CASE REPORT

Hemodynamic monitoring using PiCCO® system in a 10 months old infant suffering from serious burn injury

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Abstract

In this study, authors present a case report of a 10 months old patient with burn injuries involving 20.5 % body surface area, grades 2a and 2b. According to the continuous monitoring of hemodynamic parameters by PiCCO® (Pulsion Medical Systems, Munich, Germany), fluid therapy was successfully managed. Despite of an increasing EVLWI (extravascular lung water index) it was possible to preserve the child from lung edema and subsequent artificial lung ventilation by the early targeted therapeutic interventions. Moreover, the study analyzes the possibilities and indications of less invasive hemodynamic monitoring supplied by PiCCO® in children *(Tab. 2, Fig. 3, Ref. 7)*. Full Text (Free, PDF) *www.bmj.sk*.

Key words: PiCCO^R, hemodynamic monitoring, children, indications, burn injury, fluid therapy, analgesia, sedation.

Burn injuries represent a significant component in small children's morbidity and mortality. Depending on the severity of burn injury, burn injuries are divided into three grades:

Grade I – involves only epidermis injury, presents with painful skin redness like in insulation; will heal spontaneously

Grade II – extends up to the dermis, presents with skin redness and builds blisters with wet base; profound hyperalgesia is typical. After a gently pressure on the injured area, the red color disappears. Deep second grade burn injury is less painful due to nociceptor destruction. Superficial second grade 2a burns heals spontaneously, deep 2b needs surgical intervention.

Grade III – extends to the subcutis. Superficial third grade burns have blisters with dry base, in deep third grade burns the skin delaminates. Nails and hairs get loose somewhat painless. Third grade burn injury always needs a surgical intervention (1).

Deliberation of vasoactive substances from the burned tissue destroys capillary endothelial cells and may cause "capillary leak" syndrome also in remote areas all over the body. Other factors participating on edema include hypoproteinemia with subsequent low oncotic and elevated osmotic pressure in the burned tissue. Additional inhalation trauma and/or burned airways always present a very serious situation in children (2).

Early onset of an adequate fluid resuscitation may significantly reduce the incidence of multiorgane failure (MOF) and mortality of burned patients. In the first 24 hours, cardiac output decreases due to hypovolemia, elevated systemic vascular resistance and myocardial depressant factor (MDF) (2). Children, in contrast to adults, have an increased body surface area to weight ratio, lower concentration ability in the kidney and decreased fluid reserves. Their skin is thin so practically all burn injuries tend to third grade injury (3).

During the first 24 hours after burn injury, we use the modified Parklands' form for fluid replacement and maintain urine output over 1.5 ml per kilogram body weight per hour in our institution. In severe cases, we use the PiCCO^R to monitor hemodynamic parameters.

Invasive monitoring of hemodynamic parameters, regardless of the method used, provides beneficial effects by giving overview in both basic and derived hemodynamic parameters. Interpretation of measurements, derived parameters and their relationships need correct clinical interpretation, regarding the actual situation in a given patient. Physician should choose the hemodynamic monitoring system for the particular patient, able

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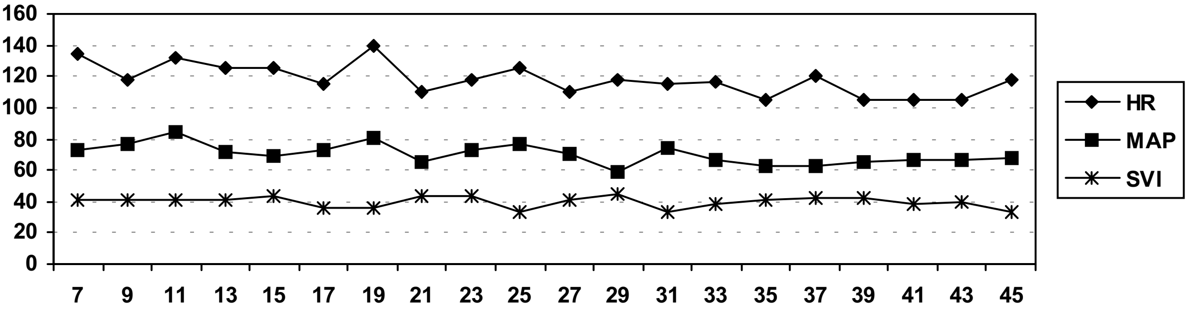

Fig. 1. Characteristics of hemodynamic parameters over the time (time from injury in hours).

