Review Article

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Anesthesia for the patient with a recently diagnosed concussion: think about the brain!

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Some patients require emergent, urgent, or elective surgery in the time period immediately following diagnosis of concussion. However, changes in brain homeostatic mechanisms following a concussion and concern for secondary brain injury can complicate the decision as to whether or not a surgery should proceed or be postponed. Given the paucity of available evidence, further evaluation of the use of anesthesia in a patient with concussion is warranted. This article summarizes what is currently known about the relevant pathophysiology of concussion, intraoperative anesthesia considerations, and effects of anesthesia on concussion outcomes in an attempt to help providers understand the risks that may accompany surgery and anesthesia in this patient population. While most contraindications to the use of anesthesia in concussed patients are relative, there are nonetheless pathophysiologic changes associated with a concussion that can increase risk of its use. Understanding these changes and anesthetic implications can help providers optimize outcomes in this patient population.

Keywords: Brain concussion; Brain ischemia; General anesthesia; Intracranial hypotension; Post-concussion syndrome.

Introduction

According to the American Medical Society for Sports Medicine's position statement, concussion is defined as a traumatically induced transient disturbance of brain function involving a complex pathophysiological process [1]. It has been estimated that as many as 3.8 million sports-related concussions occur annually. However, data suggest that up to 50% of concussions go unreported and the actual occurrence rate is much higher [2]. The majority of patients with concussions (80% to 90%) recover within seven to 10 days after the injury [3]; however, some patients develop persistent post-concussion symptoms and can need more than four weeks to recover [4-6].

During this time period when a patient is recovering from a concussion, patients with a recent concussion will sometimes require surgery that may or may not be related to the head injury [7]. In some cases, providers will need to counsel patients on which procedures need to be completed promptly and which need to be postponed until the concussion symptoms resolve. This decision is complicated because changes in brain physiology and concern for secondary exacerbation of functional neurological dysfunction can make administration of anesthesia more challenging [8] and few studies have been performed evaluating the impact anesthesia has on concussion symptoms [7,9].

Since there are no current clinical guidelines to rely on in these situations, clinical

judgment must be used to decide when the risks of postponing the surgery outweigh the possible risks of anesthesia to a patient with a diagnosis of concussion. Therefore, in order to help providers understand the risks of anesthesia as it relates to concussion, this review will summarize what is currently known about the relevant pathophysiology of concussion, intraoperative anesthesia considerations, and effects of anesthesia on concussion outcomes.

Pathophysiology of concussion

After an acceleration/deceleration injury, complex pathophysiologic changes in the brain occur including ionic shifts, changes to cerebral blood flow (CBF) autoregulation, alterations in cerebral metabolism, release of neurotransmitters, changes to the blood-brain barrier integrity, and expression of inflammatory cytokines (Table 1) [7]. While a full discussion of all changes is beyond the scope of this article, ionic shifts, altered CBF autoregulation, and autonomic nervous system dysfunction warrant review.

Concussions are associated with ionic shifts. Studies have shown that following brain injury, an ionic shift occurs at a cellular level, altering the neuronal transmembrane potential [10]. Restoration of a normal neuronal transmembrane potential requires an increase in activity of sodium-potassium (Na^+-K^+) pumps. In turn, glucose metabolism must increase to meet the needs of the sodium-potassium pumps. When glucose supply cannot match this demand, anaerobic metabolism occurs leading to an accumulation of intracellular lactate. As a short-term solution, an increase in intracellular calcium and sequestration of calcium into mitochondria occurs. However, calcium sequestration can eventually lead to mitochondrial dysfunction, impair mitochondrial oxidative metabolism, and worsen the energy deficit activating pathways that lead to cell death [9]. These changes create a vulnerable state that can potentially be complicated by the stresses of surgery and anesthesia.

In addition to the neuronal metabolic changes, a severity-dependent decrease in CBF occurs following concussion [11-14]. This injury-induced decrease in CBF further worsens the imbal-

Table 1. Pathophysiologic Changes Associated with Concussion

· Ionic shifts shifts
· Impaired cerebral blood flow autoregulation
· Changes to cerebral metabolism
· Neurotransmitter release
· Disruption of blood-brain barrier
· Expression of inflammatory cytokines
· Autonomic nervous system dysfunction

ance between oxygen demand and supply. The decrease in CBF and perfusion deficit following sport-related concussions can last for a month or longer prolonging recovery and increasing the duration of measurable symptoms [15].

