Original Article

Target-controlled Infusion Propofol Versus Sevoflurane Anaesthesia for Emergency Traumatic Brain Surgery: Comparison of the Outcomes

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Abstract

Background: **The choice of anaesthetic techniques is important for the outcome of traumatic brain injury (TBI) emergency surgery. The objective of this study was to compare patient outcomes for target-controlled infusion (TCI) of propofol and sevoflurane anaesthesia.**

Methods: ***A*** **total of 110 severe TBI patients, aged 18–60, who underwent emergency brain surgery were randomised into Group T (TCI) (*n* = 55) and Group S (sevoflurane) (*n* = 55). Anaesthesia was maintained in Group T with propofol target plasma concentration of 3–6 μg/mL and in Group S with minimum alveolar concentration (MAC) of sevoflurane 1.0–1.5. Both groups received TCI remifentanil 2–8 ng/mL for analgesia. After the surgery, patients were managed in the intensive care unit and were followed up until discharge for the outcome parameters.**

Results: **Demographic characteristics were comparable in both groups. Differences in Glasgow Outcome Scale (GOS) score at discharge were not significant between Group T and Group S (*P* = 0.25): the percentages of mortality (GOS 1) [27.3% versus 16.4%], vegetative and severe disability (GOS 2–3) [29.1% versus 41.8%] and good outcome (GOS 4–5) [43.6% versus 41.8%] were comparable in both groups. There were no significant differences in other outcome parameters.**

Conclusion: **TCI propofol and sevoflurane anaesthesia were comparable in the outcomes of TBI patients after emergency surgery.**

Keywords: *traumatic brain injury, infusion, propofol, Glasgow Outcome Scale*

Introduction

Traumatic brain injury (TBI) is one of the main causes of morbidity and mortality worldwide. Data from the United States show that an estimated 1.7 million cases of TBI occur every year that may cause severe disability and death (1). Based on the first Malaysian National Trauma Database, 42.8% of 123,916 registered trauma patients had severe TBI with a Glasgow Coma Scale (GCS) score of 3–8 on admission (2). Other local data showed that, out of 5,836 paediatric patients (aged 0–19) who were admitted to emergency departments for trauma, 742 (12.7%) suffered from brain injuries. The overall rate of childhood brain injury for that one-year period was 32 per 100,000 children, while the incidence of moderate to severe brain injury was approximately 8 per 100,000 children (3).

A good anaesthetic technique during emergency surgery for TBI is crucial for cerebral protection, preserving cerebral perfusion pressure (CPP), preventing further increases in intracranial pressure (ICP), reducing cerebral metabolic rate of oxygen consumption ($CMRO_2$) and preventing secondary insults. Furthermore, the anaesthetic technique of choice for neurosurgery should maintain or only minimally interfere with cerebral autoregulation and responsiveness to CO_2. It should also be able to maintain relaxation of the brain and provide fast, predictable recovery for early evaluation of the surgery (4). The debate between total intravenous anaesthesia (TIVA) and inhalational anaesthesia for neurosurgery with high ICP remains inconclusive.

Inhalational anaesthesia is a common anaesthetic in most surgeries, including neurosurgery. In general, inhalational agents can provide reduction of $CMRO_2$ but, on the other hand, they can also cause cerebral vasodilatation, which might subsequently lead to an increase in cerebral blood flow (CBF) and ICP. The precaution of limiting minimum alveolar concentration (MAC) of inhalational agents to the range 1.0–1.5 is very important during neurosurgery for high ICP patients in preventing further worsening of brain condition. Sevoflurane is a better inhalational agent than desflurane for intracranial surgery with intracranial hypertension because of its fewer cerebral vasodilatory effects and better haemodynamic stability (5). Sevoflurane also preserves or slightly reduces CBF, reduces $CMRO_2$ to 50% under 1 MAC and widely preserves CO_2 responsiveness. However, it produces a dose-dependent elevation in ICP and reduction in cerebrovascular resistance (CVR) (6).

TIVA is a more common anaesthetic of choice for high ICP patients because of its more favourable effects on the brain. TIVA is an anaesthesia technique that conventionally uses all drugs intravenously, particularly propofol in combination with opioids, throughout anaesthetic management. The effects of cerebral vasoconstriction, reduction of CBF, reduction of ICP and reduction of $CMRO_2$ of propofol to the brain are the basis for TIVA being preferred for emergency TBI surgery. Nowadays, TIVA can be delivered more effectively with the availability of target-controlled infusion (TCI) mode. TCI is a method of infusing drugs via a special infusion pump linked to software that uses a pharmacokinetic model to control the infusion rate of each specific drug. The only two drugs that currently have validated pharmacokinetic models in the TCI pump are propofol and remifentanil. In TCI, the drugs are delivered by setting the target plasma concentration or target effect concentration.

