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Case report

Use of the Licox® in a head-injured patient with a tibial shaft fracture: A novel method of assessing the effect of reamed intramedullary nailing on brain tissue oxygenation

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1. Introduction

Previous series have reported on the advantages of early long bone stabilization in polytrauma patients, most notably with respect to early mobilization and limiting pulmonary complications and length of stay in the intensive care unit (ICU).[4,6,7,12,16,23,25] However, the role of long bone stabilization in patients with significant head injury remains unclear. Early surgery may lead to a decrease in pulmonary complications and length of stay, but known sequelae of reamed intramedullary nailing (e.g., fat emboli and peri-operative fluid shifts) may lead to secondary brain injury and detrimentally impact long-term neurologic function.[8] The studies attempting to investigate this issue have been retrospective in design, used varying outcomes measures and endpoints, and thus, have come to dichotomous conclusions.[5,15,17,24,27,28,30,33] A recent study was able to demonstrate that intracranial pressure (ICP) increased while cerebral perfusion pressure (CPP) decreased after femoral nailing.[1] These findings suggest that intramedullary nailing may adversely affect cerebral oedema and perfusion in patients with head injury.

While CPP and ICP have classically been utilized as markers of brain oedema and perfusion, more recently, measurement of the partial pressure of brain tissue oxygen (PbO_2) has been used as an additional measure to guide treatment. This parameter gives a more accurate estimate of brain hypoxia, which may be independent of ICP or CPP.[13,19,26,32] Brain tissue oxygenation can be measured directly by a Licox® monitor (Integra, Plainsboro, NJ). Clinically, PbO_2, as measured by the Licox®, is an independent predictor of outcome after head injury.[3] Furthermore, PbO_2 guided management has been directly correlated with improved outcomes and mortality.[10,20,29] Here we report on the peri-operative measurement of brain oxygenation in a patient with head injury who underwent reamed intramedullary nailing of a midshaft tibia fracture.

2. Case

A 43-year-old male pedestrian presented to the resuscitation bay after being struck by an automobile (Table 1). The patient lost consciousness at the scene. He was haemodynamically stable, but intermittently confused upon arrival. Primary survey was significant for a GCS of 14. Secondary survey revealed an obvious closed deformity of the right leg. CT scan of the head demonstrated a subdural haematoma extending between the left frontal and parietal regions, while CT scan of the abdomen revealed a small right adrenal haemorrhage. A comminuted midshaft fracture of the tibia and fibula was diagnosed on plain radiographs. According to the Association for the Advancement of Automotive Medicine's 1990 revision, the patient's Abbreviated Injury Scale Scores were five for head and neck, three for extremity and one for abdomen, yielding an Injury Severity Score of 35.[2]

Within the first 6 h of injury, the patient's neurologic status deteriorated as he lost the ability to follow commands and became semi-purposeful in movement. Repeat head CT revealed an evolving subdural haematoma. The patient was intubated and an intracranial pressure monitor and Licox® device were placed by the neurosurgery service (Table 2). Initial ICP was 11 mmHg and PbO_2 was 5 mmHg. The PbO_2 improved rapidly to 30 mmHg with administration of 100% FiO_2 and a fluid bolus. An elevated brain temperature of 102 °F was noted, but returned to normal with ice and acetaminophen. The patient remained sedated with propofol

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Table 1
Patient data.

Age	Sex	Injury	ISS	Operative Time (min)	EBL (mL)	Nail type	Concurrent procedures	GSC			Discharge destination
								Admit	Surgery	Discharge	
43	M	Pedestrian struck by auto	35	195	550	Antegrade tibial	None	14	9	15	TBI rehab

TBI, traumatic brain injury.

and phenytoin was administered for seizure prophylaxis. Pre-operatively, his ICP, CPP and PbO_2 remained stable with means of 15.2 mmHg, 95.0 mmHg and 41.0 mmHg, respectively. Evaluation by the critical care and neurosurgery services deemed to patient suitable for intramedullary nailing of the tibia. The patient's pre-operative GCS was 9.

Thirty-six hours post-injury the patient underwent uncomplicated reamed intramedullary nailing of his right tibia with an operative time of 195 min and an estimated blood loss of 550 mL. The tourniquet was only inflated during the exposure. Intra-operatively, the mean ICP and CPP were 18.1 mmHg and 82.7 mmHg, respectively. Post-operatively, the patient remained intubated and sedated with propofol. However, his PbO_2 fell below 10 mmHg and he was noted to be febrile to 102.5 °F. In an effort to improve the PbO_2, the FiO_2 was increased to 100%, acetaminophen was administered and a cooling blanket was applied. The patient's PbO_2 increased to greater than 20 mmHg with these measures. Additionally, the post-operative haemoglobin was discovered to be 9.4 gm/dl and the patient received one unit of packed red-blood cells. The mean 24-h post-operative ICP, CPP and PbO_2 were 16.5 mmHg, 72.4 mmHg and 17 mmHg, respectively. The patient's neurologic status remained stable and all intracranial monitoring was discontinued 4 days post-injury.

The patient's ICU course was complicated by ventilator dependent respiratory failure and pseudomonal pneumonia diagnosed 10 days post-injury. The patient was treated with appropriate antibiotics, weaned from the ventilator, and extubated 13 days post-injury. On post-injury day 14, the patient was transferred out of the ICU. His neurologic status slowly improved and 26 days post-injury, the patient was discharged to a traumatic brain injury rehabilitation facility with a GCS of 15.

