Original Article

Perioperative and Anesthetic Adverse Events in Thailand (PAAd Thai) Study Database: Neuroanesthesia

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Background: The incident report in neurosurgical anesthesia was part of the Perioperative and Anesthetic Adverse Events in Thailand Study (PAAd Thai) of the Royal College of Anesthesiologists of Thailand in 2015. There were scarce reports of perioperative anesthetic adverse events in neurosurgical cases.

Objective: To investigate anesthetic complications and causes, and contributing factors including corrective strategies for the prevention of adverse events in neurosurgical cases.

Materials and Methods: A prospective descriptive study was conducted in 22 hospitals across Thailand. Perianesthetic adverse incidents were reported by a standardized incident report form during 12 months period (between January and December 2015). Adverse events of neurosurgical cases were reviewed to demonstrate the causes. Descriptive statistics were used.

Results: Among the first 2,000 incident reports from the PAAd Thai study, 228 critical incidents from the 157 incident report forms of neurosurgical cases were reported. The incidents commonly occurred in male patients (56.0%). The major age range was 40 to 70 years. The common adverse events included cardiac arrest within 24 hours (36.3%), death (33.1%), reintubation (15.3%), desaturation (10.8%), severe arrhythmia (10.2%), and difficult intubation (6.4%). Anesthesia was considered as part of the contributing factors in 70 reports while it was considered as the sole factor in 26 reports.

Conclusion: Cardiac arrests, death, and reintubation were common incidents in neurosurgical anesthesia. Common factors contributing to the incidents were inexperience, severe increased intracranial pressure, inadequate preanesthetic evaluation, emergency condition, inappropriate decision, and communication. Factors minimizing the incidents were vigilance, having experience, experienced assistant, improvement of training, comply to practice guidelines, and effective communication. Suggested corrective strategies were quality assurance activity, improvement of supervision, additional training, improvement of communication, compliance with guidelines, and more equipment.

Keywords: Adverse events, Anesthesia, Multicentered study, Incident report, Neuroanesthesia

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Neurosurgical anesthesia posed a high incidence of perioperative complications. The operative site ranked third for the occurrence of anesthetic incidents in The Multicentered Study of Model of Anesthesia Related Adverse Events in Thailand by Incidence Report (the Thai Anesthesia Incidents Monitoring Study [Thai AIMS] in 2008[(1)] and the Perioperative and Anesthetic Adverse Events in Thailand Study [PAAd Thai] in 2017[(2)]). There were scarce reports of perioperative complications in neurosurgical anesthesia. Manninen et al reported 54.5% of early postoperative complications within

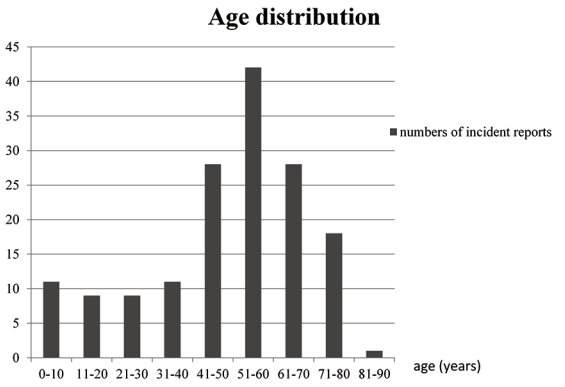

Figure 1. Age distribution of patients in 157 incident reports.

four hours following neurosurgical procedures[3]. However, the reported complications included non-serious complications such as nausea and vomiting. Other reports in neurosurgical anesthesia focused on intraoperative anesthetic complications in specific procedures such as pediatric neurosurgery[4,5], functional neurosurgery[6], awake craniotomies for epilepsy surgery[7], deep brain stimulation surgery[8], intracranial neuroendoscopic procedures[9], endovascular neurosurgery[10], and surgery in the sitting position[11]. Cardiovascular complications such as hypertension, hypotension, and arrhythmias were the common reported events in these studies. Surgical interventions causing hemorrhage or vascular occlusion leading to neurological deterioration were other common events. Three studies reported intraoperative venous air embolism[4,8,11].