There have been few previous studies comparing TIVA and inhalational anaesthesia, especially during elective neurosurgery. A comparison of a propofol TCI and remifentanil combination versus a sevoflurane and remifentanil combination for maintenance of anaesthesia in elective intracranial surgery showed that more hypotensive events and requirements for rescue therapy (labetalol and ephedrine) were observed in the sevoflurane group. However, there was little difference in recovery time (7). Another study in elective supratentorial craniotomy demonstrated no benefit to using TIVA with remifentanil over balanced inhalational anaesthesia, sevoflurane-fentanyl, in terms of patients' recovery and cognitive functions (8). However, there are limited studies comparing these two techniques for emergency TBI surgery, particularly with respect to the outcomes of the patients.

The objective of the present study was to compare the outcome of TBI patients after emergency surgery under TIVA/TCI of propofol and sevoflurane anaesthesia techniques in terms of percentage of successful extubation, percentage of required tracheostomy, length of intensive care unit (ICU) and hospital stay, score on the Glasgow outcome scale (GOS) and mortality.

Material and Methods

This study was a prospective, double-blinded and randomised controlled trial, conducted after approval from the University Ethics Committee. All potential recruits were identified after the neurosurgical team posted emergency cases of either craniotomy or craniectomy for TBI. All patients were initially stabilised and resuscitated in the emergency department (ED) according to the standard management of TBI before surgery, including intubation, sedation, analgesia and haemodynamic stabilisation. Severe TBI patients with a GCS score of ≤ 8 were intubated, and sedation was started with midazolam infusion and fentanyl infusion as analgesia. An immediate CT scan of the brain was performed before any decision was made about surgical

intervention. Haemodynamic stability was maintained, aiming at mean arterial pressure (MAP) above 80 mmHg to ensure adequate CPP, and noradrenaline was started if MAP was not optimised after adequate fluid resuscitation. The ED physician was not informed about any enrolment in the study. A total of 110 patients undergoing emergency craniotomy/craniectomy for severe TBI were enrolled for the study after written informed consent was obtained from next of kin.

Subjects included in the study were aged 18–60, with American Society of Anaesthesiologist (ASA) classification of I–II and GCS of 3–8 post initial resuscitation. The exclusion criteria were polytrauma involving other major organ injuries, previous history of allergies to the study drugs, pregnancy and preoperative haemodynamic instability (such as severe hypovolaemic shock).

An independent person not involved in the study performed randomisation and allocation concealment, and patients were divided into two main groups: Group T (TCI propofol) and Group S (Sevoflurane). We used a block randomisation method, where six blocks of ballot cards that stated the four different sequences of grouping were put inside an opaque envelope. One card was randomly chosen each time to decide the group for the first four samples, and this routine was repeated until the total sample size was reached. Each sequence of allocations was numbered and subsequently concealed in the opaque envelope. The seal was broken only before surgery by the anaesthetist in charge.

The choice of anaesthetic management was blinded to the patients and their next of kin. The anaesthetist in charge of providing anaesthesia was not involved in the study, and the intraoperative assessor was blinded to the study groups. The intraoperative assessor was the second medical officer who documented all related intraoperative data collected from the first officer in charge after finishing the surgery and before transporting the patient to Neuro ICU. The anaesthesia technique given was blinded from the assessor. The first investigator, who was also blinded to the study groups, performed the post-operative and outcome assessments.

Once in the operation theatre, an electrocardiogram, pulse oximetry, capnography and non-invasive blood pressure monitoring were applied to all patients. Arterial blood pressure and central venous pressure (CVP) were monitored after induction of anaesthesia.

Group T was started with TCI of propofol using the Marsh pharmacokinetic model at 4 μg/mL. This was subsequently maintained at 3–6 μg/mL throughout the surgery. At the same time, TCI of remifentanil 2–8 ng/mL was also started.

In Group S, the patients were started with sevoflurane MAC 1–1.5, and TCI of remifentanil 2–8 ng/mL was started at the same time. IV rocuronium 0.6 mg/kg was given in both groups for muscle relaxation.

