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Incidence and Contributing Factors of Anesthesia-Related Critical Events in Neurosurgery in a Tertiary Academic Hospital in a Developing Country: a Retrospective Study

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Abstract

Background and aim: Neurosurgery is regarded as high-risk surgery due to comorbidities of patients, urgency and complexities of procedures. Mostly, reported complications were surgical-related complications. Very few studies reported anesthesia-related complications. This study aims to determine the incidence and contributing factors of anesthesia-related complications in neurosurgical unit.

Methods: Total 12,418 patients of this retrospective study had neurosurgical procedures during 7 years (2014-2020). Every incident report would be extensively reviewed by 3 investigators to classify the contributing factors of complications together with severities and outcomes. The immediate (first 24 hours) and delayed (7 days) outcomes were recorded. The outcomes were classified as complete recovery, prolonged ventilation, prolonged hospital stay, vegetative state and death. The descriptive analysis was used for the outcome.

Results: There were 214 incidents of 184 patients per 12,418 anesthetics or 1.7%. Top five complications were lip trauma (53 events, 28.8%), difficult intubation (36 events, 19.6%), reintubation (23 events, 12.5%), dental injury (18 events, 9.8%), esophageal intubation (15 events, 8.2%). Top three contributing factors were inexperience (38.4%), inappropriate decision (17.8%) and patient factor (15.5%). Major complications such as death, cardiac arrest, stroke and convulsion were found in 23 cases, mostly related to patient factor, surgical factor and inappropriate decision. Nearly half (n=91, 44%) had complete recovery during immediate postoperative period.

Conclusion: Airway complications were the most anesthesia-related complications in neuroanesthesia and the most contributing factor was inexperienced trainee. Attention should be focused on improving in-training in airway management and developing protocols to minimize human and system errors.

Keywords: airway management, anesthesia, factor, incidence, intubation, neurosurgery

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Introduction

Neurosurgery in our hospital has provided services for many years with such various types of patients: neonate, pediatric and adult. There are many neurosurgical procedures such as craniotomy, craniectomy, spine surgery, clipping aneurysm, ventriculostomy, and others. Neurosurgical patients are at risks of neurological and systemic complications in both elective and non-elective procedures. The co-morbidities, complexities of procedures, and urgent or emergency procedures increase the risks which leads to prolonged ventilatory support, ICU stay and extended hospital stay.[1]

The common neurological complications in the postoperative period of elective and non-elective neurosurgeries include new neurological deficits, delayed cerebral ischemia, seizures and intracerebral hematoma.[1] Systemic complications include pain, nausea and vomiting, respiratory and cardiovascular insufficiency, hospital acquired infection and surgical site infection.[1,2] Due to potential physiologic changes, anesthesia is regarded as a high-risk activity.[3] For the pediatric patients, anesthesia-related complications can be divided into minor and serious complication. Minor complications such as sore throat, nausea, vomiting or lesions in oral cavity can be happened frequently but also rapid recovery. More serious complications are laryngospasm/ bronchospasm, aspiration, hypoxemia, arrhythmia or bradycardia, transfusion/medication error.[3,4] In the adult patients, perioperative anesthesia-related complications were hypo/hypertension, intubation difficulty, allergic reaction, pain, nausea and vomiting.[5] Mostly reported complication after neurosurgery were surgical related complications[2,6,7], very few studies[5,8] reported about anesthetic related complication so this topic is still needed to be explored. Previous research used the incident report to analyzed the factor that related to the incidents and the common factors related to incidents were inexperience, lack of vigilance, inadequate preanesthetic evaluation, inappropriate decision, emergency condition, inadequate supervision and ineffective communication.[5]

Critical incident reporting system can be used as a tool to detect problems, identify near miss incidents and to improve the safety and quality of anesthesia.[9] The incident reporting form can promote voluntary reporting of critical incidents in our department. Learning from critical events can improve the safety and quality of anesthesia.[2] This study aims to report the incidence of complication in neurosurgery analyze the contributing factors and related outcomes in these patients who underwent neurosurgery in a tertiary academic hospital in Thailand.

Methods

This retrospective data (1 January 2014 to 31 December 2020) from neurosurgical unit in a tertiary academic hospital in Thailand were analyzed. The development of the study met the standards of ethics in research involving human beings (COA no. si116/2020-Siriraj Institutional Review Board).

