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ABSTRACT

Introduction: Hypovolemia is a major complication of trauma patients, leading, if not treated rapidly, to tissue and organ hypoperfusion and the development of multiple organ failure. During the out-of-hospital management of trauma patients, it is recommended to maintain the blood pressure the first time with the fluid administration and if it is not sufficient the second time by a vasopressor.

The aim of these treatments is to avoid microcirculation alteration with a deficit of tissue perfusion and oxygen delivery to vital organs. In trauma patients, peripheral muscle tissue oxygen saturation (StO2) measured by near-infrared spectroscopy (NIRS) was shown to be more reliable than systemic hemodynamic variables as an index of severity of traumatic shock.

Keywords: prehospital microvascular management - StO2 - NIRS - lactate - mountain traumatology.

Classification: NLM Code: WO 700

Language: English

Great Britain Journals Press

LJP Copyright ID: 392881

London Journal of Medical and Health Research

Volume 23 | Issue 6 | Compilation 1.0

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ABSTRACT

Introduction: Hypovolemia is a major complication of trauma patients, leading, if not treated rapidly, to tissue and organ hypoperfusion and the development of multiple organ failure. During the out-of-hospital management of trauma patients, it is recommended to maintain the blood pressure the first time with the fluid administration and if it is not sufficient the second time by a vasopressor.

The aim of these treatments is to avoid microcirculation alteration with a deficit of tissue perfusion and oxygen delivery to vital organs. In trauma patients, peripheral muscle tissue oxygen saturation (StO2) measured by near-infrared spectroscopy (NIRS) was shown to be more reliable than systemic hemodynamic variables as an index of severity of traumatic shock.

The objective of this prospective study was to compare hemodynamic variables and the lactate values with the regional tissue oxygenation saturation monitoring (StO2) measured by near-infrared spectroscopy in the prehospital management of mountain trauma patients.

Material and Methods: This prospective observational cohort study was performed during 13 months. Helicopter emergency teams enrolled mountain trauma patients. At the arrival of the emergency team, the control of an external hemorrhage was first performed. The fluid loading was recommended first with crystalloids (isotonic saline 0,9 %) and after if it was not sufficient, norepinephrine is proposed if the object blood pressure was not reached after the infusion of one liter and half of crystalloids.

The objective of systolic blood pressure (SBP) was 80-90 mmHg in patients with no head injury and 120 mmHg in case of severe head injury. For each patient, the following data were recorded: patient's demographics, mechanism and altitude of the trauma, the suspected injuries and the severity of trauma, vital signs as GCS, heart rate (HR), non invasive systolic and diastolic arterial pressure, oxygen saturation with a pulse oximeter and epitympanic temperature. The MGAP score (Mechanism of injury, GCS, Age, systolic arterial Pressure) was calculated. Regional tissue oxygen saturation (StO2) was measured using near-infrared spectroscopy (NIRS) after securing the StO2 probe to the thenar eminence of the hand. The venous blood lactate level was collected while the venous catheter was inserted during the prehospital management (lactate T0) and at the hospital admission to Emergency Medical Service (lactate Adm). The volumes of intravenous fluids and the vasopressor doses, if associated with volume expansion, administered during the prehospital management were recorded.

Results: During 13 months, 30 mountain trauma patients were prospectively enrolled in the helicopter mountain rescue units. The victims of an accident were often skiing in 57%, paragliding in 13% and snowshoeing in 10%. The StO2 measure was achieved in 96 % of cases whatever was the outside temperature (even if < 5 °C) with low body temperature patients (mild hypothermia 32-35 °C in 20%, severe hypothermia 28-32 °C in 3 % of cases). In these conditions, the SpO2 value could only be obtained in 16,6 %. The volume expansion was performed with isotonic saline in 48% of patients, and 15% needed isotonic saline and a continuous infusion of norepinephrine. According to the Northern French Alps Emergency Network Classification,

London Journal of Medical and Health Research

43% of trauma patients were stabilized before the hospital admission but in 7% of cases the outdoor resuscitation didn't permit the patient's stabilization before the hospital arrival.