In order to understand the significance of this change, it helps to review normal CBF autoregulation. In the normal brain, several homeostatic mechanisms assist in coupling cerebral oxygen demand with oxygen supply. The most important of these mechanisms include pressure autoregulation, CBF changes in response to a change in arterial partial pressure of carbon dioxide ($PaCO_2$), and CBF changes in response to metabolic demand. Changes in arterial $PaCO_2$ induce a pH difference between the blood and the cerebrospinal fluid, which through several proposed mechanisms results in a linear direct relationship between $PaCO_2$ and CBF between a $PaCO_2$ of 20 and 60 torr. Increased $PaCO_2$ results in arterial dilation and blood flow to the brain increases approximately 2 cc/100 g/min per torr increase. Conversely, decreasing $PaCO_2$ will result in a similar decrease in CBF [16].

Following minor traumatic brain injury, efficacy of pressure autoregulation is reduced [14] and CBF becomes more linearly related to mean arterial pressure whereas the response to changes in $PaCO_2$ remains relatively intact. Therefore, given the reduced capabilities of pressure autoregulation, the combination of hyperventilation and even mild hypotension can lead to significant cerebral ischemia in a patient with concussion, making the use of anesthesia a concern in this patient population.

Autonomic nervous system dysfunction after a concussion may also impact surgical considerations. Dysregulation of the autonomic nervous system in the first 72 h even after mild traumatic brain injury and concussion has been described [17]. Since the autonomic nervous system is responsible for cardiac function, several investigators have attempted to establish the relationship of cardiac function as a measure of the autonomic nervous system's dysregulation.

One measurement under assessment is heart rate variability, the change in the interval between each heart beat noted as the R wave to R wave (R to R) interval on electrocardiogram. In a systematic review by Blake et al. [18], nine studies were evaluated and the authors concluded that cardiac autonomic function is altered in patients with concussion. It is important to note, however, that the studies in the review were limited by small sample sizes, methodological heterogeneity, and limited follow-up of subjects. In other research, heart rate variability has been introduced as a promising and useful test to assess and monitor athletes with concussion [19]. Overall, while further research is needed to understand this relationship of cardiac function and autonomic nervous system dysfunction in relation to concussion,

it must be recognized that the autonomic nervous system dysfunction may also present a challenge in patients undergoing surgery.

Much remains unknown regarding post-concussion pathophysiology, but the above changes including ionic shifts, altered CBF autoregulation, and autonomic nervous system dysfunction may present challenges for patients requiring anesthesia and surgery. It has also been suggested that a second insult to the concussed brain especially prior to recovery from the first insult, can result in worsened cellular metabolic changes and more significant cognitive deficits [20]. Therefore, it is important to consider the brain's vulnerability after concussion since some of these patients will have concomitant injuries causing hypoxemia, hypotension, anemia, and hyperglycemia that all can worsen the underlying brain injury [1]. An effort should be made to address any concomitant conditions promptly to avoid further brain injury prior to surgical procedures. When patients need to proceed to surgery, it then becomes a matter of how best to ensure optimal outcomes for these patients.

Intraoperative anesthesia considerations in patients with concussion

Intraoperative anesthetic management affects hemodynamic, ventilation, and metabolic parameters, and can potentially cause a 'secondary injury' to the concussed brain that is vulnerable and already dysfunctional. Because of concern for this secondary injury worsening or prolonging the symptoms of the concussion, it may be prudent to postpone elective surgery until the patient is ready to return to school or normal daily activities [20]. However, some patients need to proceed to the operating room for an urgent or emergent surgery. Therefore, it is useful to discuss intraoperative hemodynamic and metabolic guidelines as well as the effect different routes of administration and types of anesthetic agents may have on this population.

Once the decision has been made to have a procedure, understanding how surgery and anesthetics may interact with the pathophysiologic changes that occur following concussion can help minimize the risk of harm. Since no clear guidelines are available for the subset of patients with concussion, using the intraoperative hemodynamic goals for patients with traumatic brain injury undergoing surgery can serve as a general guide for managing the recently concussed surgical patient (Table 2) [21].

