The American Journal of Surgery (2015) 210, 1070-1075

The American Journal of Surgery®

Southwestern Surgical Congress

Evaluation of StO_2 tissue perfusion monitoring as a tool to predict the need for lifesaving interventions in trauma patients

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KEYWORDS:
Shock;
Perfusion;
Near-infrared spectroscopy;
Occult shock;
Trauma

Abstract

BACKGROUND: Hemorrhage remains the leading cause of mortality in preventable trauma deaths. Earlier recognition of hemorrhagic shock decreases the time to implementation of life-saving interventions improves patient survival. The presence of hemorrhagic shock is not always apparent using standard vital signs monitoring, a clinical state referred to as occult shock.

METHODS: This prospective, observational study was performed at Memorial Hermann Hospital in Houston, TX. Prisoners, pregnant women, and patients with burn injuries greater than 20% total body surface area or bilateral upper extremity fractures were excluded. Hutchinson Technologies Spot Check StO_2 device was used to measure StO_2 values.

RESULTS: StO_2 values less than 75% were predictive of the need for blood product transfusions ($P < .01$) and the need for emergency surgeries. Nearly one-third of patients who presented with a systolic blood pressure 120 mm Hg or more presented with StO_2 less than 75% and had a median base deficit of 5 (3 to 6.5).

CONCLUSIONS: Admission StO_2 measurements less than 75% predict the need for blood products and emergent surgical procedures and may be used as an adjunct method for identifying shock. StO_2 measurements can aid where laboratory values are unavailable.

Hemorrhage remains a leading cause of death among trauma patients. More than 80% of potentially survivable traumatic injuries in combat theaters across the world are due to hemorrhage.[1,2] Similarly, in the United States, unintentional injuries are among the top 2 causes of death for all age groups, and hemorrhage and hemorrhagic shock are responsible for up to 40% of trauma-related deaths.[3,4] Death from injury has increased by 23% over the last decade, and death by unintentional injury is currently the leading cause of years of potential life lost up to the age of 75 years.[5–7] Although preventing death from traumatic brain injury is currently difficult, the early detection and rapid resuscitation with blood products and definitive intervention for hemorrhagic shock with lifesaving interventions (LSIs) hold great promise in improving outcomes in critically injured and bleeding trauma patients. Patients undergoing massive

The authors declare no conflicts of interest.

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Manuscript received April 10, 2015; revised manuscript August 27, 2015

0002-9610/$ - see front matter
http://dx.doi.org/10.1016/j.amjsurg.2015.08.006

transfusion protocols requiring greater than 10 U of blood can cost up to $6,000 in blood products alone—underlying the expensive cost of trauma management.[8–10] These statistics, characterizing trauma and its cost, both financial and personnel, in both war zones and in the United States, underscore the importance of developing an algorithm for better predicting the need for expensive LSIs.

The early detection of hemodynamic compromise is critical for triage of patients and the implementation of LSIs. Shock is defined as tissue hypoperfusion at the cellular level.[10] Cellular perfusion is difficult to accurately measure early after injury. Standard vital signs such as heart rate and blood pressure are traditionally used as surrogates; however, these are notoriously poor indicators of shock.[11] The presence of hemorrhagic shock is not always apparent using standard vital signs monitoring, a clinical state referred to as occult shock. In a study by Holcomb et al, it was determined that patients with stable Glasgow coma scale (GCS) motor scores and systolic blood pressure (SBP) still required an LSI 21% of the time, underscoring a substantial percentage of patients whose hemorrhagic shock and tissue hypoperfusion would be undertriaged with standard vital signs monitoring.[12] Owing to the body's complex compensatory mechanisms in response to injury and hemorrhage, vital signs are often preserved within normal ranges leading to delayed recognition. Commonly used laboratory parameters such as base deficit, lactate, hematocrit, and pH are not available immediately on arrival nor in prehospital scenarios domestically or in military theaters. These limitations in the monitoring of patients with traumatic injuries present a difficult challenge in identifying which patients are at risk for further irreversible hemodynamic deterioration.

The InSpectra StO_2 Spot Check monitor (Hutchinson Technology, Inc., Hutchinson, MN) uses near-infrared spectroscopy (NIRS), a technique using near-infrared light and its spectrophotometric properties to detect the percentage of oxygenated hemoglobin in tissues. Low-StO_2 values indicate a shift in the oxygen delivery—oxygen consumption relationship toward inadequate perfusion. NIRS-derived data of StO_2 readings have been shown to be indicative of the severity of hemodynamic compromise in animal models and also was found to differentiate between resuscitatable and nonresuscitatable subjects.[13] The objective of this study was to determine whether NIRS-derived StO_2 measurements could be used to identify patients in occult shock and predict the need for LSIs.[14,15]

Methods

This prospective, observational study was approved by the institutional review board and conducted on adult trauma patients ($\geq$16 years), at the highest level of activation at the Texas Trauma Institute at Memorial Hermann Hospital in Houston, TX. Waiver of consent was given by the institutional review board because of the nature of the trauma patients. Prisoners, pregnant women, and patients who were received from another hospital were excluded from the study, as shown in Figure 1. Traumatic burn patients were included with burns less than 20% total body surface area and without hand burns. On arrival to the trauma center, the InSpectra StO_2 Spot Check (Hutchinson Technology, Inc.) was placed on the thenar eminence of the patient's hand on the arm not used for recording noninvasive blood pressure. Patients with upper extremity fractures and vascular compromise were not used for monitoring. The StO_2 readings were taken on emergency room (ER) arrival and then were recorded every 5 minutes if possible for the 1st 60 minutes after ER admission. If LSIs were implemented, the StO_2 value was recorded immediately pre-LSI and post-LSI. Interventions categorized as LSIs were as follows: intubation; surgical airway; cardiopulmonary resuscitation; defibrillation; thoracotomy; tube thoracostomy; aortic balloon occlusion; pericardiocentesis; transfusions of platelet, plasma, or red blood cells; and administration of pressors (atropine, epinephrine, or dopamine). Transport to the operation room (OR) within 1 hour after arrival was delineated as emergency surgery and was considered an LSI. GCS scores were calculated using the universal GCS, and assessment of blood consumption (ABC) scores were calculated using the presence of penetrating mechanism, hypotension as defined by SBP less than 90 mm Hg, tachycardia as defined by heart rate greater than 120 bpm, and presence of positive ultrasound focused assessment with sonography in trauma examination to derive a score between 1 and 4.[14,15] Occult shock was defined in this study as a patient who presented with admission StO_2 75% or less and SBP greater than 120 mm Hg.

Statistical analysis

The StO_2 data were statistically analyzed to evaluate for the presence of trends and significance. Vital signs, outcomes, and procedures performed were also recorded for data analysis. Statistical analysis was performed using a Mann-Whitney test for continuous variables and Fisher exact test for categorical data, and a P value less than .05 was considered significant.

Results

During the period of June 2014 to August 2014, 62 patients were included in the study with a median age of 42 years (26–58), 67% male, and 69% blunt injuries with a mortality of 9.7%. Twenty-three patients presented to the trauma unit with a StO_2 value less than 75% and received a total of 46 LSIs. These 46 LSIs given in the ER included 22 units of packed red blood cells, 25 U of fresh frozen plasma, 10 U of platelets, 2 intubations, 1 tourniquet, and 9 immediate transportations to the OR. Any transfusion of blood products, whether singular or multiple, was counted as 1 LSI. There was no difference in StO_2 values between blunt and penetrating groups, injury type, age, or sex (Table 1). Patients who presented with an StO_2 less than