We found a significant correlation of the initial StO2 value (StO2 T0) to the blood lactate level collected at hospital admission (lactate Adm) (R^2= 0,40; p = 0,0003). The StO2 T0 value permits to predict a lactate level > 2 mmol/l at the hospital admission (AUC= 0,86, threshold value of StO2 < 73,5%) with a good sensitivity and specificity.

Discussion: The results of our study demonstrate that NIRS derived StO2 is a non-invasive measure able to predict tissue hypoperfusion and feasible in the outdoor setting whatever the outside and the patient body temperature. Alterations in regional tissue perfusion often precede global signs of shock therefore StO2 may represent an important screening tool for early identifying trauma patients who require an intensive and preventive resuscitation. Thus, monitoring tissue oxygenation provides information about the state of microcirculation.

In hypovolemic patients, the decrease of StO2 (thenar eminence) is due to the decrease of the muscle blood flow because of centralization of blood flow to vital organs. Peripheral tissues are the first to reflect hypoperfusion in shock. Poor peripheral perfusion may therefore be considered as an early predictor of tissue hypoperfusion and ongoing shock. Tissue hypoperfusion is a recognized pathophysiological process leading to multiple organ dysfunction and death. In trauma patients with severe shock, StO2 was lower than in milder grades of shock or in normal individuals. StO2 within one hour of admission was lower in trauma patients who developed multiorgan dysfunction (MODS) or died and so a low StO2 was a strong predictor of MODS and death. In hypovolemic trauma patients, low StO2 predicts adverse outcomes.

Conclusion: Prehospital measurement of StO2 is feasible in mountain trauma patients and may become a useful parameter of the severity of injury and in the identification of tissue hypoperfusion. StO2 monitoring appears feasible and reliable even when the other routine parameters such as SpO2, HR and NIBP are inconsistent or not possible to measure. In our study, the StO2 T0 value was permitted to predict a lactate level superior to 2 mmol/l at the hospital admission, which was in accordance with the results of several previous studies. We believe that NIRS-determined StO2 may become a useful parameter of trauma patient monitoring in the prehospital setting, in particular in austere environments and during air transport and in the future, StO2 value could even become integrated into trauma scores.

Keywords: prehospital microvascular management - StO2 - NIRS - lactate - mountain traumatology.

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I. INTRODUCTION

Hypovolemia is a significant complication of trauma patients, leading, if not treated rapidly, to tissue and organ hypoperfusion and the development of multiple organ failures. So, during the out-of-hospital management of trauma patients, it is recommended to maintain the blood pressure using first fluid administration and, if not sufficient, second a vasopressor support (norepinephrine). These interventions should be continued until the correction of hemodynamic parameters: static (blood pressure, heart rate, cardiac index) and dynamic parameters (pulse pressure variation, stroke volume) (1). The real aim of these interventions is to avoid microvascular alteration with a deficit of tissue perfusion and oxygen delivery to vital organs, well documented in patients with hemorrhagic shock.

Many studies highlight the predictive value of microvascular perfusion and the correlation of microvascular hypoperfusion with the development of multiple organ dysfunction syndrome and mortality (2)(3). Microcirculation (diameter of vessels < 100 µm) is currently considered as a vital organ, which is responsible for tissue oxygen supply (4). In a study, an early increase in microcirculatory perfusion was associated with reduced multi-organ failure and that independently of the systemic hemodynamic variables that remained unchanged (5). In the case of trauma patients, peripheral muscle tissue oxygen saturation (StO2) determined by near-infrared spectroscopy (NIRS) was shown to be more reliable than systemic hemodynamic variables as an index of severity of traumatic shock (6) (7) (8).

The objective of our prospective study was to compare hemodynamic variables and venous blood lactate values with the regional tissue oxygenation saturation (StO2) using near-infrared spectroscopy in the prehospital management of mountain trauma patients.

