RESUSCITATION OF A POLYTRAUMATIZED PATIENT WITH LARGE VOLUME CRYSTALLOID-COLLOID INFUSIONS – CORRELATION BETWEEN GLOBAL AND REGIONAL HEMODYNAMICS: CASE REPORT

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SUMMARY – Aggressive large volume resuscitation is obligatory to achieve necessary tissue oxygenation. An adequate venous preload normalizes global hemodynamics and avoids multiorgan failure (MOF) and death in patients with multiple injuries. Large volume resuscitation is associated with complications in minimally monitored patients. A properly guided resuscitation procedure will finally prevent MOF and patient death. Transpulmonary thermodilution technique and gastric tonometry are used in venous preload monitoring, calculating volumetric hemodynamic variables and estimating splanchnic perfusion as well. We present a 24-year-old man with multiple injuries resuscitated with large volume infusions and monitored by transpulmonary thermodilution technique and gastric tonometry. It is very important to monitor regional hemodynamics that enables clinician to maintain the required relations between global and regional hemodynamics. It prevents the development of MOF and patient death.

Key words: Resuscitation – methods; Multiple trauma – complications; Hemodynamics; Emergency treatment – methods; Case report

Introduction

Hemorrhagic shock is the main cause of shock in patients with multiple trauma¹. Inappropriate treatment leads to cell hypoxia and death². Intravenous infusion fluids are the main therapy for patient stabilization and reduction of shock effects³.

The main goals of therapy are divided into three groups: (a) mean arterial pressure (MAP), heart frequency and diuresis optimization; (b) venous preload, cardiac output (CO), mixed venous oxygen saturation (SvO₂), oxygen delivery (DO₂) and regional hemodynamics (splanchnic perfusion) maintaining; and (c) hypoperfusion laboratory markers (lactates, pH, base loss) normalization⁴. Venous preload is defined as the level of venous preload that can achieve adequate cardiac function and systemic perfusion⁵. The lack of optimal venous preload predictors and empirical fluid infusions are closely connected with a high risk of overfilling, intravascular and extravascular compartment. Hyperthermia, coagulopathy and abdominal compartment syndrome are the most common complications of large volume resuscitation⁶. According to some authors, aggressive volume resuscitation performed within the first 24 hours of trauma improves patient outcome⁷.

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Methods

We used minimally invasive hemodynamic monitoring PiCCO (Pulsion, Medical System, Germany) and gastric tonometry (Tonocap, Datex-Ohmeda, USA). PiCCO is an abbreviation that means pulse contour cardiac output. PiCCO continuously analyzes the curve of invasive arterial pressure after initial measurement of CO by transpulmonary thermodilution technique without using pulmonary artery catheter. Thermistor probe is inserted through brachial artery. We give a bolus of 20 mL of cold water, temperature about 5°C, through central venous catheter. Thermistor then measures change in the blood temperature and extrapolates hemodynamic calculations from the pulse contour and shape of the hemodynamic curve. It is also adjusted to monitor invasive pressure as an important parameter in global hemodynamics.

PiCCO data are related to: (a) venous preload: intrathoracic blood volume (ITBV), global end-diastolic volume (GEDV), stroke volume variation (SVV), pulse pressure variation (PPV); (b) heart contractility: stroke volume (SV), global ejection fraction (GEF); and (c) afterload: systemic vascular resistance (SVR).

The volume substitution was monitored by parameters that are related to venous preload: ITBV, GEDV and central venous pressure (CVP) measurement. These actions prevent overfilling and optimize volume load.

Gastric tonometry is a monitoring device for regional-splanchnic perfusion. It measures pH in gastric mucosa by diffusion of CO₂ from gastric content to cuff of tonometric probe. Gastric pH (pHi) is an indicator of stomach and splanchnic perfusion. pH values of 7.2 and lower are indicative of hypoperfusion. This method measures CO₂ gap in two ways, i.e. as a difference between pCO₂ in gastric mucosa and arterial blood (PaCO₂); and gastric mucosa and expired air (EtCO₂), in normal conditions lower than 10-15 mm Hg.