3. Discussion

Treatment of long bone fractures in polytrauma patients is a complicated and controversial topic. There is evidence that early fixation of long bone fractures has beneficial effects mainly with respect to decreasing pulmonary complications and decreasing hospital and ICU stays.[4,6,7,12,16,23,26] Regarding this subject, the Eastern Association of the Surgery of Trauma's practice guidelines state "Polytrauma patients undergoing long bone stabilization within 48 h of injury have no improvement in survival when compared to those receiving later stabilization; however, there may be some patients who will have fewer morbidities.[11]"

Concern remains amongst treating surgeons for the subset of trauma patients with head injury or severe pulmonary injury who may be harmed by early fracture fixation, especially reamed intramedullary nailing. In patients with head injury, there is concern that hypotension, hypoxia, fat emboli or fluid shifts may lead to decreased cerebral perfusion and secondary brain injury, which may impact neurologic outcome.[3,8,15,30] These concerns are supported by two studies in sheep which demonstrated that ICP and brain oedema increase in the setting of reamed intramedullary nailing of long bones and a recent study in humans that showed reamed intramedullary nailing is associated with a decrease in intra-operative CPP.[18,22] However, the clinical literature pertaining to this subject has been retrospective and come to varying conclusions. Some authors have shown that early fracture fixation is detrimental to parameters believed to be important for neurologic perfusion.[15,30] In contrast, other authors have found no difference in outcome with respect to mortality, length of ICU stay, or neurologic outcome.[5,17,24,27,28,33] The Eastern Association of the Surgery of Trauma's review of the subject supported the latter by concluding that "There is no compelling evidence that early long bone stabilization in mild, moderate, or severe brain injured patients either enhances or worsens outcome.[11]" However, without high quality evidence supporting the safety of early long bone fracture fixation in head injured patients, concern persists that intramedullary nailing could adversely affect neurologic outcome.

Recently, partial pressure of oxygen in the brain has been used as an additional measure to guide the management in head injury.[29] It has been observed that cerebral ischaemia can occur independently from changes in ICP and CPP, and it is believed that mechanisms other than perfusion related ischaemia may play a role is brain ischaemia after head injury.[19,21,32] Thus, brain oxygen directed therapy attempts to maximize brain tissue oxygen by increasing oxygen delivery to the brain and decreasing metabolic demand. These goals are most often achieved through modulation of the fraction of inspired oxygen, correcting metabolic delivery through volume management and increasing the oxygen carrying capacity by transfusion, or decreasing demand by correcting pain, fever or seizure. This differs from CPP directed management that puts more emphasis on volume status and vascular resistance.

PbO_2 in this report was measured through the placement of a Licox® device into the brain parenchyma along with intracranial pressure and temperature probes. The Licox® contains a Clark-type polarographic microcatheter in the tip of a flexible probe with an oxygen sensing area of 13 mm^2 and has been shown to be both accurate and reliable.[9,14] Brain O_2 values between 20 mmHg and 40 mmHg are considered normal, while brain PbO_2 values below 15 mmg are associated with ischaemia.[29] The likelihood of death has been shown to increase with increasing duration of time with PbO_2 at or below 15 mmHg.[31] Additionally, PbO_2 has been shown

Table 2
Mean MAP, ICP, CPP and PbO_2 during the 24-h pre-, intra-, and 24-h post-operative periods.

MAP			ICP			CPP			PbO_2		
24 H Pre	Intra	24 h post	24 h pre	Intra	24 h post	24 h pre	Intra	24 h post	24 h pre	Intra	24 h post
110.2	100.8	88.9	15.2	18.1	16.5	95	82.7	72.4	41.0	NR	17.0

MAP, mean arterial pressure; ICP, intracranial pressure; CPP, cerebral perfusion pressure; PbO_2, brain partial pressure of oxygen; NR, not recorded; values are in millimetres of mercury.

to be an independent predictor of outcome after head injury and PbO_2 directed management has been shown to improve neurologic outcome and mortality when compared to CPP directed therapy.[3,10,20,29] With the growing use of PbO_2 guided treatment of head injury, this is the first case to report the effect of reamed intramedullary nailing on brain oxygenation in head injury.

Despite stable mean pre-operative ICP, CPP and PbO_2 values of 15.2 mmHg, 95.0 mmHg and 41.0 mmHg, respectively as well as maintenance of a peri-operative CPP greater than 70 mmHg, a significant drop in PbO_2 was noted immediately after surgery. This decrease in PbO_2 required measures including increasing the FiO_2, aggressively treating fever and timely blood transfusion to improve brain oxygenation. While it is unclear if this post-operative decrease in PbO_2 affected outcome, it suggests the possibility of occult brain hypoxemia, despite reassuring ICP and CPP, in the acute post-operative period after reamed intramedullary nailing.

In conclusion, reamed intramedullary nailing may be associated with decreased brain oxygenation in patients with head injuries. Brain tissue oxygenation monitors such as Licox® may be a valuable adjunct to traditional monitoring devices in patients with combined orthopaedic and head injuries, especially in the peri-operative setting. At present, we are unable to draw definitive conclusions regarding the cause of the decrease in PbO_2. Nonetheless, this case may be of clinical use or guide the design of future trials. Further studies of prospective design are needed to better define the effect of intramedullary nailing and its timing on brain oxygenation.

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