II. MATERIAL AND METHODS

This prospective observational cohort study was performed for 13 months. Helicopter emergency teams enrolled mountain trauma patients. We excluded from our study: Patients dead at emergency team arrival, patients with Glasgow Coma Scale<4, patients with bilateral fractures of the upper extremities or with bilateral thenar eminence damage, pregnant women and patients < 18 years of age.

2.1 Interventions

First and if necessary, at the arrival of the helicopter emergency team, the control of an external hemorrhage was first performed if necessary. A peripheral vein catheter was inserted. The fluid loading was recommended first intention with crystalloids (isotonic saline 0,9 %).

In several cases, if not sufficient norepinephrine is proposed if the object blood pressure is not reached after the infusion of one liter and half of crystalloids. The objective of systolic blood pressure (SBP) was: 1/80-90 mmHg in patients with no head injury and 2/ 120 mmHg in case of severe head injury. If the objective of SBP wasn't reached by fluid loading alone, a vasopressor support (norepinephrine) was initiated (9)(10).

2.2 Data collection and StO2 measurements

For each patient, the following data were recorded: the patient's demographics, the mechanism and the altitude of the trauma, the suspected injuries and the severity of trauma according to the trauma grading in the Northern French Alps Emergency Network (11) (Table 1), the vital signs as GCS, heart rate (HR), non invasive arterial pressure (systolic and diastolic), oxygen saturation with a pulse oximeter and epitympanic temperature. The MGAP score (M*echanism of injury*, G*CS*, A*ge, systolic arterial* P*ressure*) was calculated (12).

Regional tissue oxygen saturation (StO2) was measured using near-infrared spectroscopy (NIRS) after securing the StO2 probe to the thenar eminence of the hand (Model TM InSpectra StO2 SpotCheck, Hutchinson Technology, MN, USA). StO2 was measured at the arrival of the emergency team and after that every 10 minutes until the arrival at the hospital.

The venous blood lactate level was collected while the venous catheter was inserted during the prehospital management (lactate T0) and at the hospital admission to Emergency Medical Service (lactate Adm).

The volumes of intravenous fluids and the vasopressor doses, if associated with volume expansion, administered during the prehospital management were recorded.

2.3 Statistical analysis

Data are presented as mean value ± standard deviation, and the percentage. The predictive value on the outcome of the slope was calculated using a receiver operator characteristic (ROC) curve, the area under the curve (AUC) was computed.

III. RESULTS

For 13 months, 30 mountain trauma patients were prospectively enrolled in two helicopter mountain rescue units. Twenty-one patients were males and nine were females, from 16 to 77 years (mean age 43 ± 20 years), victims of an accident of skiing in 57% of paragliding in 13% and of snowshoeing in 10% (Figure 1). The median altitude of the rescue interventions was 1290 ± 639 meters. The StO2 measure was achieved in 96 % of cases whatever was the outside temperature (even if < 5 °C) and with low bodies patients' temperatures (mild hypothermia 32-35 °C in 20%, severe hypothermia 28-32 °C in 3 % of cases). In these hypothermia conditions, the SpO2 value could only be obtained at 16,6 % (Table 2). The volume expansion was performed with isotonic saline in 48% of patients, and 15% needed isotonic saline and a continuous norepinephrine infusion.

According to the Northern French Alps Emergency Network Classification (Figure 2), 43% of trauma patients were stabilized before the hospital admission. In 7% of cases the outdoor resuscitation didn't permit the patient's stabilization before the hospital arrival.

In two patients the MGAP score (Figure 3) was high (11 and 14) predicting an increased risk of adverse clinical outcome (mean mortality of 46%).

The initial StO2 measure was available in these 2 cases (StO2 T0 values of 64% and 66% respectively) but the SpO2 couldn't be obtained.

We found a significant correlation of the initial StO2 value (StO2 T0) to the blood lactate level collected at hospital admission (lactate Adm) (R^2= 0,40; p = 0,0003). The StO2 T0 value permits to predict a lactate level > 2 mmol/l at the hospital admission (AUC= 0,86, threshold value of StO2 < 73,5%) with a good sensitivity and specificity (Figures 4a and 4b).

