ANAESTHETIC MANAGEMENT IN SEVERE TRAUMATIC BRAIN INJURY

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Traumatic brain injury (TBI) is a major health problem in the world due to its mortality and morbidity. In general, the brain injury is caused by several accidents involving the vehicles and the human factor.

A young male 19 years old, 54lbs consulted by a neurosurgeon for craniotomy. The indication for craniotomy is the epidural hematomas in left front parietal according to the result of CT-Scan. The vital signs consist of blood pressure 110/70 mmHg; heart rate 98 x/min; respiratory rate 24 x/min; body temperature 37,5^{o}C GCS $E_1V_1M_3$. Patients were induced with 100 mg Fentanyl, Propofol 100 mg, intubation with rocuronium 40 mg, 70 mg lidocaine, and maintenance with isoflurane and oxygen Inhalants and continuous propofol and fentanyl and rokuronium intermittent additions. Infusion is attached in two lanes. The operation lasted for four hours. With attached nasal oxygen cannula and 3 liters / min, the patient was transferred to the ICU. After being treated for 2 days in the ICU, the patient was then transferred to ward with a GCS postoperative E3V5M6. Anesthesia for traumatic head injury requires an understanding of the pathophysiology of emphasis intracranial pressure (ICP) local and overall; setting and maintenance of intra

cerebral perfusion; how to avoid the consequences of systemic secondary effect on the brain.

Careful perioperative preparation and structured very important in the treatment of severe traumatic head injury anesthesia, which include preoperative patient preparation, preparation completeness of drugs, devices, and monitoring, as well as planning the implementation of anesthesia until postoperative management. Besides the principal brain protection, ensure the airway remains free of all time, adequate ventilation, circulation and non-pharmacologic are principles in the management of anesthesia in patients with severe head injury.

Keywords: traumatic brain injury, anesthetic management, intracranial pressure

Introduction

A recent studies have championed the importance of maintaining cerebral perfusion pressure (CPP) to prevent secondary brain injury following traumatic head injury. Data from these studies have provided little information regarding outcome following severe head injury in patients with an intracranial pressure (ICP) greater than 40 mm Hg, however, in July 1997 the authors instituted a protocol for the management of severe head injury in patients with a Glasgow Coma Scale score lower than 9. The protocol was focused on resuscitation from acidosis, maintenance of a CPP greater than 60 mm Hg through whatever means necessary as well as elevation of the head of the bed, mannitol infusion, and ventriculostomy with cerebrospinal fluid drainage for control of ICP. Since the institution of this protocol, nine patients had a sustained ICP greater than 40 mm Hg for 2 or more hours, and five of these had an ICP greater than 75 mm Hg on insertion of the ICP monitor and

later experienced herniation and expired within 24 hours. Because of the severe nature of the injuries demonstrated on computerized tomography scans and their physical examinations, these patients were not aggressively treated under this protocol. The authors vigorously attempted to maintain a CPP greater than 60 mm Hg with intensive fluid resuscitation and the administration of pressor agents in the four remaining patients who had developed an ICP higher than 40 mm Hg after placement of the ICP monitor. Two patients had an episodic ICP greater than 40 mm Hg for more than 36 hours, the third patient had an episodic ICP greater than of 50 mm Hg for more than 36 hours, and the fourth patient had an episodic ICP greater than 50 mm Hg for more than 48 hours. On discharge, all four patients were able to perform normal activities of daily living with minimal assistance and experience ongoing improvement. Data from this preliminary study indicate that intense, aggressive management of CPP can lead to good neurological outcomes despite extremely high ICP. Aggressive CPP therapy should be performed and maintained even though apparently lethal ICP levels may be present. Further study is needed to support these encouraging results.