Case Report

A 24-year-old man was admitted to intensive care unit (ICU) after having sustained a motorbike accident. He had multiple injuries. His incoming vital parameters upon admission were as follows: Glasgow Coma Score (GCS) 12 points (3,3,6), noninvasive blood pressure (RR) 50/40 mm Hg, sinus tachycardia 165/minute, respiratory frequency 16/minute, arterial oxygen saturation (SaO₂) 90%, and afebrile.

Clinical examination followed by radiological diagnostic procedures revealed severe trauma with hemorrhagic shock; bilateral frontal intracerebral hematomas; paraplegic lower extremities; left femur complicated fracture with hemotoma forming compartment syndrome; left lower leg complicated fracture with compartment syndrome; left femoral and saphenous vein and left femoral circumflex artery rupture; and left iliac and right pubic bone fracture.

He was immediately endotracheally intubated and mechanically ventilated (pressure controlled ventilation) after developing acute respiratory insufficiency. Therapeutic procedures were divided in two parts: first, resuscitation with large volume of intravenous fluids in order to maintain adequate venous preload and normalize global and regional hemodynamics; second, the patient was prepared for urgent surgical procedure that took four hours according to the criteria for damage control surgery.

Surgical procedure was performed as follows: incision of the left lower leg and evacuation of the hemotoma; ligature of the left circumflex femoral artery; sutures of the left saphenous vein; fasciotomy of the left upper leg; and external fixation of the left femur and tibia. Simultaneously, volume resuscitation was guided by global hemodynamic parameters (PiCCO) and regional hemodynamic parameters (Tonocap). He was mechanically ventilated for 7 days. Additional surgical procedures were performed according to the criteria for damage control surgery.

Ultimate length of hospitalization in ICU was 21 days. Recurrent acute respiratory insufficiency de-

| Table 1: Fluids for intravenous infusion used during the first 24 hours of resuscitation |
|-----------------------------------------------|--|
| Solution                                      | Total (mL) |
| Hyperoncotic hyperosmolar (10 % NaCl)         | 200        |
| Crystalloids                                  | 9300       |
| Plasma alternatives (6% HAES)                 | 2000       |
| Blood                                         | 11550 (24 doses) |
| Fresh frozen plasma                           | 2850       |
| Total                                         | 25900      |
| Intraoperatively                              | 9860 mL    |
developed on postoperative day 14 due to pulmonary microembolism. The patient was reintubated and mechanically ventilated for the next two days. Left parietal ischemia resulted in right leg paresis.

After 21 days of ICU stay, the patient was transferred to Department of Traumatology. Three months later he started rehabilitation program.

During the first 24 hours, resuscitation volume load was 25900 mL and 9860 mL intraoperatively (Table 1). The efficacy of volume resuscitation was guided by maintaining venous preload according to intrathoracic blood volume index (ITBVI) and global end diastolic volume index (GEDVI). Indexed values are absolute values per body surface. Minimal ITBVI during resuscitation was 410 mL/m² and GEDVI 328 mL/m². These values resulted in cardiac index (CI) of 2.74 L/min/m². CI could also be normalized by normalization of GEDVI and with conditional ITBVI more than 600 mL/m² (Fig. 1).

The response to volume load was monitored by SVV and PPV with consequential normalization of CI and MAP. The effect of volume load on splanchnic perfusion was monitored by pCO₂ gap; difference in partial pressure of carbon dioxide between gastric cells and arterial blood (PaCO₂); and estimated gastric mucosa acidity (pHi). In our case, we maintained pCO₂ gap 30 mmHg and lower, which was a sign of preserved splanchnic perfusion (Fig. 2). Lung function was estimated by monitoring extravascular lung water index (EVLWI) and pulmonary vascular permeability index (PVPI) to avoid pulmonary edema. CI rising, SVV and PPV less than 10% were indicative of the patient’s good response to volume load.

Discussion

In patients with multiple injuries, MOF is still very high despite advances in resuscitation, organ support techniques and better understanding of the metabolic response to trauma ranging from 14% to 42%.