IV. DISCUSSION

The results of our study demonstrate that NIRS derived StO2 is a non-invasive measure able to predict tissue hypoperfusion and is feasible in the outdoor setting whatever the outside and the body temperature. Regional alteration tissue perfusion often precedes global indications of shock therefore StO2 may represent an important screening tool for early identifying trauma patients who require intensive resuscitation.

Tissue oxygenation may reflect changes in microcirculation, which is an important target in trauma patients. Alterations of microcirculation are documented in hemorrhage and critical illness and they are in relation to tissue oxygenation.

Thus, monitoring tissue oxygenation may provide information about the state of microcirculation. In hypovolemic patients, the decrease of thenar eminence StO2 is due to the reduction of the muscle blood flow because of the centralization of blood flow to vital organs. Peripheral tissues are the first to reflect hypoperfusion in shock. Poor peripheral perfusion may therefore be considered as an early predictor of tissue hypoperfusion and ongoing shock. Tissue hypoperfusion is a recognized pathophysiological process leading to multiple organ dysfunction and death.

We chose the thenar eminence as an NIRS-derived StO2 monitoring site for several reasons: the thenar eminence is easily accessible despite all technical difficulties of rescue in the hostile mountain environment and the relatively thin fat tissue over the muscle is an advantage in minimizing variability. We found this non-invasive monitoring to be feasible in prehospital trauma patients because NIRS technology is not dependent on the identification of pulsatile flow and a previous animal study showed no significant effects of body temperature on StO2 values (8). The monitoring of pulse oximetry (SpO2) often failed and other routine parameters such as heart rate (HR) and non-invasive blood pressure (NIBP) have often spurious readings in the prehospital setting, even more in mountain conditions and during air transport.

A study performed in intensive care patients with increased blood lactate levels during 8 hours of resuscitation showed that half had low StO2 (<70%) on admission. But there was no difference in systemic circulatory variables between patients with common and average StO2.

Patients who retained low StO2 levels despite initial resuscitation had significantly worse outcomes than patients with average StO2 values.

Common StO2 values were only related to abnormalities of peripheral tissue perfusion (regional hemodynamics) but not of central organs (13). In trauma patients with severe shock, StO2 was lower than in milder grades of shock or in normal individuals (14)(15). StO2 within one hour of admission was more down in trauma patients who developed multiorgan dysfunction (MODS) or died and low StO2 was a strong predictor of MODS and death (16)(17). The lowest StO2 in trauma patients is as good as the lowest systolic blood pressure at identifying severe shock (14)(15). In hypovolemic trauma patients, low StO2 predicts adverse outcomes.

V. CONCLUSION

Prehospital measurement of StO2 is feasible in mountain trauma patients and may become a valuable parameter of the severity of the injury and identifying tissue hypoperfusion. StO2 monitoring appears feasible and reliable even when the other routine parameters such as SpO2, HR and NIBP are inconsistent or impossible to measure. In our study, the StO2 T0 value permitted us to predict a lactate level superior to 2 mmol/l at the hospital admission, which was following the results of several previous studies.

We believe that NIRS-determined StO2 may become a helpful parameter of trauma patient monitoring in the prehospital setting, in particular in austere environments and during air transport and in the future, StO2 value could even become integrated into trauma scores. However, other more extensive studies would be necessary to confirm these findings. Perhaps in the future, it would be possible to include the StO2 value, as an additional and reliable index into the four descriptive stages of the ATLS blood loss (18). In disaster medicine, it would even be possible to use it as additional criteria of quality and performance.

