in 2007 on an anonymous and voluntary basis.

**Objective:** To identify the incidence of perioperative non-hypoxic bradycardia in pediatric patients' clinical course, outcome, contributing factors and its preventive strategies in the database of the Thai anesthesia incidents monitoring study (Thai AIMS).

**Methods:** As part of the Thai AIMS, perioperative anesthesia incident reports of adverse events were collected from 51 participating hospitals across Thailand between January to June 2007. Three anesthesiologists reviewed relevant data of perioperative non-hypoxic bradycardia in pediatric patients. A descriptive statistical method was used.

**Results:** There were 49 cases of perioperative non-hypoxic bradycardia in pediatric patients (2.4% of all 1996 incident reports or 13.4% of all incident reports from pediatric patients). Anesthesia (71%) was a major factor that related to the bradycardia, whereas 19% and 10% were surgical and patient factors, respectively. Sixty percent of cases occurred during induction, of which 80% (24 out of 30 cases) and 10% were considered as anesthesia-related or combination of anesthesia and patient factors. Sixty percent (9 out of 15 cases) of bradycardia during the maintenance phase was surgery-related particularly in ophthalmologic surgery. Four cases (8.1%) of all bradycardia occurred during the emergence and recovery phase of which 78% was considered anesthesia-related. All bradycardia had complete recovery. Sixty-three percent of events were preventable. Major contributing factors were lack of adequate knowledge (55%) and inappropriate decision-making (22%).

**Conclusion:** Most perioperative non-hypoxic bradycardia incidences were anesthesia-related and most common during the induction phase. Improved supervision, additional training and vigilance were suggested corrective strategies.

**Keywords:** Bradycardia, complication ECG, incident report, pediatric anesthesia, preventable.

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Bradycardia in children during the perioperative period is not uncommon. The incidences of bradycardia vary from 0.67% to 8% dependent on patient age and condition [1-5]. Bradycardia may result in

decreased cardiac output, inadequate tissue perfusion and metabolic acidosis. These consequences of bradycardia may enhance the effect in infants and young children because of limited stroke volume and immature autonomic nervous system. Delayed detection and treatment can lead to cardiac arrest and death [6].

In Thailand, the first multicenter national registry, the Thai Anesthesia Incidents Study (THAI Study),

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provided the incidences of 24-hour perioperative anesthesia-related adverse events, but these did not include bradycardia [7, 8]. However, the THAI Study revealed that bradycardia was a risk factor of intraoperative oxygen desaturation in pediatric patients less than 5 years old [9].

The purpose of this study is to identify the incidence of perioperative non-hypoxic bradycardia in pediatric patients from the database of the Thai Anesthesia Incident monitoring study (Thai AIMS) of anesthesia related adverse events and to examine the clinical course, outcome and contributing factors for a possible future preventive strategy.

## Methods

This prospective multi-centered study, a part of the Thai AIMS, was conducted by the Royal College of Anesthesiologists of Thailand from January to June 2007. All anesthesiologists and nurse anesthetists in fifty-one hospitals ranging from district (community) hospitals to tertiary hospitals across Thailand were invited to report critical incidents on an anonymous and voluntary basis.

After being approved by each institutional ethics committee, the specific anesthesia related adverse events detected during anesthesia and during the 24 hour postoperative period were reported by filling out a standardized incident reporting form as soon as possible after occurrence of adverse or undesirable events. These included pulmonary aspiration, pulmonary embolism, esophageal intubation, endobronchial intubation, oxygen desaturation, re-intubation, difficult intubation, failed intubation, total spinal block, awareness during general anesthesia, coma/cerebro-vascular accident/convulsion, nerve injuries, transfusion mismatch, suspected myocardial infarction/ischemia, cardiac arrest, death, suspected malignant hyperthermia, anaphylaxis, drug error, equipment malfunction and cardiac arrhythmia requiring treatment. The surgical profiles, anesthesia profiles and a narrative of incidents were also recorded. Details of the present study methodology have been described [10].

The registered data of non-hypoxic bradycardia in patients whose age was  $\leq 15$  years old were included in this study. The definition of bradycardia in each age group are heart rate less than 100, 80 and 60 beats per min in pediatric patients whose ages ranged between 0-1 year, 1-8 years and 8-15 years, respectively. The descriptive statistics (frequency and

percentage) were used to analyze data using SPSS for Windows, version 12.