The present study was the prospective study of specific anesthesia-related adverse events detected during neurosurgical anesthesia up to 24 hours postoperative period. The aim of the present study was to investigate the incidents and causes of perioperative adverse events in neurosurgical anesthesia and contributing factors, factors minimizing outcomes, and suggested strategies to avoid those specific adverse events.

Materials and Methods

The present multicentered study was part of the PAAd Thai study conducted in 22 participating hospitals by the Royal College of Anesthesiologist of Thailand (RCAT) between January and December 2015. The specific critical incidents were reported in a standardized incident report form. The study was approved by each institutional ethics committee. Informed consent was exempted because the present study retrospectively analyzed the data without patient intervention. The reported events included pulmonary aspiration, suspected pulmonary embolism, esophageal intubation, endobronchial intubation, oxygen desaturation (less than 85% or less than 90% for more than 3 minute), reintubation, difficult intubation (more than 3 times or more than 10 minute), failed intubation, total spinal block, awareness during general anesthesia, coma or cerebrovascular accident (CVA) or convulsion, nerve injury, transfusion mismatch, suspected myocardial infarction or ischemia, severe arrhythmias (such as atrial fibrillation with rapid ventricular response, second or third degree atrioventricular block, ventricular tachycardia, ventricular fibrillation, bradycardia of less than 40 beats/minute), cardiac arrest, death (all causes), suspected malignant hyperthermia, anaphylaxis or anaphylactoid reaction or allergy, drug error, equipment malfunction or failure, suspected emergence delirium, wrong patient or site or surgery. Oxygen desaturation in the present study was defined as SpO_2 below 90% for more than 3 minute or once below 85% as detected by the pulse oximetry. The narrative description included anesthesia profiles, surgical profiles, and the incidents. Details of the present study methodology have been described previously[12]. All incident record forms were verified by the site manager and sent to the data management unit at the Faculty of Medicine, Chulalongkorn University.

Data of all neurosurgical patients from the first 2,000 reports were reviewed by three neuroanesthesiologists for completion and identifying mechanisms, contributory factors, factors minimizing incident, and suggested corrective strategies. Any controversy was discussed to achieve a consensus[12]. Descriptive statistics used for analysis were determined using IBM SPSS Statistics for Windows, version 22 (IBM Corp., Armonk, NY, USA).

Results

There were 228 critical incidents from the 157 incident report forms. The age of patients reported varied from 1 month to 81 years. Age distribution is shown in Figure 1. The male: female gender ratio was 88:69 (56.05%:43.95%). The distribution of the American Society of Anesthesiologists Physical Status (ASA PS) classification of the neurosurgical patients is shown in Figure 2. The critical incidents classified by the perioperative period were reported into four categories, which were cardiovascular,

Table 1. Critical incidents classified by perioperative periods for 157 incident reports

Complications	Intraoperative n (%)	PACU n (%)	Postoperative within 24 hours n (%)	Total n (%)
Cardiovascular				
Cardiac arrest	17 (10.8)	-	40 (25.5)	57 (36.3)
Death	3 (1.9)	-	49 (31.2)	52 (33.1)
Severe arrhythmia	14 (8.9)	1 (0.6)	1 (0.6)	16 (10.2)
Suspected MI	5 (3.2)	-	1 (0.6)	6 (3.8)
Respiratory				
Reintubation	2 (1.3)	11 (7.9)	11 (7.0)	24 (15.3)
Desaturation	11 (7.0)	5 (3.2)	1 (0.6)	17 (10.8)
Difficult intubation	10 (6.4)	-	-	10 (6.4)
Failed intubation	3 (1.9)	-	-	3 (1.9)
Esophageal intubation	3 (1.9)	-	-	3 (1.9)
Endobronchial intubation	1 (0.6)	-	-	1 (0.6)
Pulmonary embolism	1 (0.6)	-	1 (0.6)	2 (1.3)
Neurologic				
Convulsion	-	2 (1.3)	7 (4.5)	9 (5.7)
Coma/CVA	-	1 (0.6)	3 (1.9)	4 (2.5)
Suspected emergence delirium	1 (0.6)	2 (1.3)	-	3 (1.9)
Miscellaneous				
Anaphylaxis/allergy	7 (4.5)	-	-	7 (4.5)
Drug error	7 (4.5)	-	-	7 (4.5)
Equipment malfunction	5 (3.2)	-	-	5 (3.2)
Nerve injuries	-	-	1 (0.6)	1 (0.6)
Wrong site	1 (0.6)	-	-	1 (0.6)