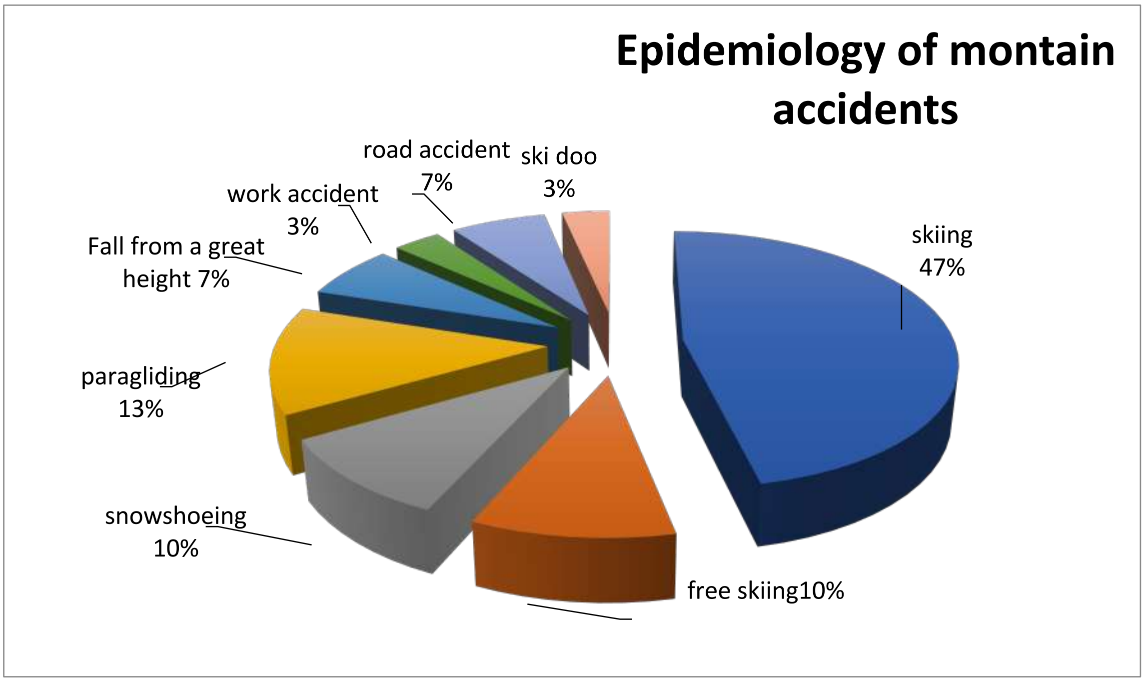

Figure 1: The Mechanisms of Trauma

Table 1: Trauma Grade in the Northern French Alps Emergency Network

Grade A: Unstable Patient

SBP <90 mmHg despite the prehospital resuscitation
Prehospital transfusion
Respiratory distress and/or mechanical ventilation difficult SpO2 <90%

Grade B: Patient stabilized

Stabilized respiratory distress with SpO2 ≥90%
hypotension corrected
Head trauma with Glasgow Coma Score <13 or motor GCS <5
Penetrating trauma of the head, neck, thorax, abdomen and above the elbows or knees
Flail chest
Amputation or crushing degloving members
Suspicion of severe trauma pelvis
Suspicion of spinal cord injury

Grade C: Stable Patient

Fall> 6 meters
Patient traumatized victim of ejection, projection, crushing and / or blast
Deceased patient and / or severe trauma in the same accident vehicle
Patient victim of a high kinetic accident at the discretion of the prehospital team

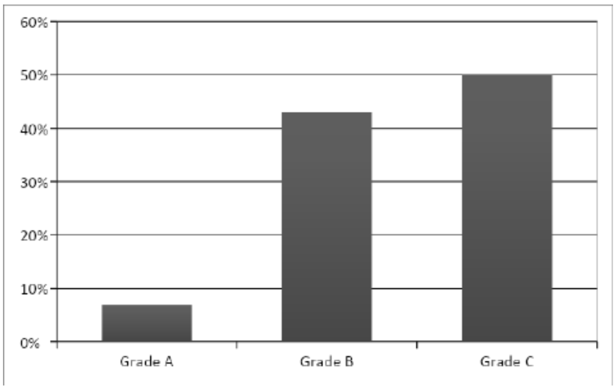

Figure 2: Trauma Grade in the Northern French Alps Emergency Network

Table 2: Comparison Reliable SpO2 Measurement Versus StO2 with Time

Time	SpO2	StO2
T0	16%	96%
T 10 minutes	26%	100%
T 20 minutes	46%	96%
T 30 minutes	66%	96%