PMID:

Traumatic brain injury (TBI) is a major public health problem and the leading cause of death and disability worldwide. Approximately 1.7 million people sustain TBI every year in the United States, leading to 275,000 hospitalizations and 52,000 deaths. TBI is a contributing factor in about 30.5% of all injury-related deaths in the United States.TBI occurs most often in children aged 0–4 years, adolescents aged 15–19 years and elderly aged 65 years and more. In all age groups, males have a higher rate of TBI than females. Falls and motor vehicle-traffic injury are the leading

causes of TBI in the United States. In the recent years, prehospital and intensive care of patients with TBI has improved substantially and evidence-based guidelines for management have been developed. However, despite the modern diagnosis and treatment, the prognosis for patients with TBI remains poor, emphasizing the need for further research and improvement in care. This review will focus on the perioperative management of TBI, with particular emphasis on recent developments, and is based on extensive Pubmed and Medline search on various aspects of perioperative management of TBI, followed by review of research focusing on intraoperative and perioperative period.

PATHOPHYSIOLOGY OF TRAUMATIC BRAIN INJURY

Pathophysiology of TBI involves primary and secondary injuries to the brain. Primary injury is the damage caused by the initial trauma involving mechanical impact to the brain tissue and skull due to acceleration–deceleration or rotational forces, resulting in skull fracture, brain contusion, expanding intracranial hematoma or diffuse axonal injury. The primary injury then initiates inflammatory process, edema formation and excitotoxicity, resulting in further increase in intracranial pressure (ICP) and reduced cerebral perfusion pressure (CPP). Severity of primary injury is the major factor determining the outcome of TBI patients. Secondary injury is a consequence of physiological insults that develop over time after the onset of the initial injury, causing further damage to the brain tissue and worsening the outcome in TBI patients. Two major factors that cause secondary injury are hypotension [systolic blood pressure (SBP) < 90 mmHg] and hypoxemia (PaO_2 < 60 mmHg).

A study analyzing data from the Traumatic Coma Data Bank demonstrated that hypotension and hypoxemia were independently associated with increased morbidity and mortality from severe TBI. A single episode of hypotension was associated with increased morbidity and mortality. A meta-analysis of 8721 patients (IMPACT study) also suggested that hypotension and hypoxia were significantly associated with unfavorable 6-month outcome. A study on the association between intraoperative hypotension and outcome demonstrated that patients who had intraoperative hypotension had over three times increased mortality than normotensive patients. Moreover, the duration of intraoperative hypotension was also inversely associated with functional outcome. Other factors implicated in secondary injury include hypoglycemia, hyperglycemia, hypercarbia and hypocarbia, and raised ICP.

THE IMPORTANCE OF PERIOPERATIVE PERIOD

Given the poor outcomes of TBI and impact of secondary insults, current TBI management focuses on prevention of primary injury and avoidance of secondary injuries. Thus, the cornerstones of modern TBI management are field resuscitation, expeditious triage, emergent surgical evacuation of mass lesions, control of ICP, and support of CPP, multimodal monitoring and optimization of physiological environment. Perioperative period may be particularly important in the course of TBI management for numerous reasons. First, despite the aggressive interventions to rapidly correct hypoxemia, hypotension, hypo and hypercarbia, and hypo and hyperglycemia in the emergency department, it is not unusual for one or more of

these complicating factors to persist or remain undetected as the patient is emergently transported to the operating room.

Hence, perioperative period may provide an opportunity to either continue ongoing resuscitation or to correct the pre-existing secondary insults. Secondly, surgery and anesthesia may predispose the patient to new onset secondary injuries (such as intraoperative hypotension due to surgical blood loss or effect of anesthetic agents, new onset hyperglycemia due to stress response, etc.), which may contribute adversely to outcomes. Since secondary injury is largely preventable/treatable, the perioperative period may be a potential window to initiate interventions that may improve the outcome of TBI. Perioperative management involves rapid evaluation, continuation of resuscitation (cerebral and systemic), early surgical intervention, intensive monitoring and anesthetic planning.