## Results

There were 49 incident reports of non-hypoxic bradycardia in pediatric patients according to the definition of this study. The characteristics of these patients are shown in **Table 1**. Most patients were in the 1-8 year group (60%), generally healthy according to the American Society of Anesthesiologists Physical Status (ASA PS) 1-2 (74%) and undergoing elective surgery (78%). The anesthetic of choice was mainly general anesthesia alone (94%). Pulse oximetry was used in all cases, while electrocardiography (ECG), noninvasive blood pressure (NIBP), airway pressure, capnometry (EtCO<sub>2</sub>) and body temperature were monitored during anesthesia in 98%, 96%, 74%, 67% and 25% levels, respectively. All bradycardia events were not premedicated with atropine. The outcome of all patients was complete recovery.

We categorized factors related to bradycardia into four categories: patient, surgical, anesthetic and management factor. The major factors relating to the bradycardia included anesthetic factors (35 out of 49 cases; 71%), surgical factors (9 out of 49 cases; 19%) and patient factors (5 out of 49 cases; 10%), respectively (**Table 2**). There was no bradycardia case relating to a management problem.

Bradycardia was a frequent occurrence during the induction phase of anesthesia (30 out of 49 patients; 60%) (**Table 3**). Twenty-four out of thirty patients were associated with an anesthetic cause alone. Three out of thirty incidents were due to a combination of anesthetic cause and patient's condition. Two out of thirty incidents were associated with patient's condition only and we could not find the cause of bradycardia in one patient. During the maintenance phase, the majority of cases were associated with surgical causes (60%). Twenty-seven percent were associated with an anesthetic cause and two cases were due to an unknown cause. There were four patients who developed bradycardia in the emergence and recovery periods.

**Figure 1** shows surgery specialties related to bradycardia. Ophthalmologic surgery was the most common surgery during which bradycardia occurred. The others were general and orthopedic surgery. As shown in **Table 3** eye surgery was also the commonest area associated with surgery-related bradycardia.

**Table 1.** Demographic and anesthetic characteristics of pediatric patients in non-hypoxic bradycardia cases.

Characteristics	Number (%)
<i>Age</i>	
0-1 year	9 (19)
1-8 years	30 (60)
8-15 years	10 (21)
<i>American Society of Anesthesiologists Physical Status (ASA PS)</i>	
I	18 (37)
II	19 (39)
III	10 (20)
IV	2 (4)
<i>Emergency state</i>	
Emergency case	11 (22)
Elective case	38 (78)
<i>Anesthetic technique</i>	
General anesthesia	46 (94)
Spinal	2 (4)
General anesthesia + caudal block	1 (2)
<i>Monitoring</i>	
Pulse oximeter	49 (100)
Electrocardiography (EKG)	48 (98)
Noninvasive blood pressure (NIBP)	47 (96)
Airway pressure	36 (74)
Capnometry (EtCO <sub>2</sub> )	33 (67)
Body temperature	12 (25)

**Table 2.** Causes of bradycardia classified by each phase of anesthesia.

	Induction period	Maintenance period	Emergence and recovery period	Total
Anesthetic cause	24	4	3	31
Anesthetic and patient condition	3	0	0	3
Patient condition	2	0	0	2
Surgical cause	0	9	0	9
Unknown cause	1	2	1	4
<b>Total</b>	<b>30</b>	<b>15</b>	<b>4</b>	<b>49</b>

**Table 3.** Surgical specialties and bradycardia related to surgical factors.

Surgical specialties	Bradycardia related to surgical factors, n (%)	Total cases, n (%)
Ophthalmologic surgery	4 (40)	10 (20.4)
General surgery	1 (10)	9 (18.4)
Orthopedic surgery	0	9 (18.4)
Ear-nose-throat surgery	1 (10)	7 (14.3)
Cardiac surgery	2 (20)	5 (10.2)
Diagnostic procedure	0	3 (6.1)
Endoscopy	0	2 (4.1)
Plastic surgery	1 (10)	1 (2)
Obstetric surgery	0	1 (2)
Thoracic surgery	0	1 (2)
Urologic surgery	0	1 (2)
<b>Total</b>	<b>9 (100)</b>	<b>49 (100)</b>