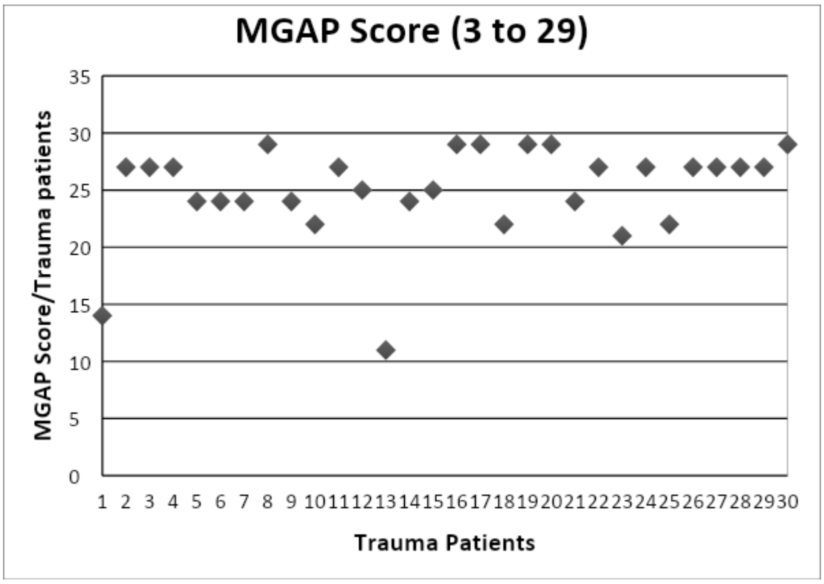

Figure 3: MGAP Score

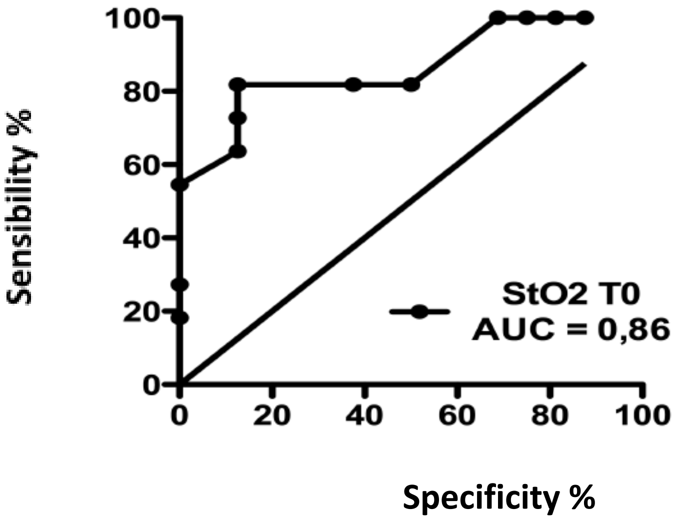

Figure 4a

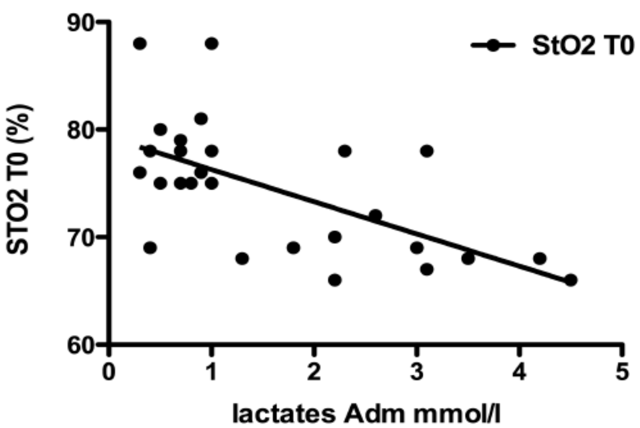

Figure 4b

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