Volume resuscitation is the basis of hemodynamic stabilization of patient in hemorrhagic shock. Appropriate venous preload is the first step in maintaining adequate perfusion in patients with multiple traumas. In this way, volume resuscitation has favorable effect on splanchnic perfusion monitored by gastric tonometry and results in better values of prognostic scores. In our case, we used Acute Physiology and Chronic Health Evaluation Score (APACHE II) and Multiple Organ Dysfunction Score (MODS) for status evaluation on admission. On admission, APACHE II score was 28 with 63% predictive mortality; at 48 hours it was 10 with 11.3% predictive mortality. MODS was 9 in the first 24 hours (hospital mortality rate of 50%); at 48 hours MODS was 3 (hospital mortality rate of 11.3%). Standard therapeutic procedure during fluid resuscitation has to achieve correction of global hemodynamic variables that correlate with blood pressure, consequently leading to variable

![Fig. 1. Changes in intrathoracic blood volume index (ITBVI), global end diastolic volume index (GEDVI) and cardiac index (CI) during volume resuscitation.](image1)

![Fig. 2. pCO₂ gap during volume resuscitation.](image2)
outcome of critically ill patients. Outcome variability is the consequence of unrecognized shock masked by the patient compensatory mechanisms that lead to the state of shock despite normal blood pressure and heart frequency. Corrected global hemodynamics is not a predictor of damaged tissue oxygenation recovery. Regional variables of splanchnic perfusion are considered as better predictors of the existence of unrecognized shock.

Poëze et al. showed that there was no superior hemodynamic variable in critically ill patients, which could be recognized as outcome predictor. The variables of splanchnic perfusion were found to be better predictors of outcome. In our case, the aforementioned variables also proved to be better predictors in relation to global hemodynamics, pressure and volume variables. On the other hand, supranormal volume resuscitation could result in intestinal perfusion reduction and development of abdominal compartment syndrome causing MOF and patient death. Only carefully selected patients can benefit from volume resuscitation (preload responsiveness).

Optimization of the circulating blood volume in a patient with multiple trauma is the most important point in normalization of global hemodynamics, which should be achieved as soon as possible, along with maintaining adequate splanchnic perfusion.

In most cases, correct diagnosis and therapy depend on precise measurement of hemodynamic parameters in critically ill patients. Although pulmonary artery catheter is the “gold standard” of hemodynamic monitoring, less invasive methods such as PiCCO, Lithium Dilution Cardiac Output Measurement (LiDCO plus; LiDCO, Cardiac Sensor Systems, United Kingdom), transthoracic and transesophageal echocardiography are used for hemodynamic monitoring and volume status assessment in critically ill patients.

PiCCO as a less invasive method analyzes the curve of invasive arterial pressure after initial measurement of cardiac output using transpulmonary thermodilution technique.

Volumetric parameters such as ITBVI and GEDV are the parameters that evaluate venous preload. Together with EVLWI, they make possible optimization of volume therapy in critically ill patients.

In routine assessment of volume status, cardiac load is assessed by measuring CVP and PCWP (pulmonary capillary wedge pressure). These filling pressures of the heart are indirect indicators of volume status; hence intravascular volume does not correlate with the values of the mentioned pressures. ITBVI is a better indicator of venous preload than CVP and PCWP in critically ill patients.

Determination of volumetric parameters was found to be a very good method in resuscitation of patients with multiple trauma. In our case, ITBVI reflected both changes, i.e. changes in volume status and cardiac output. ITBVI is an indicator of total venous preload. In septic patients with pulmonary edema, ITBVI and GEDVI as volume variables are better indicators of EVLW assessment than pressure variables. Assessing ventricular filling and recognition of patients that will benefit from volume resuscitation preload are important determinants of good clinical outcome.

PiCCO hemodynamic monitoring allows for assessment of SVV. In patients on mechanical ventilation, this functional hemodynamic monitoring may identify those that will benefit from therapy with intravenous fluid-volume responsiveness. It shows the potential of cardiac output increase upon volume load.

Clinical studies show that changes in cardiac index are in correlation with changes in ITBVI, but not with SVV. Continuous monitoring of SVV is a predictor, but also allows for opportune therapy as part of overall hemodynamic treatment.