Initial Assessment and Ongoing Resuscitation

The initial assessment and stabilization is usually achieved in the emergency department and resuscitation initiated before the patient is transported to Computed Tomography (CT) scanner and then to the operating room. Nevertheless, it is important for the anesthesia team to perform another rapid assessment as the patient is received in the operating room. The assessment should always begin with airway, breathing and circulation, followed by a rapid assessment of neurological status and associated extracranial injuries and attention to specific secondary injury mechanisms and ongoing treatment thereof. Information about time and mechanism of injury can be valuable. Brief neurological assessment is performed by using Glasgow Coma Scale (GCS) score and pupillary responses. Associated thoracic,

abdominal, spinal and long bone injuries may be stable or evolve during the perioperative period and must be considered in differential diagnosis of new onset hypotension, anemia, hemodynamic instability or hypoxemia during anesthesia and surgery. As the patient is transported to the operating room, all resuscitative measures should continue.

Airway Management

Patients with TBI requiring surgery will invariably require tracheal intubation. In fact, most patients are likely to arrive in the operating room already intubated. However, some patients, particularly those with extradural hematoma, may be conscious and breathing spontaneously. The indwelling tracheal tube can possibly migrate during transport, leading to endobronchial intubation or even dislodgement, and hence, adequate position of the tube must always be confirmed. In the select patients who may not be already intubated, airway management is complicated by a number of factors, including urgency of situation (because of pre-existing/worsening hypoxia), uncertainty of cervical spine status, uncertainty of airway (due to presence of blood, vomitus, debris in the oral cavity or due to laryngo-pharyngeal injury or skull base fracture), full stomach, intracranial hypertension and uncertain volume status. All TBI patients requiring urgent surgery must be considered to have full stomach and airway management must account for possible underlying cervical spine injury. Although it has been reported that patients with craniocerebral trauma had an incidence of cervical spine injury (CSI) similar to that of the general trauma

population, emerging evidence suggests a higher incidence of cervical injury in patients who have experienced craniocerebral trauma, especially among those with increasing severity of craniocerebral injury as determined by low GCS score and unconsciousness.

The choice of technique for tracheal intubation is determined by urgency, individual expertise/skills and available resources and generally incorporates rapid sequence intubation with cricoid pressure and manual in-line stabilization. The anterior portion or cervical collar may be removed when manual in-line stabilization is established to allow greater mouth opening and facilitate laryngoscopy. Newer airway devises, particularly Glidescope videolaryngoscope, have gained popularity in recent years for use in trauma victims and may be useful in difficult airway scenarios. However, the intubation time using Glidescope may be longer due to difficulty in passing the tracheal tube through the glottis despite easier visualization.

Nasal intubation should be avoided in patients with base of skull fracture, severe facial fractures or bleeding diathesis. In any case, it is advisable to have a back-up plan ready in case of difficult intubation, given the significant risk of intracranial hypertension resulting from increased cerebral blood volume (CBV) because of hypoxemia and hypercarbia.

Choice of induction agents and muscle relaxants is important for successful uncomplicated airway management. Sodium thiopental, etomidate and propofol are commonly used to induce anesthesia before intubation. All these agents decrease the systemic hemodynamic response to intubation, blunt increases in ICP, and decrease the cerebral metabolic rate for oxygen ($CMRO_2$). However, propofol and thiopental may cause cardiovascular depression leading to hypotension, especially

in the presence of uncorrected hypovolemia. Etomidate may be advantageous due to little change in blood pressure during induction despite reduction of $CMRO_2$.

However, it may lead to adrenal insufficiency causing delayed hypotension and requiring vasopressor use. Ketamine, which causes limited cardiovascular compromise, has been associated with increased cerebral blood flow (CBF) and increased ICP, and as such, may be relatively contraindicated for intubating patients with risk for or pre-existing increased ICP. The choice of muscle relaxant for rapid sequence induction is between succinylcholine and rocuronium. Succinylcholine may contribute to increased ICP which can be blunted by administration of an adequate dose of an induction agent such as thiopental. While the clinical significance of the effect of succinylcholine on ICP is questionable, increases in ICP secondary to hypoxia and hypercarbia are well documented and much more likely to be clinically important. Hence, in patients with TBI, clinicians may not avoid using succinylcholine.