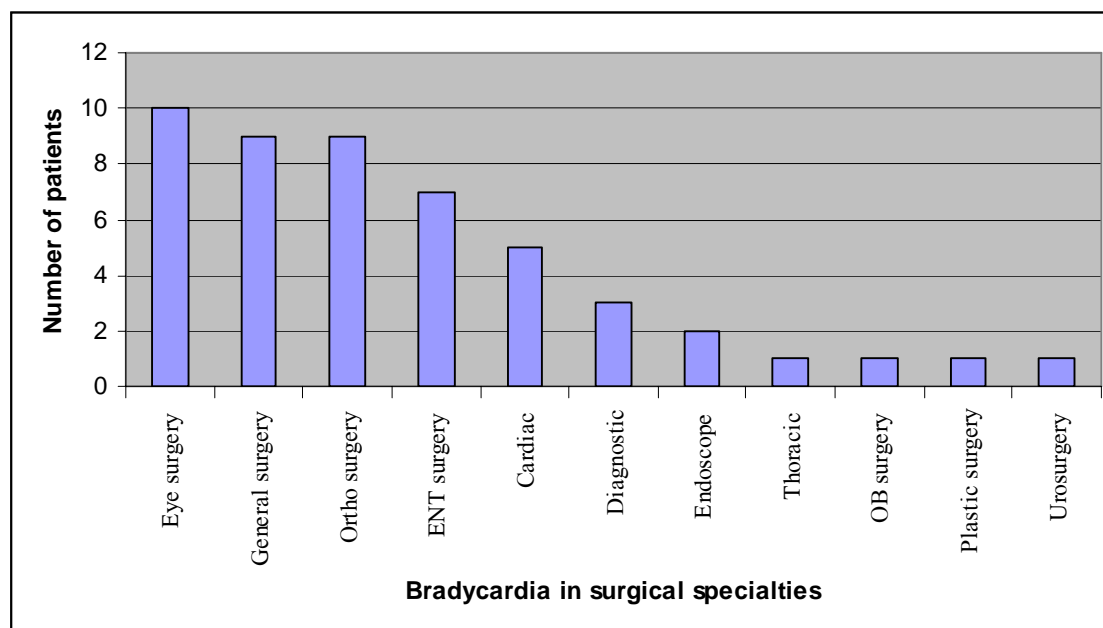


Fig. 1 Surgical specialties related to non-hypoxia-related bradycardia.

Sixty-three percent of bradycardia events were preventable (Table 4). The preventable cases were attributed to human error (59%) and lack of knowledge base (55%). Only four percent were related to skill and rule base respectively. According to the anesthetic personnel who attended the cases and site managers, the contributing factors mainly were lack of knowledge

and inappropriate decision as shown in Table 5. The factors that might have decreased the incidents were previous experience (61%), high vigilance (49%) and improved training (33%). The suggestion of preventive strategies was improvement of supervision and additional training (59%) and quality assurance activity (53%).

Table 4. Preventability of bradycardia related to each contributing factor.

Contributing factor	Preventable number (%)	Unpreventable number (%)	Total number (%)
<i>Anesthetic factor</i>	26 (74)	9 (26)	35 (100)
<i>Surgical factor</i>	1 (11)	8 (89)	9 (100)
<i>Patient factor</i>	4 (80)	1 (20)	5 (100)
<b>Total</b>	31 (63)	18 (37)	49 (100)

Table 5. Contributing factors of bradycardia and the strategies for minimizing and preventing the incidences.

Incidence of bradycardia	Number (% of 49 cases)
<b>Contributing factors</b>	
Lack of adequate knowledge and inappropriate decision	27 (55)
Inexperience	11 (22)
<b>Factors minimizing incidents</b>	
Previous experience	30 (61)
High vigilance	24 (49)
Improved training	16 (33)
<b>Suggested preventive strategies</b>	
Improved supervision	29 (59)
Additional training	29 (59)
Quality-assurance activity	26 (53)

## Discussion

Perioperative bradycardia incidences in this study were 49 out of 1996 incident reports (2.4%) or 49 out of all 364 pediatric patient records reviewed (13.4%). Children between 1 to 8 years old were the highest risk group. These results agreed with Cohen's report [11] in 1990, the most frequent problems in age 1 to 10 years were arrhythmia while neonates had the highest rate of respiratory problems [11]. This study excluded hypoxia-related bradycardia [11]. The incidences among the infant group were thus lower.