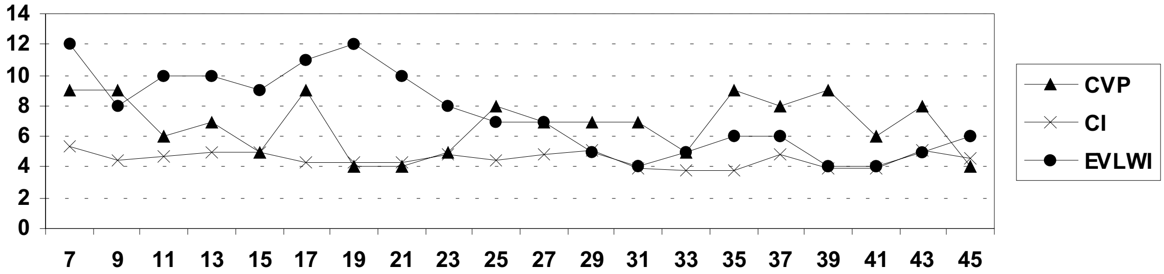

Fig. 2. Characteristics of hemodynamic parameters in time (time from injury in hours).

to give valid data. Simplicity and low invasivity clearly precedes complicated and invasive hemodynamic monitoring systems.

The PiCCO® (Pulse Contour Cardiac Output, Medical System, Munich, Germany) monitoring system enables a minimal invasive hemodynamic monitoring for both anesthesia and intensive care medicine setting. Recently, it is the first device which facilitates hemodynamic monitoring of even the youngest and smallest patient population. Minimal invasivity in this case means the possibility to use standard devices, namely arterial and central venous catheters, without the need to insert some additional catheter.

Cardiac output (CO) is continuously calculated from the arterial pulse wave analysis, based on the parameters from transpulmonary thermodilution and from central venous pressure (CVP). Indexed parameters are calculated in relation to patient's height and weight.

Cardiac output is determined by the Stewart-Hamilton thermodilution method. Eight grade Celsius cold crystalloid solution is used as an indicator fluid and injected rapidly (at least less than 5 seconds) into the distal lumen of the central venous catheter probe – PV 4045. Cardiac output is calculated from the equation:

$$CO = [(T_b - T_i) \times V_i \times K] : (\int \Delta T_b \times dt)$$

where T_b and T_i are blood and injectate temperatures, respectively. V_i represents injectate volume, K is correction constant and ($\int \Delta T_b b \times dt$) represents the area below the thermodilution curve.

Hemodynamic parameters are presented in the indexed form, what makes the clinical interpretation easier in a broad spectrum of pediatric population. The therapeutic schemata enclosed to the device are very helpful for quick clinical orientation in monitored parameters. Naturally, therapy decisions must be targeted to the individual patient (2).

Case report

A 10 months old male, weight 10 kg, height 70 cm was scald (trunk and extremities) with boiling water. Burn injury involved 20.5 % of body surface area, the severity was 2a and 2b. First surgical dressing – wound toilet and coverage with xenotransplantate and Dermaziner ointment application was performed in analgosedation with ketamine. After this intervention, the patient was admitted on our Pediatric Intensive Care Unit in the Institute of Pediatric Anesthesia and Intensive Care Medicine, Children's University Hospital Bratislava, Slovakia for observation and subsequent therapy. After admission, central venous catheter (5.5 French, 3 Lumina, Arrow[R]) was inserted through right jugular internal vein and an arterial line (Pulsiocath® PV 2013L07) through the right femoral artery was inserted in general anesthesia and endotracheal intubation. Both catheter positions were controlled by X-ray. Urinary bladder catheter (8 French) was placed too. After termination of general anesthesia and subsequent adequate spontaneous ventilation, the patient was extubated and a complex antibiotic, analgesic, fluid and supportive therapy was provided. Continuous monitoring of heart rate, central body temperature, urine output, breathing frequency, blood