Anesthetic Management

The major goals of anesthetic management of TBI are to

- maintain CPP;
- treat increased ICP;
- provide optimal surgical conditions;
- avoid secondary insults such as hypoxemia, hyper and hypocarbia, hypo and hyperglycemia; and
- provide adequate analgesia and amnesia.

Anesthetic technique

Important pharmacodynamic and pharmacokinetic differences exist between intravenous and volatile anesthetic agents. Intravenous agents including thiopental, propofol and etomidate cause cerebral vasoconstriction and reduce CBF, CBV, $CMRO_2$and ICP.Opioids have no direct effects on cerebral hemodynamics in the presence of controlled ventilation.All volatile anesthetic agents (isoflurane, sevoflurane, desflurane) decrease $CMRO_2$ and may cause cerebral vasodilation, resulting in increasing CBF and ICP. But at concentration less than 1 minimum alveolar concentration (MAC), the cerebral vasodilatory effects are minimal and hence they may be used in low concentrations in patients with TBI. Nitrous oxide can increase $CMRO_2$ and cause cerebral vasodialation and increased ICP and should be avoided. Importantly, the effects of anesthetic agents (inhalation vs. total intravenous anesthesia) on outcome of TBI have not been demonstrated. In the absence of conclusive evidence, either anesthetic technique may be employed judiciously. However, more importantly, the principles of anesthetic management should adhere to the current guidelines for the management of severe TBI

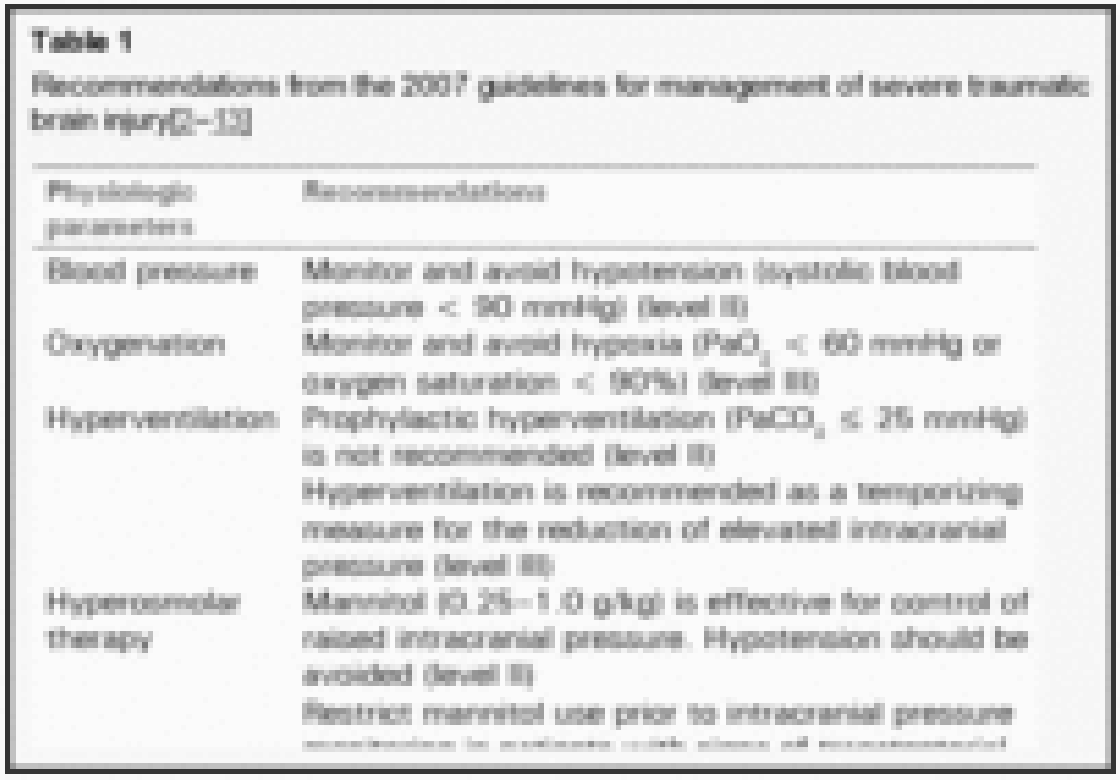

Table 1

Recommendations from the 2007 guidelines for management of severe traumatic brain injury[2–13]