All patients submitted to elective or non-elective procedures in neurosurgical unit were included. The anesthesia related adverse

events came from department data and then every incident patient would be extensively reviewed. Exclusion criteria was incomplete data in the medical records. Patients' characteristics included in the analysis were age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA), type of operation, operative time, and anesthetic time.

Anesthesia related adverse event was defined as any event that affected the safety of the patient while under the care of anesthesiologist from preinduction period until 24 hours after discharge from the recovery room.[5] The anesthesiologist or anesthesiologist-in-training reported the immediate complication through the complication checklist and nurse anesthetists reported the complication that occurred in 24 hours after surgery during post-anesthesia visits using the same checklist. The events reported include death, cardiac arrest, coma, stroke (new event), convulsion (new event), nerve injury, suspected myocardial ischemia (changes in EKG and/or clinical suspected that and/or confirm by cardiac enzyme or echocardiogram), pulmonary aspiration, failed intubation, difficult intubation (defined as intubation ≥ 3 times by experienced anesthesiologist or more than 10 minutes), reintubation (within 24 hours after extubation), esophageal intubation, desaturation (SpO_2 below 90% for more than 3 minutes), dental injury, lip trauma, eye injury, anaphylaxis, drug error, severe hypo/hypertension, significant arrhythmia (such as atrial fibrillation with rapid ventricular response, second or third degree atrioventricular block), equipment malfunction, transfusion mismatch, awareness, respiratory insufficiency (increase CO_2 that leads to metabolic disturbance). We classified groups of complications into airway complications, respiratory complications, cardiovascular complications, neurological complications and others. Examples of complications that were classified as "others" included intravenous fluid leakage, abrasion at face in prone position, minor eye injury, accidental disconnection of arterial line or intravenous line, and so on. All the complications were reviewed in detail by three investigators to classify the contributing factors of complications together with severities and outcomes. The contributing factors reported in this work include non-compliance with surgical safety check list, inappropriate decision (for example: use the same airway equipment or same operator for several intubation attempts), inadequate knowledge (for example: delayed detection of esophageal intubation), inexperience (first-year trainee anesthetists), fatigue (on duty more than 8 hours), inadequate personnel (less than 2 anesthetic personnel for one operating room), communication defect (for example: did not give antiseizure drug), emergency condition (raised intracranial pressure which need emergency operation), inadequate preanesthetic evaluation and preparation (for example: emergency case evaluation and preparation was done by surgeon and sometimes seem inadequate), inadequate equipment/monitoring, errors in drug (label, dose, route), and blood bank problem (for example: inadequate or delayed blood or blood product availability).

The postoperative period data were divided into immediate (first 24 hours) and long term outcome (within 7 days) outcome.[8] The

following outcomes were complete recovery, prolonged ventilator, prolonged ICU stay, total hospitalization time, vegetative and death.

Sample size calculation was based on perioperative and anesthetic adverse events in Thailand8, the prospective incident report was 3,022 incidents out of 333,219 anesthetics (0.9%).

Sample size of cause of complications

$$n = \frac{z^2_{1-\frac{\alpha}{2}} p(1-p)}{d^2}$$

Proportion (p) = 0.009, Error (d) = 0.002., Alpha (α) = 0.05, Sample size = 8,566

However, due to retrospective data and underreport incidents, our neurosurgical unit provided anesthesia around 1,500 cases per year so the authors decided to review data for seven years which should cover 9,000 patients.

All analyses were performed using the SPSS18™ (SPSS Institute Inc., Chicago, IL, USA). The descriptive analysis was carried out by means±standard deviation or median (min, max) and frequencies or number (%).

Results

Between 1 January 2014 and December 2020, 12,418 patients underwent anesthesia in neurosurgical unit in a tertiary academic hospital in Thailand. From a total of 12,418 neurosurgical patients, there were 313 patients having an anesthesia-related complications. All of the patients that had complications were screened, 129 patients were excluded due to incomplete data (for example; did not note the details of events, could not open files in the database), not anesthesia-related complications and repeated reports of the same patients. So, there were 214 incidents of 184 patients included in this study. The incidence was 214 events per 12,418 anesthetics or 1.7%. Patient's flow chart demonstrating the number of patients eligible for inclusion into the study and analysis as shown in Figure 1.