The goals of intraoperative management were to maintain systolic blood pressure (SBP) > 90 mmHg, CVP 8–12 mmHg, temperature 36 °C –37 °C, PaO_2 > 100 mmHg, $PaCO_2$ 35–40 mmHg and haematocrit 30 g/dL. Packed red blood cells and other blood products were transfused when clinically indicated. After completion of surgery, the patients were transferred to Neuro ICU with propofol infusion as sedation and fentanyl infusion as analgesia. All intraoperative complications were documented.

Neuro ICU management was standardised in all patients based on the goals of cerebral protection strategies: CPP > 60 mmHg, ICP ≤ 20 mmHg, sedation with propofol 0.5–4.0 mg/kg/h and fentanyl infusion 1–2 mcg/kg/h for 24 to 48 hours, SBP ≥ 90 mmHg and CVP 8–12 mmHg. Mechanical ventilation was strategised to maintain $PaCO_2$ 35–45 mmHg and PaO_2 > 100 mmHg. Arterial blood gas was measured hourly during surgery to monitor PaO_2 and $PaCO_2$. After cerebral resuscitation was completed, each patient was assessed for GCS. Extubations were decided when patients fulfilled the criteria, and then tracheostomy was decided if the GCS remained poor. All subsequent managements in Neuro ICU were carried out according to the standard management of Neuro ICU.

Patients' progress was followed up, and outcome parameters were recorded. The outcome parameters were percentage of successful extubation, percentage of tracheostomy requirement, length of mechanical ventilation, length of ICU and hospital stay, mortality rate and GOS at discharge. Complications in Neuro ICU were also documented.

The sample size was calculated using PS Power and Sample Size Calculations software, Version 3.0, based on a previous study by Grathwohl et al. that showed significant differences (75% versus 54%) in good neurological outcomes (GOS 4–5) between

TIVA and inhalational anaesthesia (9). With an expected improvement of 20%, power of study of 80%, alpha of 0.05 and expected dropout rate of 10%, for each group 55 samples were calculated (total samples 110).

All numerical parameters with normal distribution were presented as mean (standard deviation), and parameters that were not normally distributed were presented as median. The independent *t*-test was used for numerical data comparison between the groups, and the repeated measures analysis of variance test (ANOVA) was used for comparison of haemodynamic parameters at different time intervals. The statistical analysis was performed by SPSS version 22 software, and $P < 0.05$ was considered as a significant difference.

Results

A total of 110 patients were enrolled for this study. The demographic characteristics were not significantly different between the two groups, as shown in Table 1. The mean age was comparable in both groups [33.9 (16.4) versus 32.3 (14.5); $P = 0.59$], which was mainly in the middle age group. The majority of patients in both groups were male [80.0% vs. 81.8%; $P = 0.81$]. The severity of TBI was also comparable if based on GCS post resuscitation [7(1) versus 7 (3); $P = 0.07$] and Marshall Classification [3.3 (0.8) versus 3.3 (0.8); $P = 0.91$].

No intraoperative parameters were significantly different between the groups, as shown in Table 2. Duration of surgery was comparable at around 4 hours in both groups [4.2 (1.5) versus 4.0 (1.5); $P = 0.39$]. The amount of blood loss was also comparable between the groups [1.2 (0.8) versus 1.2 (0.7); $P = 0.98$]. Most post-operative parameters and ICU complications were not significantly different between the groups, as shown in Table 3, except for the requirement of inotropic support, which was higher in the sevoflurane group [40.0% versus 60.0%; $P = 0.04$].

There were no significant differences in post-operative outcome, as shown in Table 4. Differences in GOS at discharge was not significant between Group T and Group S ($P = 0.25$), where the percentages of mortality (GOS 1) (27.3% versus 16.4%), vegetative and severely disabled (GOS 2–3) (29.1% versus 41.8%) and good outcome (GOS 4–5) (43.6% versus 41.8%) were comparable in both groups. There were also no significant differences in percentage of successful extubation ($P = 0.55$), duration of ventilation ($P = 0.27$), duration of ICU ($P = 0.49$) or hospital stay ($P = 0.30$).