PACU=postanesthesia care unit; MI=myocardial infarction; CVA=cerebrovascular accident
Data were not mutually exclusive

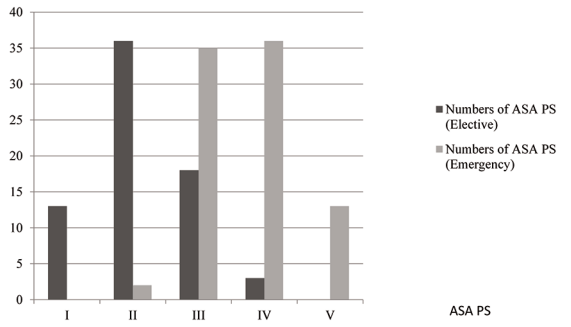

Figure 2. American Society of Anesthesiologists Physical Status (ASA PS) classification of patients in 157 incident reports.

respiratory, neurologic, and miscellaneous. The three most common critical incidents were 57 cardiac arrests, 52 deaths, and 24 reintubations. The three most common cardiovascular critical incidents were cardiac arrest, death, and severe arrhythmia. The three most common respiratory critical incidents were reintubation, desaturation, and difficult intubation. The most common neurologic critical incident was convulsion. Detail of adverse events is shown in Table 1.

The 57 cardiac arrest cases resulted in 44 deaths. Fifty-two cardiac arrest cases (91.23%) were neurosurgical related, i.e., 33 cases (57.89%) of severe increased intracranial pressure (ICP), 16 cases (28.1%) of intraoperative bleeding, and three cases (5.26%) of surgical complications (postoperative hemorrhage and convulsion) (Table 2).

There were eight cases of postoperative death without reported arrest, which were four cases of severe traumatic brain injury (TBI), three cases of intracranial hemorrhage (ICH), and one case of subarachnoid hemorrhage (SAH).

There were 16 cases of severe arrhythmias. The

Table 2. Possible causes of cardiac arrest and death

Causes	Cardiac arrest (n=57) n (%)	Death (n=52) n (%)
Severe increased ICP		
TBI	14 (24.6)	18 (34.6)
ICH	10 (17.5)	11 (21.2)
SAH	5 (8.8)	6 (11.5)
Others	4 (7.0)	4 (7.7)
Massive bleeding	16 (28.1)	10 (19.2)
Surgical complications	3 (5.3)	2 (3.9)
Respiratory problems	1 (1.8)	-
Pulmonary embolism	1 (1.8)	-
Cardiovascular problems	2 (3.5)	1 (1.9)
Sepsis	1 (1.8)	-

ICP=intracranial pressure; TBI=traumatic brain injury; ICH=intracranial hemorrhage; SAH=subarachnoid hemorrhage

most common cause was severe increased ICP in five cases (31.25%). The other causes were medications in three cases (18.75%), hypovolemia in two cases (12.5%), respiratory problems in two cases (12.5%), inadequate anesthesia in two cases (12.5%), cardiac disease in one case (6.25%), and stress induced cardiomyopathy in one case (6.25%) (Table 3).

There were 24 cases of reintubation. The causes of reintubation were convulsions in seven cases (29.17%), surgical complications in seven cases (29.17%), residual anesthetics agents in seven cases (29.17%), and respiratory problems in three cases (12.5%) (Table 3).

There were 17 cases of desaturation. The causes of desaturation were malposition of endotracheal tube in five cases (29.41%), severe hypotension from intraoperative bleeding in three cases (17.65%), residual anesthetic agents in three cases (17.65%), and pulmonary edema in two cases (11.76%). The causes of the other four cases were difficult intubation, equipment malfunction (vaporizer malposition), human error (negligence in turning on a ventilator), and patient factor (apnea of newborn) (Table 3). There were 10 cases of difficult intubation that resulted in three cases of failed intubation. Two of these three cases resulted in cancellation of surgery and one case resulted in tracheostomy.