The age of patient report varied from below 1 year to 103 years old. The median age was 56 years old. Seventy-nine patients (42.9%) were male. Most of patients were in ASA II (47.3%). Emergency surgery was 24 cases. Among these 184 patients were divided into intracranial surgery (71.2%), spine surgery (13.0%), and others (15.8%) such as nerve transfer, spinal cord stimulation, revise VP shunt, burr hole, etc. For the postponed case after induction, operative time will be 0 minute. All of the patient's characteristics were shown in Table 1.

Most incidents occurred during the induction phase of anesthesia (63.0%), other phases occurred within 24-hours post operative period (16.8%), during maintenance (8.7%), emergence (7.6%), recovery room (6.5%), and preinduction period (3.8%) respectively.

Information regarding to the complications was recorded in data record form and was discussed with three investigators (one senior staff who has more than 20 years of experience in neuroanesthesia) to summarize the contributing factors case by case by expert consensus. Some patients had more than one adverse event and also more than one contributing factor. There were 214 adverse events (Table 2) and the total of 258 contributing factors (Table 3).

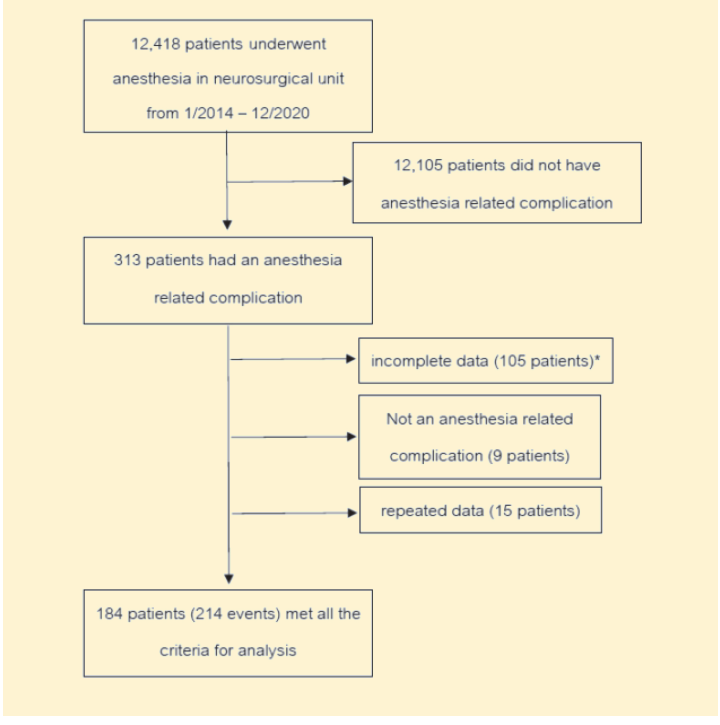


Figure 1 Patient's flowchart demonstrating the number of patients eligible for inclusion into the study and analysis. * Incomplete data: no details of events, the events classified as others.

Table 1 Patient's characteristics

Characteristics	Patients (n=184)
Gender; n (%) Male/Female	 79 (42.9)/105 (57.1)
Age (years); median (min, max)	52 (<1, 103)
ASA physical status; n (%) ASA I ASA II ASA III ASA IV	 15 (8.2) 87 (47.3) 64 (34.8) 18 (9.8)
BMI (kg/m^2); mean±SD	23.35±5.19
Elective/Emergency surgery; n (%)	160 (87.0)/24 (13.0)
Types of operation; n (%) Intracranial surgery Spine surgery Others	 131 (71.2) 24 (13.0) 29 (15.8)
Operative time (min); median (min, max)	150.0 (0, 625.0)
Anesthesia time (min); median (min, max)	232.5 (40.0, 735.0)

Data presented as number (%), mean±standard deviation (SD), or median (min, max)
ASA: American Society of Anesthesiologists, BMI: body mass index
For the postponed case at preinduction or after induction, operative time will be 0 minute.