Gastric tonometry assesses splanchnic perfusion and facilitates clinician’s decision on the necessary supranormal values of global hemodynamic parameters. In life threatening hypovolemia and intestinal ischemia as early signs, it will protect from MOF development. Gastric tonometry as a minimally invasive method and prognostic indicator of occult hypovolemia is a guide for appropriate therapeutic procedure. This way of intestinal perfusion monitoring can decrease the episodes of mesenterial ischemia and improve outcome in critically ill patients. Gastric tonometry as a noninvasive method of intestinal mucosa perfusion (stomach or sigmoid colon) is sensitive for lower blood flow.

pHi under 7.2 indicates ischemia. Problems with pHi determination are due to the fact that equal arterial blood and gastric mucosa bicarbonate concentration with regional perfusion changes can disturb this relation.
Clinical studies show that low pH in patients with multiple traumas is associated with the development of MOF and death\(^\text{14}\). Chang \textit{et al.}\(^\text{5}\) report that supranormal values of venous preload during resuscitation were connected with better patient outcome and lower incidence of MOF and death. Low pH during resuscitation can be understood as an indicator of insufficient resuscitation and a mechanism of MOF development\(^\text{35}\). Studies focused on therapeutic treatment in order to increase pH showed improvement in patient outcome\(^\text{36}\). Gomersall \textit{et al.}\(^\text{33}\) evaluated 210 patients with pH lower than 7.35 after resuscitation. This group of patients received colloid and dobutamine infusions. The authors conclude that therapy titrated towards high pH in critically ill patients cannot be accepted. There was no difference in disease outcome. The reason for this is either disability to produce significant clinical change in pH or it is simply a marker of disease rather than a factor of MOF pathogenesis\(^\text{37}\).

Large volume resuscitation is obligatory in polytraumatized patients to achieve adequate tissue perfusion. It is associated with complications and minimally invasive monitoring is necessary for its optimization. Volumetric parameters allow for appropriate preload assessment, which is the basis of volume resuscitation. Regional hemodynamics monitoring is important and enables the clinician to maintain the relation between global and regional hemodynamics, thus preventing MOF and patient death.

**Conclusion**

In patients with severe trauma, aggressive volume resuscitation is an imperative to achieve adequate tissue oxygenation. It is associated with complications and minimally invasive monitoring carries the potential for its optimization. Volumetric parameters allow for an appropriate assessment of preload, which is the basis of volume resuscitation. Regional hemodynamics monitoring is important and enables the clinician to maintain the relation between global and regional hemodynamics, thus preventing MODS and death in these patients.

**References**

Sažetak

REANIMACIJA BOLESNIKA S VIŠESTRUKIM OZLJEDAMA VELIKIM VOLUMENOM KRISTALOIDNIH-KOLOIDNIH INFUZIJA – KORELACIJA IZMEĐU OPĆE I REGIONALNE HEMODINAMIKE: PRIKAZ SLUČAJA

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Agresivna reanimacija velikim volumenom je neophodna kako bi se postigla potrebna tkivna oksigenacija. Dostatnom prethodnom venskom opskrbom normalizira se opća hemodinamika i izbjegava višeorgansko zatajenje i smrt kod bolesnika s višestrukim ozljedama. Reanimacija velikim volumenom udružena je s komplikacijama u slučaju nedostatnog nadzora bolesnika. Ispravno voden postupak reanimacije u konačnici će spriječiti višeorgansko zatajenje i smrt bolesnika. Tehnika transpulmonalne termodilucije i želučana tonometrija primjenjuju se u nadzoru venske opskrbe, izračunavanju volumetrijskih hemodinamskih varijabla i procjeni visceralne prokrvljenosti. Prikazuje se slučaj 24-godišnjeg mladića s višestrukim ozljedama, kod kojega je provedena reanimacija infuzijama velikog volumena i nadzor pomoću tehnike transpulmonalne termodilucije i želučane tonometrije. Vrlo je važno nadzirati regionalnu hemodinamiku, jer to kliničaru omogućuje održavanje potrebnih odnosa između opće i regionalne hemodinamike. Time se priječi razvoj višeorganskog zatajenja i smrt ovakvog bolesnika.

Ključne riječi: Reanimacija – metode; Višestruke traume – komplikacije; Hemodinamika; Hitno liječenje – metode; Prikaz slučaja