Physiologic parameters	Recommendations
Blood pressure	Monitor and avoid hypotension (systolic blood pressure < 90 mmHg) (level II)
Oxygenation	Monitor and avoid hypoxia (PaO_2 < 60 mmHg or oxygen saturation < 90%) (level III)
Hyperventilation	Prophylactic hyperventilation ($PaCO_2$ ≤ 25 mmHg) is not recommended (level II) Hyperventilation is recommended as a temporizing measure for the reduction of elevated intracranial pressure (level III)
Hyperosmolar therapy	Mannitol (0.25–1.0 g/kg) is effective for control of raised intracranial pressure. Hypotension should be avoided (level II) Restrict mannitol use prior to intracranial pressure

Table 1

Recommendations from the 2007 guidelines for management of severe traumatic brain injury.

Ventilation

Ventilation should be adjusted to ensure adequate oxygenation and gas exchange. Inspired oxygen concentration is adjusted to maintain PaO_2 >60 mmHg. Monitoring arterial PCO_2 is recommended since end-tidal CO_2 may not be reliable. Hypercarbia should be avoided but hypocarbia must not be used indiscriminately. Excessive hyperventilation may cause cerebral vasoconstriction leading to ischemia. Hence, hyperventilation should be used judiciously for short-term control of ICP and to facilitate surgical exposure during craniotomy. Normocarbia should be restored before dural closure to avoid development of tension pneumocephalus. Monitoring

cerebral oxygenation is recommended when utilizing hyperventilation for prolonged periods. In the intraoperative period, this may be accomplished by jugular venous oximetry and in the postoperative period by brain tissue oxygenation ($PbtO_2$) or CBF monitoring (e.g. using Transcranial Doppler ultrasonography).

Monitoring

In additional to standard American Society of Anesthesiology (ASA) monitors, arterial catheterization is recommended for beat-to-beat blood pressure monitoring and for blood gas analysis and blood glucose monitoring during craniotomy. Central venous pressure (CVP) may be useful, particularly for resuscitation and when vasopressors are administered. However, it is advisable not to delay surgical evacuation of expanding intracranial hematoma because of institution of invasive monitoring.

According to the current guidelines, ICP monitoring is recommended in all salvageable patients with a severe TBI (GCS < 9) and an abnormal CT scan (hematomas, contusions, swelling, herniation or compressed basal cistern), and in patients with severe TBI with a normal CT scan if two or more of the following features are noted at the admission: age > 40 years, unilateral or bilateral motor posturing, or SBP < 90 mmHg. The use of multimodal monitoring for postoperative and intensive care of patients with TBI is increasing and monitoring cerebral oxygenation (global or focal) or CBF and metabolism parameters may be helpful in making important treatment decisions.

Intravenous Fluids, Blood Pressure Management and Vasopressor Use

Hypotension following TBI can compromise cerebral hemodynamics and cause cerebral ischemia. Therefore, blood pressure management, including choice of fluids and vasopressors, is of paramount importance. Brain Trauma Foundation guidelines for the management of TBI recommend avoiding hypotension (SBP < 90 mmHg) and maintaining CPP between 50 and 70 mmHg. Warm, non-glucose containing isotonic crystalloid solution is preferable for TBI patients. The role of colloid is controversial. A*post-hoc* analysis of the Saline versus Albumin Fluid Evaluation (SAFE) study demonstrated that resuscitation with albumin was associated with higher mortality rate and unfavorable neurological outcome at 24 months.