Table 1. Demographic Characteristic

Variables	Propofol (*n* = 55)	Sevoflurane (*n* = 55)	*P-value*
[e]Age (years)	33.9 (16.4)	32.3 (14.5)	0.59 [a]
[d]GCS (3-8)	7 (1)	7 (3)	0.07 [a]
[e]Marshall (I-IV)	3.3 (0.8)	3.3 (0.8)	0.91 [a]
[f]Sex			
Male	44 (80)	45 (81.8)	0.81 [b]
Female	11 (20)	10 (18.2)	
[f]Types of head injury			
Open skull fracture	0	1 (1.8)	0.31 [c]
EDH	13 (23.6)	19 (34.5)	
SDH	5 (9.1)	9 (16.4)	
Contusion	5 (9.1)	4 (7.3)	
Cerebral oedema	1 (1.8)	0	
Mixed	31 (56.4)	22 (40)	
Other associated injuries	16 (29.1)	17 (30.9)	0.83 [b]

[a] Independent t test, [b] Pearson Chi-square, [c] Fisher exact test, [d] Median (IQR), [e] Mean (SD), [f] *n* (%)

Table 2. Intra operative data

Variables	Propofol (n = 55)	Sevoflurane (n = 55)	P-value
[d]Duration of anaesthesia (hour)	4.2 (1.5)	4.0 (1.5)	0.39[a]
[d]Amount of total blood loss (litre)	1.2 (0.8)	1.21 (0.7)	0.98[a]
[e]Types of surgery:			
Craniotomy	12 (21.8)	23 (41.8)	0.0[c]
Craniectomy	40 (72.7)	28 (50.9)	
Craniectomy and other surgical/ orthopaedic procedure	3 (5.5)	4 (7.3)	
[e]Inotropes required	16 (29.1)	19 (34.5)	0.54[b]
[e]Intra operative complications:	46 (83.6)	46 (83.6)	1[b]
Hypothermia (T < 35 ^{O}C)	1 (1.8)	2 (3.6)	0.56[b]
Hypotension (SBP < 90mmHg)	17 (30.9)	19 (34.5)	0.68[b]
Hypoxia (PO_2 < 100 mmHg)	0	2 (3.6)	0.15[b]
Hypocarbia (PCO_2 < 35 mmHg)	20 (36.4)	16 (29.1)	0.42[b]
Hypercarbia (PCO_2 > 45 mmHg)	7 (12.7)	7 (12.7)	1[b]
Acidosis	11 (20.0)	10 (18.2)	0.81[b]
Hyperglycemia	7 (12.7)	4 (7.3)	0.34[b]
Hypokalemia	9 (16.4)	10 (18.2)	0.80[b]
Hyponatremia	0	0	0
Anaemia	16 (29.1)	19 (34.5)	0.54[b]
Coagulopathy	5 (9.1)	10 (18.2)	0.17[b]
Cerebral oedema	25 (45.5)	21 (38.2)	0.44[b]
[e]Transfusion requirement:			
No transfusion	14 (25.5)	14 (25.5)	0.80[c]
Pack cells only	22 (40.0)	19 (34.5)	
Pack cell + other blood products	19 (34.5)	22 (40.0)	

[a] Independent t test, [b] Pearson Chi-square, [c] Fisher exact test, [d]Mean (SD), [e] n(%)

Tables 3. Post-operative data

Variables	Propofol (n = 55)	Sevoflurane (n = 55)	*P-value*
Duration of cerebral resuscitation (hours)	39.4 (35.4)	39.3 (50.8)	0.99[a]
Duration of ventilation (days)	7.2 (6.8)	5.7 (7.2)	0.27[a]
Duration in ICU (days)	8.4 (7.27)	7.3 (7.3)	0.49[a]
Duration in ward (days)	14.2 (23.4)	10.6 (10.8)	0.30[a]
Inotropes require in ICU	22 (40.0)	33 (60.0)	*0.04[b]
ICU complications:	25 (45.5)	18 (32.7)	0.17[b]
Ventilator associated pneumonia (VAP)	10 (18.2)	7 (12.7)	0.43[b]
Sepsis	8 (14.5)	6 (10.9)	0.57[b]
Diabetes insipidus	3 (5.5)	4 (7.3)	0.70[b]
Repeat craniectomy	5 (9.1)	5 (9.1)	1[b]
Others	19 (34.5)	10 (18.2)	0.05[b]

[a] Independent t test, [b] Pearson Chi-square, [c] Fisher exact test, [d] Mean (SD), [e] n(%)