Table 2 Adverse events within 24 hours

Types of anesthesia adverse events	Number (n=214)
Airway complications	
- Lip trauma	53 (24.8)
- Difficult intubation	36 (16.8)
- Reintubation	23 (10.7)
- Dental injury	18 (8.4)
- Esophageal intubation	15 (7.0)
Respiratory complications	
- Pulmonary aspiration	3 (1.4)
- Desaturation	9 (4.2)
- Respiratory insufficiency	2 (0.9)
Cardiovascular complications	
- Significant arrhythmia	6 (2.8)
- Suspected MI/ischemia	2 (0.9)
- Cardiac arrest	4 (1.9)
Neurological complications	
- Convulsion	7 (3.3)
- Stroke	2 (0.9)
Others	
- Anaphylaxis	4 (1.9)
- Drug error	4 (1.9)
- Awareness	1 (0.4)
- Death	10 (4.7)
- Others	15 (7.0)

Data presented as number (%), MI: Myocardial infarction

Table 3 Contributing factors of adverse events

Contributing factors	Number (n=258)
Inexperience	99 (38.4)
Inappropriate decision	38 (17.8)
Patient factor	40 (15.5)
Lack of vigilance	14 (5.4)
Surgical factor	13 (5.0)
Inadequate preanesthetic evaluation	13 (5.0)
Emergency condition	10 (3.9)
Communication defect	7 (2.7)
Others	11 (4.2)

Data presented as n (%)

Top five of complications were lip trauma (53 events, 28.8%), difficult intubation (36 events, 19.6%), reintubation (23 events, 12.5%), dental injury (18 events, 9.8%), esophageal intubation (15 events, 8.2%). All of top five complications were airway related. Airway related complication occurred more frequently compared with other complications

Top three of the contributing factor of this study were inexperience (38.4%), inappropriate decision (17.8%) and patient factor (15.5%). For other and infrequent contributing factors such as inadequate equipment/monitoring, errors in drug, inadequate personnel, not familiar with environment and fatigue were found only 1-2% each.

Inexperience was the most contributing factor for lip trauma (91.0%), difficult intubation (56.0%), dental injury (72.0%) and esophageal intubation (80.0%). Contributing factors including lip trauma, difficult intubation, dental injury, and esophageal intubation were shown in Figure 2.

Reintubation mostly related to inappropriate decision (69.6%), inadequate knowledge (21.7%), patient factors (21.7%), communication defect (17.4%), emergency condition (13%), surgical factor (13%), and inexperiences (8.7%). Contributing factors related to death, cardiac arrest, stroke and convulsion are shown in Figure 3.

The patient factor, inappropriate decision, inadequate preanesthetic evaluation, emergency condition, inadequate knowledge and lack of vigilance are major contributing factors for the respiratory complications, respectively.

We analyzed demographic data in major complications (death, cardiac arrest, stroke and convulsion) in 23 patients. The median age was 52 years old with 103 years old at maximum and 4 months at minimum. Eight patients were men and 15 patients were women. ASA classification