The neurologic complications were convulsion, coma and emergence delirium (Table 1). Nine cases of convulsion resulted in seven cases of reintubation. There were four cases of coma and three cases of suspected emergence delirium.

Table 3. Possible causes of severe arrhythmias (n=16), reintubation (n=24), desaturation (n=17)

Causes of severe arrhythmias (n=16)	n (%)
Severe increased ICP	5 (31.3)
Medications (anesthetic agents 1 case, drug error 2 cases)	3 (18.8)
Hypovolemia	2 (12.5)
Respiratory problems (airway obstruction and accidental extubation)	2 (12.5)
Inadequate anesthesia	2 (12.5)
Cardiac diseases (post mitral valve replacement)	1 (6.3)
Stress induced cardiomyopathy	1 (6.3)
Causes of reintubation (n=24)	
Convulsion	7 (29.2)
Residual anesthetic agents	7 (29.2)
Surgical related	
Hematoma	3 (12.5)
Brain edema	1 (4.2)
Injury to cranial nerve	3 (12.5)
Respiratory problems	
Endotracheal tube problems	1 (4.2)
Pulmonary edema	1 (4.2)
Bronchospasm	1 (4.2)
Causes of desaturation (n=17)	
Malposition of endotracheal tube	5 (29.4)
Severe hypotension	3 (17.6)
Inappropriate extubation	3 (17.6)
Pulmonary edema	2 (11.8)
Difficult intubation	1 (5.9)
Equipment malfunction	1 (5.9)
Human error (negligence in turning on a ventilator)	1 (5.9)
Patient (new born apnea)	1 (5.9)

ICP=intracranial pressure

The miscellaneous complications were allergy or anaphylaxis in seven cases, drug error in seven cases, equipment malfunction in five cases, nerve injury in one case, and wrong site operation in one case) (Table 1).

Anesthetic factors were involved in the causes of the incidents for 70 reports while anesthetic factors were the sole causes in 26 reports. Patient factors were the other common causes of the incidents as there were 59 reports resulting from the sole patient factors.

Immediate outcomes were complete recovery in 30 cases (19.1%), cardiac arrest in 57 cases (36.3%), and death in 52 cases (33.1%). Long-term (7-day) outcomes were complete recovery in 54 cases

Table 4. Immediate and long-term (7-day) outcomes for 157 incident reports

Immediate outcomes	n (%)
Complete recovery	30 (19.1)
Cardiac arrest	57 (36.3)
Death	52 (33.1)
Cancellation/postponement of surgery	8 (5.1)
Major physiological change	
Respiratory	29 (18.5)
Cardiovascular	13 (8.3)
Neurological	6 (3.8)
Unplanned intensive care unit admission	1 (0.6)
Minor physiological change	2 (1.3)
None	20 (12.7)
Other	
Dental injury	1 (0.6)
Wrong side	2 (1.3)
Skin rash	2 (1.3)
Long-term (7-day) outcomes	
Complete recovery	54 (34.4)
Death	52 (33.1)
Prolonged hospital stay	6 (3.8)
Prolonged ventilator support	8 (5.1)
Disability	3 (1.9)
None	26 (16.6)

(34.4%), death in 52 cases (33.1%), and none in 26 cases (16.6%) (Table 4).

Common factors contributing to the incidents were inexperience, patients' condition (severe increased ICP), emergency condition, inadequate preoperative evaluation, inappropriate decision, and communication (Table 5). Factors minimizing the incidents were vigilance, having experience, none (because of patients' conditions), experience assistant, improvement of training, and compliance to the guideline (Table 5). Suggested corrective strategies for prevention of occurrence of incidents were quality assurance activity, improvement of supervision, none, additional training, improvement of communication, and compliance with guidelines (Table 5).