Table 4. Post-operative outcome

Variables	Propofol (n = 40)	Sevoflurane (n = 46)	*P-value*
[e] Rate of successful extubation among the survival:			
Extubated	26.0 (65.0)	27.0 (58.7)	0.55[b]
Tracheostomy	14.0 (35.0)	19.0 (41.3)	
[d] GCS when patient extubated	(n = 26) 10.4 (1.9)	(n = 27) 10.3 (1.9)	0.98[a]
[d] GCS when patient decided for tracheostomy	(n = 14) 6.3 (2.3)	(n = 19) 6.7 (2.0)	0.59[a]
[e] Mortality rate:			
Death	15.0 (27.3)	9.0 (16.4)	0.17[b]
Survive	40.0 (72.7)	46.0 (83.6)	
[e] GOS at discharge:			
GOS 1-death	15.0 (27.3)	9 (16.4)	0.25[c]
GOS 2-3- vegetative to severe disabled	16 (29.1)	23 (41.8)	
GOS 4-5- moderate disabled to good recovery	24 (43.6)	23 (41.8)	

[a] Independent T test, [b] Pearson Chi-square, [c] Fisher exact test, [d] Mean (SD), [e] n(%)

Discussion

The demographic characteristics of both groups in our study were comparable. In general, the mean ages of TBI patients in both groups were in the middle age group, 32–34, and the majority were male. Our results are similar to another prospective cohort study on characteristics of 110 severe TBI patients undergoing decompressive craniectomy in Kuala Lumpur Hospital. That study showed a median age of 28 years and mean (SD) age of 35.7 (18.3) years for this group of patients, and 86% were male (10). Based on data from North Carolina on TBI-related ED visits, the visit rate was also higher for men (7.9 visits per 1,000 person-years) than for women (6.8 visits per 1,000 person-years). Visit rates were highest in elderly patients over the age of 85 (30.6 visits per 1,000 person-years) (1). Data from India relating to moderate or severe TBI showed that the mean age of their patients was 32.15 (16.76) years and the ratio of male to female was 6.5:1. Most patients were in the age group 21–40 (11).

Our study shows comparable results between the groups with respect to intraoperative parameters, post-operative parameters and patient outcomes. Only the use of inotropic support was significantly higher in the sevoflurane group than in the TIVA group (60% versus 40%), and this did not affect the outcomes of the patients. Despite different intraoperative anaesthetic techniques being used on the two groups, we standardised the sedative agents while patients were in Neuro ICU, which caused similar haemodynamic effects in both groups. The use of inotropic support for TBI patients is common, mainly to optimise CPP ≥ 60 mmHg. This might be the reason for the similar outcomes between the two groups despite the different percentages of inotropic consumption. Mortality was comparable in both groups, even though the percentage was slightly higher in Group T (27.3% versus 16.4%). The percentage of good outcomes (GOS 4–5: moderately disabled to good recovery) was also comparable between the two groups (43.6% versus 41.8%). The only available study that investigated the effect of anaesthetic technique on neurological outcomes after TBI was a retrospective study by Grathwohl et al. on combat-related TBI (9). Good neurologic outcomes (GOS 4–5) and decreased mortality were more significantly associated with TIVA than with inhalational anaesthesia (75% versus 54% and 5% versus 16%, respectively). The factors associated with good neurological outcomes were significantly associated with GCS of 8 or greater (odds ratio, 13.3; $P < 0.001$) and the use of TIVA (odds ratio, 2.3; $P = 0.05$). However, after further analyses by controlling confounding factors, the authors could not find any association between the type of treatment and the neurologic outcome. In their study, they also included those on ketamine in the TIVA group. The duration of ventilation, duration of ICU stay and duration of hospital stay were comparable in both groups.

Our study shows comparable percentages of ICU complications between the groups, which indicates that the potential effects of complications on outcomes were not significantly different between the two groups. It is not uncommon for ventilated TBI patients to develop ventilator associated pneumonia (VAP) because of prolonged ventilation, sepsis and diabetes insipidus, as shown by our data. This finding is similar to the study by Magni et al. on the incidence of complications after neurosurgical procedures in patients anesthetised with either sevoflurane and fentanyl or propofol and remifentanil (12). A total of 162 complications occurred in 92 patients (57%). Based on the number of complications, 50 patients (31%) had only one complication, 26 patients (16%) had two complications, and 16 patients (10%) had three or more complications. Respiratory impairment (28%) was the most frequent complication and was reported as occurring frequently only in the first hour after surgery. The number of complications was comparable in both groups: 77 (48 %) were found in Group S and 85 (52%) in group T.