There were many factors that increased the risk of bradycardia during the perioperative period. In this study, bradycardia occurred most frequently in the induction phase of anesthesia (30 out of 49 cases; 60%). Anesthesia was the major cause of these incidents (24 out of 30 cases; 80%), and all these anesthesia-related bradycardia events had medical causes. During all phases of anesthesia various drugs that related to bradycardia were used. First, sevoflurane is a major agent for inhalation induction at present because it provides a pleasant odor, rapid induction, no irritation to the airway. When comparing sevoflurane to halothane, it cause not only less hemodynamic depression but also fewer incidences of bradycardia [12-14]. However bradycardia was not absent. Green et al. [15] compared inhalation induction with sevoflurane in unpremedicated infants by using a high concentration technique and incremental dose. They found that seven patients developed bradycardia after a nodal rhythm and the onset of nodal rhythm would come earlier in the high concentration group. Although the patients were premedicated with atropine, bradycardia still occurred. Sigston et al. [4] demonstrated rapid induction with 8% sevoflurane in atropine premedicated pediatric patients (age: three months to three years) with an incidence of bradycardia of 8% (2 out of 25 cases). They had to reduce the inspired vapor concentration to 50% when there was clinical hypoventilation. Anesthetic personnel should induce anesthesia with high vigilance for bradycardia. ECG monitoring should be done in all infants and small children, and the concentration of the inhalation agents should be reduced when clinical hypoventilation occurred.

Second, succinylcholine-induced bradycardia was reported as self-limited to asystole [4, 16, 17]. Administration of succinylcholine with caution may decrease such incidences. On the contrary, Fleming

et al. [18] reported no bradycardia during intubation in 20 children with only thiopental and succinylcholine. No inhalation agent or narcotics and no atropine were used. Third, propofol alone or combined with other drugs such as succinylcholine and fentanyl were associated with bradycardia as well [16, 19]. During attempted intubation, vagal reflex was stimulated by laryngoscopy and by insufficient anesthesia [18, 20]. A combination of the various drugs mentioned above was used during induction in all cases. This might explain the high incidence in this study.

The maintenance period of anesthesia took the second highest incidence (15 out of 49 cases; 30%). Sixty percent of the incidents were related to the surgical factor. Doyle et al. [20] observed that reflex bradycardia occurred in various types of surgery. Bradycardia due to the oculocardiac reflex was most common in our study (40%). This reflex is stimulated by traction or pressure on the globe, orbital contents, or extra-ocular muscles [21]. This stimulus triggers electrical impulses into the afferent arm via parasympathetic fibers in the ciliary nerves and the ophthalmic nerve from the Gasserian ganglion. The impulse runs to the spinal tract of the trigeminal nerve and travels along the vagus nerve in the efferent arm. The reflex is greatly exaggerated in the presence of hypoventilation, hypoxemia and acidosis. The reflex is important and may lead to cardiac arrest during eye surgery [22]. In general abdominal surgery, bradycardia may result from manipulation of the intra-abdominal contents or retraction of the wound edges [20]. In the emergence and recovery period anesthesia-related bradycardia still plays the major part in the incidences in this study. Bhananker *et al.* [23] found that medical related cardiac arrest accounted for 18% (35/193) such as sevoflurane (3%) and neostigmine combined with an appropriate dose in the glycopyrrolate (1%).

Tay et al. [3] reported critical incidences of pediatric anesthesia and showed that cardiovascular events accounted for 10.8% (32 out of 297 cases). The incidence of arrhythmia was 2% (6 out of 297 cases) which included two cases of bradycardia. The incidence was lower in our cases (0.67% VS. 2.5%). Their study did not state whether or not the children were premedicated with atropine.

Watterson et al. [6] showed that most common causes of bradycardia were medication-related (28%), others were airway problems (16%) and autonomic reflexes (14%). These results were similar to this

study. The major contributing factor to bradycardia in our study was anesthesia or medical-related (35 out of 49 cases 71%). The surgical and patient factors were less common. Eighty-nine percent of the surgery-related bradycardia was considered to be unpreventable, while seventy-four percent of the anesthesia-related bradycardia was preventable. Insufficient knowledge and inappropriate decision by anesthetic personnel were the major contributing factors of bradycardia in this study. Previous experience of the anesthetic personnel and being highly vigilant during anesthesia might decrease the incidence. Bradycardia during the perioperative period could be prevented by improving supervision especially during the induction phase of infants and small children. Additional training and effective quality assurance would provide further education and motivate the anesthetic personnel to continue learning at the workplace [24].

### Conclusion

Most of the incidents of perioperative non-hypoxic bradycardia were anesthesia-related and frequently occurred during the induction phase. They were the result of a combination of bradycardia-related drugs. Lack of knowledge and inappropriate decision were the major contributing factors of bradycardia in this study. Improving supervision, additional training and being highly vigilant especially during the induction phase of all infants and small children are corrective strategies.

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