Discussion

The present study focused on the perioperative adverse outcomes in neurosurgical anesthesia reported in the PAAd Thai study. There were 157 reports of 228 incidents in neurosurgical anesthesia from the first 2,000 reports in the PAAd Thai study, which ranked

Table 5. Factors contributing to, minimizing and suggested corrective strategy for prevention of occurrence the incidents (n=157 incident reports)

Contributing factors	n (%)
Inappropriate decision	30 (19.1)
Inadequate knowledge	7 (4.5)
Inexperience	48 (30.6)
Haste	9 (5.7)
Communication	12 (7.6)
Not familiar with environment	1 (0.6)
Emergency condition	40 (25.5)
Inadequate preanesthetic evaluation	42 (26.8)
Inadequate preanesthetic preparation	5 (3.2)
Inadequate equipment	1 (0.6)
Inefficient equipment/monitoring	2 (1.3)
Monitor not available	1 (0.6)
Error in drug label	2 (1.3)
No ICU	3 (1.9)
Blood bank problems	3 (1.9)
Patients' condition	
Airway anatomy	4 (2.6)
Severe increased intracranial pressure	47 (29.9)
Factors minimizing the incidents	
Having experience	64 (40.8)
Experienced assistant	26 (16.6)
Vigilance	100 (64)
Effective supervision	6 (3.9)
Effective communication	14 (8.9)
Improvement of training	18 (11.5)
Adequate equipment	8 (5.1)
Adequate maintenance	3 (1.9)
Equipment check up	4 (2.6)
Adequate monitoring equipment	1 (0.6)
Comply to practice guidelines	16 (10.2)
Blood bank	3 (1.9)
ICU	3 (1.9)
Suggested corrective strategies	
Compliance with guidelines	21 (13.4)
Additional training	33 (21.0)
Improvement of supervision	47 (29.9)
Improvement of communication	22 (14.0)
More equipment	10 (6.4)
Equipment maintenance	5 (3.2)
Quality assurance activity	87 (55.5)
Good referral system	1 (0.6)
ICU	3 (1.9)
Blood bank	3 (1.9)

ICU=intensive care unit

the neurosurgical site as the third common site for the occurrence of anesthetic incidents. In 1999, Manninen et al reported early postoperative complications following 431 neurosurgical procedures to be 54.5%, which was higher than that in the general surgical population[3]. The complications reported in Manninen's study were respiratory problems (2.8%), trauma to the airway (4.4%), cardiovascular (6.7%), neurological complications (5.7%), and nausea and/or vomiting (38%). These two studies cannot be compared because Manninen et al[3] included the non-serious complications (nausea or vomiting) and the study period was only within four hours after surgery. In contrast, the present study reported only the critical incidents and the study period started from the intraoperative until 24 hours postoperative period.

While males are predominating in the trauma situation and many incident reports were from the traumatic patients. Therefore, there were more males than females in the present study. The major age distributions were in the range of 40 to 70 years with the peak in the 50 to 60 years old. The reason is that the age prevalence of some diseases, such as hypertensive intracranial hemorrhage and subarachnoid hemorrhage usually occur in this middle age group. Another demographic characteristic was that the incidents occurred in the emergency situations more than in the elective cases. Because the neurosurgical patients that required emergency operations were high risk patients with preexisting poor conditions, higher perioperative adverse events were reported in these patients.

Fifty-seven and 52 cases of cardiac arrest and death within 24 hours were reported from the 504 and 404 cardiac arrest and death within 24 hours cases from the first 2,000 incident reports in the PAAd Thai study. Two major causes of these high critical incidents of cardiac arrest were severe increased ICP (33 cases) and intraoperative bleeding (16 cases). Charuluxananun et al reported TBI was the second causes of death in the Thai Anesthesia Incidents Study (THAI Study)[13]. Martins et al reported 33.3% mortality of severe TBI in Brazilian patients[14] in contrast to 26.4% in a Swiss level one trauma center[15] and 13% in New York State[16]. Therefore, the prevention of the accidents in accordance with the protocol management of increased ICP would be the best way to decrease this high mortality rate[12,17]. Proper control of hypertension is another strategy to decrease the incidence of ICH in the hypertensive patients. Surgical bleeding were the major causes of cardiac arrest in six cases that included five cases of brain tumors and one case of SAH). The other 10 bleeding cases with cardiac arrest were the combination of bleeding, increased ICP, and coagulopathy. Severe hypotension can occur when ICP suddenly decreased during opening the bone flap in the patients with high ICP. This hypotension combined with severe hypovolemia from bleeding can result in cardiac arrest. Blood bank problems were another cause of delayed resuscitation resulting in two cases of cardiac arrest. Therefore, preoperative and intraoperative evaluation and preparation for intraoperative blood loss, improvement of surgical skill, and meticulous monitoring of blood pressure and bleeding should be done during craniotomy to prevent cardiac arrest from massive bleeding. The other common cardiovascular incident was severe arrhythmias. The causes of severe arrhythmia were patients' factors (increased ICP, stress induced cardiomyopathy, and cardiac disease), anesthetic factors (medications or inadequate anesthesia), or the combination of both factors (hypovolemia or respiratory problems). These severe arrhythmias were severe bradycardia and tachycardia (supraventricular tachycardia, atrial fibrillation with rapid ventricular response, and ventricular tachycardia). All cases needed medical treatment except two cases from respiratory problems, which were managed by reintubation.