Our study aimed to see the effects of different anaesthetic techniques, TIVA/TCI and sevoflurane anaesthesia, on the outcomes of emergency TBI patients. Our main TIVA technique was TCI mode using the Marsh model because of our greater familiarity with that model compared to the Schneider model. Furthermore, the Marsh model uses target plasma concentration and is potentially more haemodynamically stable than the Schneider model, which commonly uses target effect-site concentration (C_et). C_et usually provides higher bolus of target concentration, which might cause more sudden drops in BP and CPP. There were few other previous studies comparing these two techniques without assessing the outcome of the patients. Bastola et al. compared propofol, sevoflurane and desflurane to determine the ideal neuro anaesthetic agent in

elective craniotomy patients for supratentorial tumours, based on their haemodynamic effects, the relaxation of the brain and the characteristics of emergence (13). That study found comparable results among the groups in terms of haemodynamics, brain relaxation, emergence time, early emergence (< 15 min), emergence quality (coughing and agitation) and post-operative complications. However, response times to verbal commands were significantly prolonged with sevoflurane [8.0 (2.9) min] when compared to propofol [5.3 (2.9) min] and desflurane [5.2 (2.6) min]. Weninger et al. compared the TCI technique with a combination technique using methohexitone and sevoflurane on brain tumour patients for elective stereotactic biopsy. All groups received remifentanil as analgesia. Haemodynamics were found to be largely stable in the TCI group. Recovery was also comparable between the groups (14).

The NeuroMorfeo trial was a multicentre trial involving fourteen Italian neuroanaesthesia centres (15). It was designed to compare post-operative recovery between three anaesthesia maintenance techniques, sevoflurane-remifentanil, sevoflurane-fentanyl and propofol-remifentanil, in elective supratentorial surgery. Perioperative endocrine stress responses were shown to be significantly blunted with propofol-remifentanil. Times to reach an Aldrete score of at least 9 after tracheal extubation, haemodynamic variables, the surgical field quality and post-operative assessments were similar. Liao et al. compared a combination of remifentanil either with propofol or sevoflurane in elective craniotomy in respect of a small number of parameters (16). Their results suggested that the induction and maintenance of anaesthesia with sevoflurane could be a better choice for patients with the risk of cerebral hypoperfusion or inadequate oxygen delivery, because it increased jugular bulb oxymetry ($SjVO_2$), lumbar CSF pressure (LCSFP) and CPP, as well as decreasing cerebral oxygen extraction ratio (COER). Propofol-based TIVA might be suitable for patients with high ICP, because it decreased $SjVO_2$, LCSFP and CPP, as well as increasing COER. Valencia et al. compared sevoflurane and propofol in respect of cerebral cortical oxygenation measured by near-infrared spectroscopy (NIRS) (17). Their findings suggested that sevoflurane could be a good option for patients with compromised cerebral oxygenation in the absence of intracranial hypertension.

Our study had a small number of limitations. Preoperative management of patients (at the site of accident, during transportation, in the peripheral hospital and in our ED after TBI) was not taken into consideration for this study. Management at these earlier phases and all earlier complications might also influence the outcomes of patients. Other managements in Neuro ICU (such as hyperosmolar therapy, barbiturate coma and cerebral haemodynamic management) were also not included in this data collection. We also did not follow up the patients' longer-term GOS (e.g. at 3 months, 6 months and 1 year) to see the longer-term outcome of the patients.

Conclusion

Our study showed that TIVA/TCI propofol anaesthesia was comparable in the outcome parameters with sevoflurane anaesthesia in terms of percentage of mortality, GOS, percentage of successful extubation, percentage of tracheostomy requirement, duration of ventilation, length of ICU and hospital stay. Even though these two different anaesthesia techniques might have a major influence on the outcome of emergency TBI surgery, other managements in Neuro ICU (not addressed in this study) might also play an important role.

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Authors' Contributions

Conception and design: YMN, WMNWH, RHMZ, WFWMS
Analysis and interpretation of the data: YMN, WMNWH
Drafting of the article: YMN, WMNWH, RHMZ, WFWMS
Critical revision of the article for important intellectual content: YMN, WMNWH, RHMZ, WFWMS
Final approval of the article: YMN, WMNWH, RHMZ, WFWMS
Provision of study materials: YMN, RHMZ
Statistical expertise: YMN, WMNWH
Obtaining funding: WMNWH

Administrative, technical, or logistic support: WMNWH, RHMZ
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