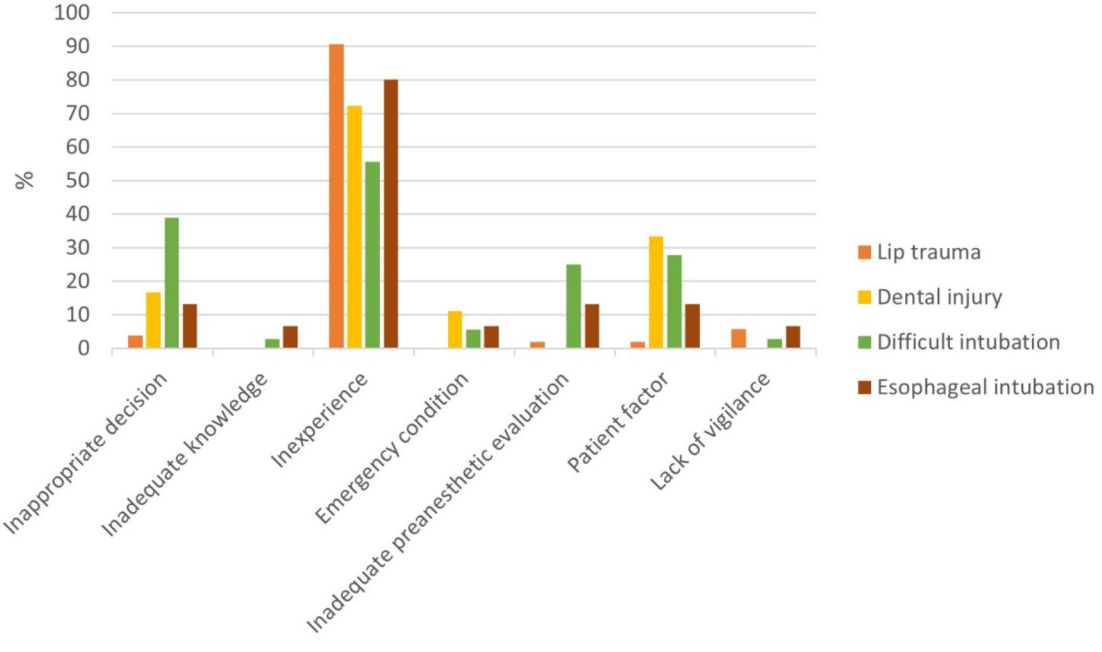
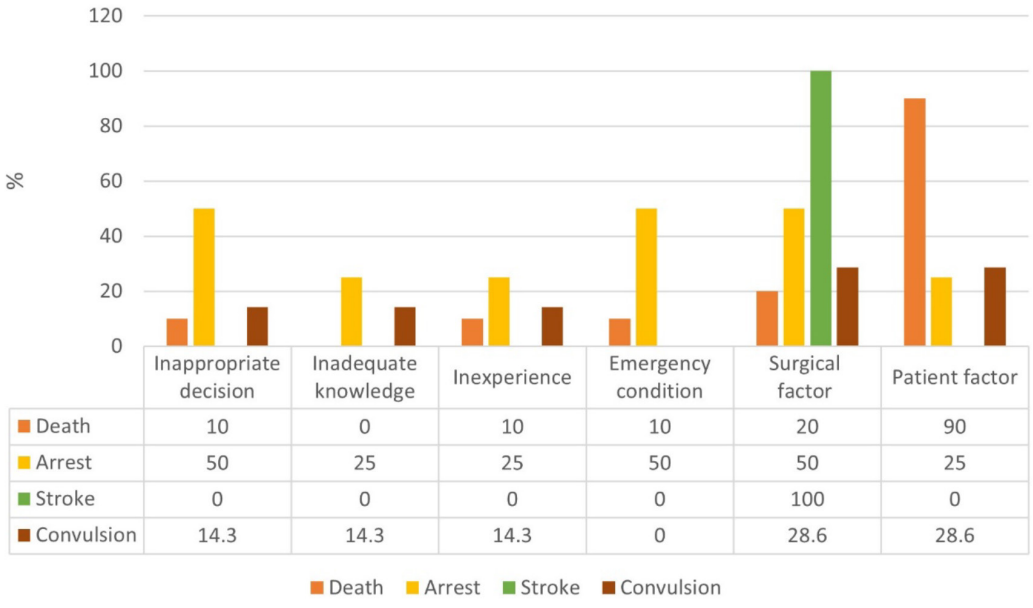


Figure 2 Contributing factors including lip trauma, dental injury, difficult intubation, and esophageal intubation



	Inappropriate decision	Inadequate knowledge	Inexperience	Emergency condition	Surgical factor	Patient factor
Death	10	0	10	10	20	90
Arrest	50	25	25	50	50	25
Stroke	0	0	0	0	100	0
Convulsion	14.3	14.3	14.3	0	28.6	28.6

Figure 3 Contributing factors including death, cardiac arrest, stroke and convulsion

was ASA II (n=9), ASA III (n=5), ASA IV (n=9) and 11 patients had emergency surgery.

The contributing factors related to death is patient factor (90%). The contributing factors for perioperative cardiac arrest were inappropriate decision (50%), emergency condition (50%), and surgical factors (50%). Communication defect regarding antiseizure was the most contributing factor associated to convulsion (57%), the other contributing factors for convulsion were surgical factors (29%), and patient factors (29%). While all patients with stroke were related to surgical factors (100%). For postoperative strokes, one was graft thrombosis and the other was brainstem infarction

Immediate and 7-day postoperative outcome

The immediate outcome included complete recovery, unplanned ICU admission, physiological change, major physiological changes (respiratory, cardiovascular, neurological), prolong emergence (failure to regain consciousness 30-60 minutes after general anesthesia), unplanned hospital admission and postpone case. The 7-day outcome included complete recovery, death, prolonged hospital stay, prolong ventilator support, disability, vegetative stage and psychic trauma.