Respiratory complications included reintubation, oxygen desaturation, and difficult intubation. Three main causes of reintubation were convulsion, residual anesthetic agents, and surgical complications. This compared to residual anesthetic agents, airway obstruction, and unstable hemodynamics shown in the THAI Study[18], and hypoventilation, airway obstruction, and respiratory failure in the Thai AIMS Study[19]. Seven cases of convulsion leaded to reintubation in the present study, which four cases occurred in the 24 hours postoperative period. Another cause of reintubation was residual anesthetic agents. Premature extubation before the patients were fully awake resulted in seven cases of reintubation and three cases of oxygen desaturation. Therefore, the patients should be fully awake and follow command before the trachea tube was extubated, especially when propofol was used as a part of anesthetic agents. Surgical complications were another cause of reintubation. Three cases were due to intracranial hematoma, one case of cerebral edema, and the other three cases were due to cranial nerves or brain injury. The anesthesiologists should communicate with the neurosurgeons whether the patients could be

extubated. The patients should be closely observed for the change in neurological and respiratory status to prevent permanent neurological deficit or death.

There were 17 cases of oxygen desaturation in the present report. The three common causes were endotracheal tube malposition, severe hypotension, and residual anesthetic agents. They were upper airway obstruction, endotracheal tube problems, and inadequate ventilation in the THAI Study[20], and laryngospasm, residual anesthetic agents, and difficult intubation in the Thai AIMS Study[21]. Endotracheal tube malposition were two cases of endotracheal dislodgment, two cases of kinked endotracheal tube during prone position, and one case of endobronchial intubation. Verification for proper position of endotracheal tube is important during neurosurgical anesthesia. Endotracheal tube malposition can cause hypoxemia and hypercarbia that will significantly increase cerebral blood flow and ICP in patients with increased ICP.

Ten critical incidents in the present report were difficult intubation. There were three cases of failed intubation. Two cases resulted in postponement of surgery and one case resulted in tracheostomy. There were some specific difficult intubation cases in neurosurgical patients such as acromegaly and cervical spine diseases. Careful preoperative evaluation and preparation for airway management is important in neurosurgical patients. Hypoxemia, hypercarbia, and hypertension during airway manipulation can cause further increases in ICP in the patients with low intracranial compliance.

Convulsion, coma or CVA, and suspected emergence delirium were three neurologic complications. There was inadequate information in the present study whether those patients who developed postoperative convulsion received peri-operative prophylaxis anticonvulsant. Perioperative administration of prophylaxis anticonvulsant for craniotomies is still a controversial issue. One meta-analysis concluded that prophylaxis anticonvulsant did not improve seizure control in brain tumor surgery[22]. Another meta-analysis concluded that prophylaxis anticonvulsant showed a tendency to prevent postoperative convulsions[23]. The present study showed that seven of nine patients that developed postoperative convulsion needed reintubation, therefore, it is reasonable to administer prophylaxis anticonvulsant for patients that undergo supratentorial craniotomy to prevent seizure. There were three cases of postoperative coma or CVA. The causes were stroke in one case, surgical complications in two cases, and convulsion in one case.