Hypertonic saline may be beneficial resuscitation fluid for TBI patients because it increases intravascular fluid and decreases ICP. Prehospital hypertonic saline resuscitation has been shown to be associated with a reduction in serum biomarker levels (S100B, Neuron Specific Enolase and Membrane Basic Protein) which correlated with better outcome. However, a double-blind randomized controlled trial comparing prehospital resuscitation of hypotensive TBI patients with hypertonic saline with standard fluid resuscitation protocols found no difference in neurological outcome at 6 months.

Vasopressors are commonly administered to treat hypotension or to augment CPP. However, there are only a few studies comparing the effectiveness of commonly used vasopressors in TBI and results of these studies are conflicting. Human data explicitly comparing vasopressors are limited to three small prospective, randomized, crossover trials comparing sequential effectiveness between norepinephrine and dopamine. Despite there being no differences in mean cerebral

flow velocity and cerebral oxygenation or metabolism between the two vasopressors, norepinephrine had more predictable and consistent effect while dopamine use led to higher ICP. A recent single-center retrospective study of patients with severe TBI who received phenylephrine, norepinephrine or dopamine reported maximum increase in MAP and CPP from baseline with phenypephrine use. There was no difference in ICP between the treatment groups after initiating the vasopressor although it was unclear whether improved MAP/CPP with vasopressor use translated into improved CBF or oxygenation. Current evidence does not support preference of one vasopressor over the other.

Blood Transfusion

Anemia is associated with increased in-hospital mortality and poor outcome in TBI. Yet, there is little evidence to support packed red blood cell (PRBC) transfusion practice standards to correct anemia in TBI. While some have suggested that patients with TBI may not benefit from a higher transfusion threshold than other critically ill patients, others have cautioned against the liberal use of blood transfusion in TBI.

Potential mechanisms of cerebral injury due to anemia include tissue hypoxia, injury caused by reactive oxygen species, inflammation, disruption of blood-brain barrier (BBB) function, vascular thrombosis and anemic cerebral hyperemia. However, a number of cerebroprotective physiological mechanisms become effective with anemia which include aortic chemoreceptor activation, increased sympathetic activity leading to increased heart rate, stroke volume and cardiac index, reduced systemic vascular resistance, and enhanced oxygen extraction.

Moreover, a number of cellular mechanisms of cerebral protection become effective in acute anemia. These include Hypoxia Inducible Factor (HIF), increased nitric oxide synthetase and nitric oxide in the brain (nNOS/NO), erythropoietin and vascular endothelial growth factor (VEGF) mediated angiogenesis and vascular repair. Although increase in CBF during acute anemia can improve oxygen delivery, high hematocrit after PRBC transfusion may potentially decrease CBF and increase the risk of cerebral ischemia. However, anemia due to hemodilution may impair cerebral autoregulation.

The overall effects of anemia on the brain might, therefore, depend on the relative balance between these competing protective and harmful factors of anemia and PRBC transfusion, and it is unclear whether transfusion trigger in patients with TBI should be any different from other critically ill patients and whether the injured brain is more susceptible to deleterious effects of anemia.

In the absence of defined optimal hemoglobin (Hb) levels, it has been suggested that neurophysiologic criteria for RBC transfusion may be more rational and may progressively replace arbitrary Hb-based transfusion triggers in neurocritical care. RBC transfusion may influence cerebral oxygenation through a number of potential mechanisms in patients with TBI. Besides increasing the oxygen-carrier capacity of blood, RBC transfusion increases the circulating volume and can increase CBF in patients with impaired cerebral autoregulation secondary to the TBI.

Transfusion also increases the blood viscosity to which the circulatory network responds with the release of nitric oxide, leading to vasodilatation and increasing functional capillary density (which quantifies capillary perfusion). In recent years,

there has been growing interest in the effect of RBC transfusion on brain tissue oxygenation ($PbtO_2$) in patients with TBI and it seems an interesting possibility that $PbtO_2$ values may be developed into potential transfusion triggers. However, most studies evaluating the effect of transfusion on $PbtO_2$ in neurosurgical patients are limited by small sample size and have failed to demonstrate a consistent response to transfusion or elucidate predictors of $PbtO_2$ response to transfusion.The potential role of brain tissue oxygenation in deciding transfusion thresholds has been discussed elsewhere.