From 184 patients who encountered adverse events, in one patient can have more than one immediate outcome, almost half of them had complete recovery in the immediate postoperative period (n=91, 44%), while some of them need postoperative intensive care as planned and unplanned ICU admission due to major physiologic changes in cardiovascular, respiratory, neurology system. Six cases, their operations were postponed as shown in Table 4.

Following postoperative day 7, the majority of (n=155, 76.4%) recovered completely, while others required a longer hospital stay (n=20, 9.9%) and prolonged use of a ventilator (n=16, 7.9%). (n=16, 7.9%). All of the cardiac arrested cases had return of spontaneous circulation and

Table 4 Immediate (24 hours) and 7-day postoperative outcome

Immediate postoperative outcome	Number
Complete recovery	91 (44.0)
Unplanned ICU admission	7 (3.4)
Minor physiologic change	40 (19.4)
Major physiologic change	68 (33.0%)
Respiratory	32 (15.5)
Cardiovascular	17 (8.3)
Neurological	19 (9.2)
Postpone case	6 (2.9)
7-day postoperative outcome	
Complete recovery	155 (76.4)
Prolonged hospital stay	20 (9.9)
Prolonged ventilatory support	16 (7.9)
Vegetative stage	1 (0.5)
Death	12 (5.9)

Data presented as number (%), ICU: intensive care unit

there were two cases end up with death in 7-day outcome and one case was in the vegetative state and only one was improved. Many patients with major physiologic changes deteriorated and dead (n=12, 5.9%) as shown in Table 4.

Discussion

There is a lot of potential risk factor associated with anesthetic related perioperative complications in neurosurgery.[5,10] However, prior to this study, the contributing factor of these perioperative complications has not been thoroughly considered.

The incidence was 214 events per 12,418 anesthetics or 1.7%, mostly occurred in induction phase. Most of the patients reported in the complications had the intracranial surgery (71.2%) and spine surgery (13.0%). In previous study, the overall postoperative complication was 13.5% with a significantly higher prevalence in intracranial surgery (22.2%) over spine surgery (11.1%)[2], the complications included blood transfusion (5%), reoperation (3.9%) and infections (pneumonia, UTI, surgical site infection). The incidences of 2 studies could not be compared because our study included only anesthesia related adverse events. Another study in anesthesia related complications in neuroanesthesia from the PAAd Thai study[5], this study collected critical events from monitoring report in one year from 22 hospitals and the critical events such as cardiac arrest (36.0%) and death (33.0%) were the most common incident reports.

Our incidents had occurred during the induction phase of anesthesia. In contrast to other studies which anesthesia related incidence occurred mostly in maintenance phase[8] and post-operative period.[9] In our case, the complications mostly were airway-related complications that occurred during induction.

Airway complications were the leading

cause of death or permanent brain damage.[11] But for this study, mostly incidence report were minor complications such as lip trauma, dental injury which can occur in any service of anesthesia and not only in neurosurgical unit. As a university teaching hospital, in the training program under supervision there will be a learning curve of trainees in airway management. Inexperience was the leading cause of minor anesthesia-related complications.

Airway management such as difficult intubation, re-intubation, esophageal intubation may lead to serious adverse outcome such as desaturation, aspiration, prolonged ventilator support.[11] Even though most of the patients were complete recovery in immediate postoperative period, these complications are preventable and can be minimized for serious adverse events. Inexperience, poor decisions, and patient factors were all common contributors to minor airway complications.

As a teaching hospital, most of trainee were inexperience and lack of knowledge. Simulation is a technique for practice which may not only reduce incidence of lip trauma and difficult intubation but also minimize the major complications.[12] Another cause of difficult intubation was inappropriate decision so careful preoperative airway evaluation and various airway management preparation are important.[13]

Twenty-three cases of reintubation were mainly inappropriate decision. Therefore, it is important to ensure that patients are fully awake, follow commands, and has adequate ventilation before the endotracheal tube is extubated.[13,14] Inadequate knowledge and communication defects were also cause of reintubation. The anesthesiologists should communicate with the neurosurgeons whether patients should remain intubated.