Other categories of complications were anaphylaxis or allergy in seven cases, drug error in seven cases, and equipment malfunction in five cases. The causes of anaphylaxis or allergy were anesthetic agents in three cases, blood and blood component in two cases, and antibiotics in two cases. All the allergies resulted in minor consequences except for one case of antibiotic anaphylaxis that caused severe hypotension and postponement of the surgery. Human errors such as drug error, equipment malfunction, and wrong side operation were still common for perioperative complications. Routine surgical and anesthesia guideline practice will prevent or decrease these complications.

The most critical incidences in the present study occurred in general neurosurgical procedures such as hematoma from TBI or hypertensive ICH, brain tumors, and ventriculo-peritoneal shunt. However, some incidents occurred as the consequence of the progression in neurosurgical anesthesia in the past 20 years according to the advancement of neurosurgical techniques. For example, total intravenous anesthesia technique was used to facilitate some intraoperative neuromonitorings. This caused respiratory complications in anesthesiologists who were not familiar with the conditions. The occasional neuroanesthesiologists and even the expert neuroanesthesiologists should review update in neurosurgical anesthesia[24] before anesthetizing the specific or new procedures to decrease perioperative complications[2-9] as inexperience and having experience were part the factors contributing to and minimizing the incidents.

Anesthetic factors involved in the causes of the events in 70 reports (44.6%) while they were considered as the only primary causes in 26 reports. The reports caused by anesthetic factors were mostly related to airway management including intubation, extubated decision, and endotracheal tube position. The other anesthetic causes of the events were anesthetic machine problems, drug errors and venous air embolism (using pressure bag on intravenous fluid bottle). Patients' factors (68.8%) were the other major factors of the incidences as these patients presented with poor conditions. Surgical factors involved 32.2% of the reports while van Lindert et al[5] reported intraoperative complications in pediatric neurosurgery were mostly related to neurosurgical procedures (78%).

The incidences of immediate outcomes including cardiac arrest, death, and major physiological

changes, and of late outcomes within seven days including death were all higher than that reported in the PAAd Thai study[2]. Therefore, incidents in neurosurgical patients resulted in more serious insults than the overall surgical patients.

Common factors contributing to the incidents were inexperience, severe increased ICP, inadequate preoperative evaluation, emergency condition, inappropriate decision and communication. Factors minimizing the incidents were vigilance, having experience, experience assistant, improvement of training, compliance to the guideline, and effective communication. Suggested corrective strategies for prevention of occurrence of incidents were quality assurance activity, improvement of supervision, additional training, improvement of communication, compliance with guidelines, and more equipment.

There were many limitations in the present study. First, the information of the study came from the first 2,000 cases of the PAAd Thai study, therefore, the researchers did not get the total number of neurosurgical cases, so the researchers could not report the incidence of each critical events. Second, the reports were voluntary, so some data may not be reported. However, the present study provided some overview of anesthetic adverse events in neurosurgical anesthesia in Thailand, which can be decreased or prevented by many anesthetic and surgical factors already discussed. Moreover, there were other medical and non-medical strategies to prevent or decrease these incidents such as the prevention of the traffic accidents, the proper control of hypertension, the adequacy of ICU, and the efficacy of the blood bank. The national health policy should be adapted to resolve these important problems.

Conclusion

The majority of adverse events in neurosurgical anesthesia were cardiovascular and respiratory complications. Cardiac arrest and death occurred mostly in the postoperative 24 hours period, while reintubation occurred equally in both post-anesthesia care unit (PACU) and postoperative 24 hours period. Some adverse events can be prevented by the experience of both anesthesiologists and neurosurgeons, while some events should be managed by the national policy.

What is already known on this topic?

Anesthesia in neurosurgical patients is considered high-risk regarding surgery and anesthesia technique. Data of adverse events related to neuroanesthesia were scarce.

What this study adds?

Perioperative adverse events related to neuroanesthesia in Thailand are 7.8% of first 2,000 cases of the PAAd Thai database. Common critical incidents were cardiac arrest within 24 hours, death within 24 hour, and reintubation. Quality assurance activity, improvement of supervision, additional training, and improved communication were suggested strategies.

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Conflicts of interest

The authors declare no conflict of interest.

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