Existing evidence suggests that both anemia and RBC transfusion are associated with poor neurological outcome in TBI. While anemia is associated with increased in-hospital mortality and lower hospital discharge GCS score, discharge Glasgow outcome score and Ranchos Los Amigos scores, RBC transfusion is associated with acute lung injury, longer intensive care unit and hospital stay, and mortality. The optimal Hb level in TBI patients is still unclear but there is no benefit of a liberal transfusion strategy (transfusion when Hb <10 g/dl) in moderate to severe TBI patients and it is not recommended.

Coagulopathy and Factor VII

Coagulation disorder is a common problem after TBI. Coagulation disorder could result from TBI and cause secondary brain injury. A recent review reported that the overall prevalence of coagulopathy was 32.7% after TBI and more than 60% in severe TBI and that the presence of coagulopathy was associated with an increased mortality and poor outcome. According to a recent prospective study, the independent risk factors for coagulopathy in TBI are GCS ≤ 8, Injury Severity Score

(ISS) ≥ 16, presence of cerebral edema, subarachnoid hemorrhage and midline shift. When brain is injured, tissue factor (TF) is released.

Subsequently, pro-coagulant factors are activated resulting in thrombin formation and conversion of fibrinogen to fibrin. Normally, antithrombotic mechanisms are also activated to counter fibrin formation. Disseminated intravascular coagulation (DIC) inhibits the antithrombotic mechanism, causing imbalance of coagulation and fibrinolysis. Currently, there are no guidelines for management of coagulopathy in TBI.

Hemostatic drugs including antifibrinolytic agents such as tranexamic acid and pro-coagulant drugs such as recombinant activated factor VII (rFVIIa) are sometimes used in treatment of coagulopathy after TBI. A Cochrane review found two randomized controlled trials that evaluated the effects of rFVIIa, but both the trails were too small to draw a conclusion regarding the effectiveness of rFVIIa for TBI patients. The Clinical Randomization of Antifibrinolytics in Significant Hemorrhage (CRASH-2) trial, a large international placebo-controlled trial evaluating the effect of tranexamic acid on death, vascular occlusion events and blood transfusion in adult trauma patients, demonstrated that tranexamic acid was associated with a reduction of mortality (RR: 0.91, 95% CI: 0.85-097, *P* = 0.0035).The risk of death from bleeding was also lower in tranexamic acid group (RR: 0.85, 95% CI: 0.76–0.96, *P* = 0.0077).

Hyperosmolar Therapy

Mannitol is the standard agent used in hyperosmolar therapy. The recommended dose of mannitol is 0.25–1 g/kg body weight. Due to osmotic diuresis which can result in hypovolemia and hypotension, mannitol is recommended only

when there are signs of transtentorial herniation or progressive neurological deterioration not attributable to extracranial causes. In patients with severe TBI and elevated ICP refractory to mannitol treatment, 7.5% hypertonic saline administered as second tier therapy can increase cerebral oxygenation and improve cerebral and systemic hemodynamics.

Glycemic Control

Hyperglycemia after TBI is associated with increased morbidity and mortality. It may reflect the extent of injury severity, reflecting a normal response to stress due to a rise in circulating counter-regulatory hormones or may worsen outcome after TBI. Secondary brain injury from hyperglycemia can ensue, leading to an increase in glycolytic rates as shown by increased lactate/pyruvate ratio, resulting in metabolic acidosis within brain parenchyma, overproduction of reactive oxygen species, and ultimately neuronal cell death.