Avoidance of airway complications requires individual preparedness, careful assessment, good planning and judgement, good communication and teamwork, knowledge and use of techniques and devices[13] and make a decision to stop performing that technique when they are failing. Anesthesiologist play an important role about the airway management perioperatively and there is a room for research to improve understanding, prevention and management of airway complication.

In the contrast, major complications such as death, cardiac arrest, stroke, convulsion, myocardial ischemia, significant arrhythmia, severe hypo/hypertension and anaphylactic reaction happen only 15.0% of total incidences or only 0.2% of total procedures in 7 years. As a leading university and referred hospital, we take care the complicated and severe cases from all over the country. So patient factors were major factors for perioperative mortality. Many patients presented in the operating room with moribund condition. The underlying cause of death, defined as the disease or condition that started the conditions that lead to death, was reported to be the CNS tumor in 91.4% of cases.[6]

From previous study, several risk factors were identified, most of them were disease related. and preoperative physical status. Perioperative death entirely due to anesthesia was a rare situation.[6]

The incidence of anesthesia-related cardiac arrest in non-cardiac surgery patients is reported to range from 0.2-1.1 per 10,000 in adults and

from 0.4-4.6 per 10,000 in children.[15] In contrast to the study about incident report in neuro-anesthesia show that incident of cardiac arrest is 36.3% caused by severe increased intracranial pressure, intraoperative bleeding and surgical complications.[5] In our study found 4 per 12,418 patients or 3.2 per 10,000. Higher ASA and older patients are also associated with perioperative cardiac arrest.[7]

For stroke, one from graft thrombosis, so anticoagulant should be given and monitored in perioperative period in the extracranial to intracranial bypass. For the brain stem infarction, apart from surgical related factors, we should maintain adequate cerebral perfusion pressure and keep normocarbia.[16]

About the convulsion, 4 out of 7 were infratentorial tumor surgery and mostly occur in neurosurgical ICU in postoperative period. Tumors involving the frontal, temporal and parietal cortex are more epileptogenic (cortical gray matter), especially those within the eloquent areas, have a higher seizure frequency.[19] The anticonvulsant drug was given to three cases intraoperative period but four cases were not. All cases were complete recovery. The contributing factor of convulsion were communication defect, inappropriate decision, inadequate knowledge and patient factors. Anesthesiologist should discuss with surgeon whether the patient should receive prophylaxis anticonvulsant drug or not.

In our study, contributing factors of the serious complications relate to not only surgical factors, patient factors, emergency surgery but also inexperience, inappropriate decision, inadequate knowledge, inadequate pre-anesthetic evaluation and preparation and communication defect which latter group refer to human errors. The stressed anesthesiologist is prone to make more errors and if death occur intraoperatively, the greater psychological stress occurs.[17] Anesthesiologists are prone to make cognitive errors and a specific training program focusing in human factors in the operating room or simulation-based learning[18] maybe helpful to improve patient safety.[15] These emphasize that human errors are important and are needed for prevention.

There were many limitations in the present study. First, as a feature of voluntary systems, some cases may be under reported. in minor incidents, some situation may impact hesitancy to report such as minor drug error. Second, some patients may have complications more than 24 hours after surgery that would have been missed. There were some incomplete data due to no details related to the events and the events were classified as others.

Studying incidence and contributing factors of anesthesia related critical events in neurosurgery helps us to detect problems, which is crucial in minimizing their recurrence. This might improve anesthesia care and patient safety. Initiating a system of reporting and to promote the development of protocols and policies are essential to improve safety in anesthesia. Every effort should be made to reduce or avoid adverse events in our anesthetic practice.

Conclusion

The incidence of anesthesia related adverse events in neurosurgery was 1.7%. In this study, airway complications were the

most anesthesia-related complications and most contributing factor was inexperienced trainee which can happen in any service of anesthesia. Attention should still be focused on improving in training, implement of safety checklists and developing the protocols to minimize human and system error.

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