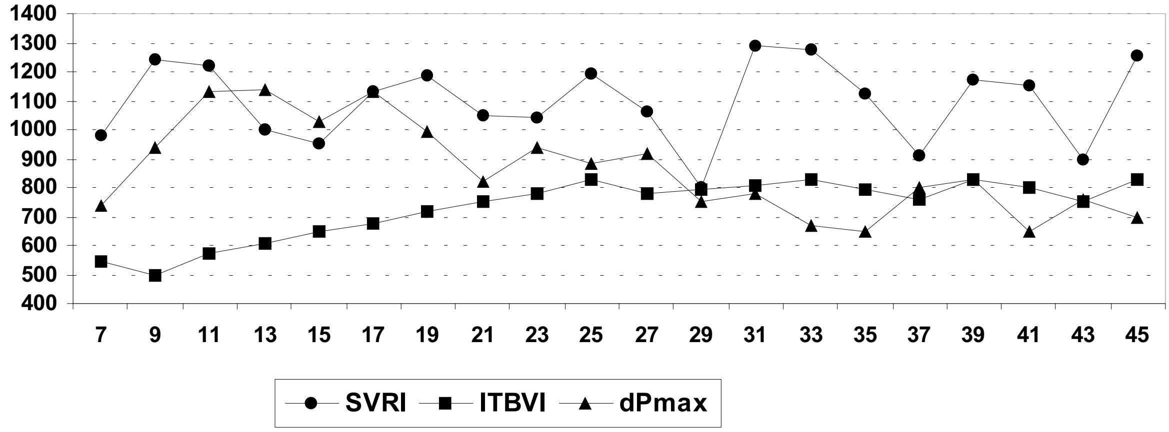

Fig. 3. Characteristics of hemodynamic parameters in time (time from injury in hours).

oxygen saturation, central venous pressure, invasive arterial blood pressure and hemodynamic parameters from PiCCO[R] was established.

During four days lasting hospitalization, analgesia was maintained by petidine, metamizol and paracetamol, sedation with midazolam and 10 % chloralhydrate per rectum was applied by need. Fluid substitution according to the modified Parkland's formula was primarily substituted with Ringer lactate and normal saline solutions, 10 % Dextrose with normal saline; even 150 ml of fresh frozen plasma was administered (once). This fluid management was continuously refined according to monitored hemodynamic parameters. Subsequently, urine production was, due to the increase of EVLWI and onset of lover extremities swelling, supported by furosemide in total dose of 11 mg on the second day (Figs 1, 2 and 3). Later, spontaneous urine production was sufficient. On the second day, the patient was able to tolerate per oral administration of fluids such as tea and later full fluid nutrition for infants. The subsequent 2 days were without complications, the child was afebrile, and all measured vital parameters were stable and acceptable. On the fourth day the patient could be discharged from the PICU and transferred to the surgical department (Tabs 1 and 2).

Discussion

1) In this patient, we expected the development of respiratory failure with subsequent need for artificial lung ventilation regarding his young age, the severity of the burn injury (2a, 2b) and a large involved body surface area (20.5 %) from the beginning. Therefore we immediately applied a minimal invasive monitoring of hemodynamic parameters using PiCCO[R]. Noninvasive blood pressure measurement was due involved all extremities almost impossible. Amount of administered fluids was primarily set up according to the modified Parklands' formula = 4 ml x body weight in kilograms x % of body burned area + 1500 ml/m^2.

2) Fluid administration was managed according to the patient's clinical status, hemodynamic parameters, urine output, biochemical examinations, perspiration losses and body temperature. Thanks to the strict monitoring of all hemodynamic parameters, it was possible to prevent general edema with consecutive respiratory insufficiency and the need for artificial lung ventilation. Our patient breathed humidified oxygen with an inspired fraction of 0.3 via face mask. Sufficient analgesia and sedation in severe sick children are very important, too (4).

3) Today, technical improvements enable us to use less invasive, but more meaningful and precise monitoring devices in critically ill patients. Lower invasiveness always means a lower risk of serious complications. In pediatric patients, we frequently identify the problem to choose the "right" magnitude of pulmonary catheter; also the insertion must not be without problems. For minimal invasive, continuous hemodynamic monitoring system

Tab. 1. Fluid balance (excluding calculation of losses by perspiration and defecation).

Day	Intake (ml)	Intake (ml/kg/day)	Output (ml)	Diuresis (ml/kg/h)	Fluid balance (ml)
1st	965	96.5	384	2.74	+581
2nd	1473	147.3	843	3.51	+630
3rd	1528	152.8	975	4.06	+553

Tab. 2. Monitored hemodynamic parameters.

Heart rate HR (1/min)
Mean arterial pressure MAP (mmHg)
Central venous pressure CVP (mmHg)
Indexed cardiac output CI (l/min/m^2)
Indexed stroke volume SVI (ml/m^2)
Indexed systemic vascular resistance SVRI (dyn.sec.cm^{-5})
Indexed intrathoracic blood volume ITBVI (ml/m^2)
Extravascular lung water index EVLWI (ml/kg)
dPmax (mmHg/s)

"PiCCO®" we do not have to immobilize the patient, as it is in the Swan-Ganz pulmonary artery catheter. In contrast, PICCO® enables sneezing and coughing without the risk of imminent pulmonary vessel perforation. The use of pulmonary catheter is still a reason to quarrel between critical care physicians, more than 35 years after its development. Despite all these negative sights, pulmonary catheter still presents the "golden standard" in an invasive hemodynamic monitoring (5).