In 2001, Van den Berghe *et al*. reported that intensive insulin therapy (target blood glucose 80–110 mg/dl) in critically ill patients was associated with lower mortality. However, more recent studies not only failed to demonstrate the mortality benefit of intensive insulin therapy but also found an increased risk of hypoglycemia. Billotta *et al*. randomized 97 severe TBI patients to intensive insulin therapy group targeting blood glucose at 80-120 mg/dl or conventional insulin therapy group targeting blood glucose below 220 mg/dl and found that both the groups had similar mortality and neurological outcome at 6 months. Although the intensive insulin therapy group had shorter ICU stay, infection rates were similar between both the

groups and episodes of hypoglycemia (glucose < 80 mg/dl) were significantly higher in the intensive insulin therapy group.

Hence, tight glucose control with intensive insulin therapy remains controversial. While a number of studies have investigated hyperglycemia in adult TBI in different contexts (admission vs. ICU, transient vs. persistent, early vs. late, etc.), none has specifically addressed the intraoperative period and the prevalence of intraoperative hyperglycemia, and its relation to preoperative glycemic patterns in adult TBI is not known. Since hyperglycemia is attributed to a stress response from the initial injury and blood glucose levels are known to increase under anesthesia even in non-diabetic patients it is possible that added stress during general anesthesia and surgery may worsen hyperglycemia and contribute to poor outcome. Moreover, individual anesthetic agents have been shown to have differential effects on blood and brain glucose levels. The only perioperative study in children with TBI demonstrated that intraoperative hyperglycemia is common, hypoglycemia in the absence of insulin treatment is not rare, and TBI severity and the presence of subdural hematoma (SDH) predict intraoperative hyperglycemia. In the author's experience in adult patients undergoing craniotomy for TBI, intraoperative hyperglycemia (glucose > 200 mg/dl) was common (15%) and hypoglycemia (glucose < 60 mg/dl) was not observed (unpublished data). We also found that the independent risk factors for intraoperative hyperglycemia were severe TBI, SDH, preoperative hyperglycemia, and age ≥65 years, and the in-hospital mortality was higher in patients with intraoperative hyperglycemia. Given the current evidence for glucose control for TBI in perioperative period, a target glucose range of 80–180 mg/dl seems reasonable.

Therapeutic Hypothermia and Steroids

Hypothermia reduces cerebral metabolism during stress, reduces excitatory neurotransmitters release, attenuates BBB permeability, and has been used for brain protection in TBI patients for decades. However, clinical evidence in terms of mortality and functional outcomes is still inconclusive. A recent meta-analysis reported statistically insignificant reduction in mortality and increased favorable neurological outcome with hypothermia in TBI.

The benefits of hypothermia were greater when cooling was maintained for more than 48 hours, but the potential benefits of hypothermia may likely be offset by a significant increase in the risk of pneumonia. These observations support previous findings that hypothermic therapy constitutes a beneficial treatment of TBI in specific circumstances. Accordingly, the BTF/AANS guidelines task force has issued a Level III recommendation for optional and cautious use of hypothermia for adults with TBI.

Steroids have not been shown to improve outcomes or lower ICP in TBI. In fact, findings from a randomized multicenter study on the effect of corticosteroids (MRC CRASH trail) showed that administration of methylprednisolone within 8 hours of TBI was associated with higher risk of death, and the risk of death or severe disability was more compared to placebo. Therefore, the use of high-dose methylprednisolone is contraindicated in patients with moderate or severe TBI.

SUMMARY

Perioperative period may be important in TBI management. While it may predispose the patient to new onset secondary injuries which may contribute

adversely to outcomes, it is also an opportunity to detect and correct the undiagnosed pre-existing secondary insults. It may also be a potential window to initiate interventions that may improve the outcome of TBI. While research focused specifically on the intraoperative and perioperative TBI management is awaited, clinical management will continue to be based on physiological optimization.

Level I recommendations are based on the strongest evidence for effectiveness, and represent principles of patient management that reflect high degree of clinical certainty. Level II recommendations reflect a moderate degree of clinical certainty. For level III recommendations, the degree of clinical certainty is not established.

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