CBF autoregulation is likely impaired [14,22], so even mild hypotension should be avoided to reduce the risk of cerebral hypoperfusion. Maintenance of mean arterial pressure at the patient's baseline value or higher is therefore appropriate. Hypovo-

lemia should be treated using isotonic normal saline rather than hypotonic fluids, which could cause cerebral edema, or colloids, which have been associated with poor outcomes in traumatic brain injury [21]. Since hypocarbia in the face of impaired pressure autoregulation may lead to cerebral ischemia, mechanical ventilation should be adjusted to maintain normocarbia during surgery [21]. Until further research is conducted on the effects of anesthesia on the subset of patients with concussion, utilizing guidelines established for traumatic brain injury may limit risks during procedures.

Current evidence does not provide any guidance regarding choice of anesthetic technique in the patient with concussion. Regional anesthesia, if appropriate for the patient and the surgical procedure, could theoretically hold an advantage in some cases in that it might allow for more hemodynamic stability during certain procedures [23]. However, neuraxial anesthesia can also cause hypotension and few data exist to support this concept.

Considering the effects of individual anesthetic agents can also help defer unintended risk in this patient population. In general, both intravenous and volatile anesthetic agents alter cerebral metabolism and CBF, the two pathophysiologic considerations of importance in patients with concussion. However, no anesthetic drug or technique has been shown to improve outcome in patients with concussion. Therefore, each agent's effects on CBF, metabolism, and response to carbon dioxide must be considered for its relative risks.

Intravenous anesthetic agents generally maintain coupling between cerebral metabolism and CBF. Propofol, one of the most commonly used intravenous sedative-hypnotic medications by anesthesiologists, has been shown to cause cerebral vasoconstriction, reduce CBF, and decrease cerebral metabolic rate for oxygen ($CMRO_2$) [24]. It is frequently used in patients with recently diagnosed concussion. Ketamine, another intravenous sedative-hypnotic medication, has traditionally been avoided in patients with traumatic brain injury out of concern for increasing CBF and intracranial pressure but a systematic review dispelled that concept [25]. Therefore, as long as an adequate mean arterial pressure is maintained, any of the intravenous anesthetic agents may be used in this patient population.

Volatile anesthetics uncouple CBF and metabolism and result

Table 2. Intraoperative Hemodynamic Goals for Patients with Traumatic Brain Injury

· Avoid hypotension to reduce risk of cerebral hypoperfusion
· Maintain mean arterial pressure at patient's baseline or higher
· Treat hypovolemia with isotonic fluid rather than hypotonic fluid
· Maintain normocarbia during surgery

in a dose-dependent decrease in $CMRO_2$ and a simultaneous increase in cerebral blood flow [21]. Like intravenous anesthetic agents, volatile anesthetics can also be used safely in patients with concussion.

In general, while postponing surgeries may be appropriate in some cases, there is no current contraindication for the use of anesthesia in the setting of concussion. When the decision is made to proceed with surgery, steps should be taken to reduce risks associated with a procedure based on understanding the interaction between the pathophysiology of concussion and use of anesthesia during a procedure.

Effects of anesthesia on outcome in patients with concussion

Anesthetic management has the potential to have a significant impact on outcome in concussed patients undergoing surgery. In addition to considering how concussion may affect the use of anesthesia, it is worthwhile to note that there is little information evaluating if anesthesia prolongs the symptoms of concussion. It is possible that the use of anesthesia may create a neurocognitive exacerbation worsening pre-surgical symptoms such as headache, dizziness, postural instability, sleep disturbances, memory impairment, decreased processing speed, attention deficit, fatigue, depression, and anxiety. This concern again suggests that it may be safest to postpone elective surgery until the patient is ready to return to school or normal daily activities if possible [20].

In conclusion, there are multiple pathophysiologic changes in the concussed brain that can make the use of anesthesia for these patients challenging. Unfortunately, without prospective, randomized, controlled trials, the effects of anesthesia on long-term outcomes after concussion remain largely unknown and decisions must be made based on physiologic considerations. The avoidance of hypotension and hypocapnia are prudent and vigilance for the autonomic changes that might occur will help to maximize the chance of a favorable outcome. But given the paucity of currently available information, clinical judgment remains key in decision-making and future studies will be needed to assess the effects between concussion and anesthesia use.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

Author Contributions

All authors (Conceptualization; Data acquisition and analysis; Investigation; Methodology; Writing–original draft; Writing–review & editing)

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