In the youngest patient's community, accuracy and correct presentation of measured values is limited due to different lung compliance and spatial relationships between intrathoracic organs. This is the reason for consensus on clearly defined indications of pulmonary catheter in the pediatric intensive care (6). There was a clear statement by the expert's group of the "Pulmonary Artery Catheter Consensus Conference in Chicago" in 1996: Clear and evident indications for pulmonary catheter in clinical practice don't exist due to lack of evident clinical studies. The Chicago consensus could only recommend monitoring of hemodynamic parameters with pulmonary catheter at children on the base of non randomized studies, patient's groups from non-controlled studies supported with Level V – "expert's opinion". This conference considered pulmonary artery catheter indicated in critical ill pediatric patients with pulmonary hypertension, in volume therapy resistant shock, Adult Respiratory Distress Syndrome with high airway pressure, and Multiorgane Distress Syndrome (7).

In our patient, the Swan-Ganz catheter for continuous cardiac output measurement could not be beneficial, because it even doesn't exist for 10 kg infant. Repeated manual measurements could be a risk for circulatory volume overload in the small infant.

After the calibration using thermodilution, PiCCO® quickly provides beat-to-beat information about cardiac output by correlating pulse contour analysis (represented by the area under the systolic part of the pressure curve) with stroke volume of the heart. Additionally, we get ITBV (intrathoracic blood volume) as a surrogate parameter of cardiac preload, the CFI (cardiac function index, calculated by the CI/GEDVi ratio) for contractility and EVLW (extravascular lung water) to give us contemporary information about capillary leakage, hyperhydratation and developing pulmonary edema. At least, PICCO®, in contrast to pulmonary catheter, enables measurement of stroke volume variation (SVV) in ventilated patients, which is a very important parameter to predict patient's volume responsiveness. The importance of this parameter was however limited in our patient due to spontaneous ventilation. In total, PiCCO® provides information about volumes instead of pressures and for that a more reliable and independent information about the volume status of a patient.

Due to the negative hsitory and a clinically normal cardiac function on admission, we didn't expect an acute development of cardiac failure with elevated pulmonary wedge pressures in our patient – this was an additional reason against a pulmonary artery catheter.

At last, pulmonary artery catheter represents a non negligible risk for lung perforation, thrombus building, infectious complications, heart rhythmus disturbances and needs a deeply sedated patient, especially in small children.

4) Extended invasive hemodynamic monitoring in adult patients with burn injury is recommended if more than 30 % of body surface area is affected (1). In the presence of additional trauma or severe concomitant disease, the total amount of burned body surface area is less important. In pediatric patients – due to their lower reserves – the indication for an extended hemodynamic monitoring may be not that restrictive. As we were able to show in this study, increased invasiveness in hemodynamic monitoring at the beginning care could perhaps prevent the patient from the need of ventilatory support and associated complications.

5) Regarding the costs, the shortening of ICU stay due to avoidance of ventilation at least equals the expenses.

6) Based on the patient's spectrum at the Institute of Pediatric Anesthesia and Intensive Care Medicine, Children's Faculty Hospital Bratislava, Slovak Republic, we postulated subsequent internal indications where PICCO^R monitoring in pediatric patients should be considered:

– Hemodynamic unstable patients who need an invasive blood pressure monitoring
– Patients with pulmonary pathology who need an agressive artificial lung ventilation with high PEEP level (>8)
– Patients with ALI and ARDS
– Patients with severe trauma, polytrauma and burn injury
– Patients with craniocerebral injury, where PICCO^R can participate in complex invasive neuron-monitoring by equilibrating volume and vasoconstrictor therapy
– Patients with heart insufficiency
– Patients in shock (hypovolemic, cardiac, septic) or MODS
– Surgery with suspected high blood loses and volume replacement, for example liver and other organ transplantations
– Patients with hormonal active tumors (pheochromocytoma, neuroblastoma, etc.)
– Patients in an acute need of extracorporeal elimination methods
– Patients with intoxications and instable circulation

7) Beside the optimal hemodynamic management, attention should be paid to the pain management: though pain is a subjective sense, which the youngest group is sometimes not able to express clearly, neither determine its origin and intensity. An adequate pain management is very important in all pediatric patients due to the prevention of the later development of posttraumatic stress disorder and complex regional pain syndrome (4).

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