The Association between Mean Arterial Pressure, Central Venous Pressure, Cerebral Perfusion Pressure, Lung Oxygenation, and Glasgow Coma Scale in Sepsis Patients in the Intensive Care Unit

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Abstract

BACKGROUND: Sepsis is the most frequent condition encountered in the intensive care unit (ICU). One of the neurological features of sepsis is sepsis-associated encephalopathy (SAE). The exact pathophysiology of SAE remains unclear. Many factors have been linked to SAE, such as hypotension, hypoxemia, and other metabolic abnormalities. However, alteration of cerebral blood flow is thought to be the main culprit behind SAE.

AIM: This study aims to evaluate and find correlations between mean arterial pressure (MAP), central venous pressure (CVP), cerebral perfusion pressure (CPP), PaO2/FiO2 (PF) ratio, Glasgow Coma Scale (GCS), and level of consciousness.

METHODS: A cross-sectional study was conducted from March 2020 to October 2020 in the ICU of H. Adam Malik Central Hospital, Medan, Indonesia. Patients over 18 years old with sepsis were included in this study. We recorded the demographic data, MAP, CVP, CPP, PF ratio, and GCS in the 1st hour of ICU admission. The data were then analyzed to find the correlation between these parameters.

RESULTS: The total subjects in this study were 62 patients, with an equal ratio of male-to-female. A quarter of the patients were intubated, affecting the GCS assessment. The median of GCS was 12. Most patients (46.8%) were over 60 years old. There was no correlation between MAP, CVP, CPP, PF ratio, and GCS, and level of consciousness in this study.

CONCLUSIONS: Our study found no correlation between MAP, CVP, CPP, PF ratio, GCS, and level of consciousness in sepsis patients.

Introduction

The mortality rate of sepsis patients in the intensive care unit (ICU) remains very high, ranging from 30% for sepsis to 80% for septic shock. The high mortality usually aligns with delay in diagnosis and treatment of sepsis. In critically ill patients, a worsening condition may occur when oxygen delivery fails to meet tissue oxygen demands. The result is compensation in the form of increased oxygen extraction. If the imbalance between oxygen delivery and extraction is not corrected rapidly, the compensatory response will slow down, causing oxygen deprivation, systemic tissue hypoxia, anaerobic metabolism, and an increase in lactate production [1, 2]

Sepsis-associated encephalopathy (SAE) is one of the most common and poorly understood neurological manifestations of sepsis. The presentation of SAE may vary, from a mild altered level of consciousness to deep coma. In sepsis patients, the brain can be affected by systemic disturbances, such as hypoxemia and hypotension. Inflammation by itself also causes profound alterations in cerebral homeostasis. Alterations of the cerebral blood flow (CBF) may represent a key component for developing SAE. Hypotension will cause reduce CBF and oxygen extraction by the brain. Other possible explanations include disruption of the blood-brain barrier and cerebral edema that may arise from inflammatory mediators, an abnormal neurotransmitter of the reticular activating system, and neuronal degeneration [3, 4, 5, 6].

Central venous pressure (CVP) is often used in ICU to monitor hemodynamic status. Factors that can reduce CVP are hypovolemia and vasodilation. Reduction in CVP may cause hypotension, resulting in lower mean arterial pressure (MAP) and CPP. Increased level of CVP has been associated with poor outcomes [7]. Tissue hypoxia can be caused by three general abnormalities: Impaired oxygen delivery, hypoxemia, and impaired cellular oxygen uptake. Hypoxemia is a condition when the PaO2 - 80 mmHg.
Managing hypoxia traditionally involves improving oxygen delivery and focuses on blood oxygenation (PaO2 and hemoglobin) and cardiac output (CO) [8], [9].

Based on these connections, we conducted this study to evaluate whether there are correlations between MAP, CVP, CPP, and lung oxygenation with the outcome of reducing GCS in sepsis ICU patients.

Methods

An analytic study with a cross-sectional design was conducted from March to October 2020 in the ICU of H. Adam Malik Central Hospital, Medan. The sampling method in this study was consecutive sampling. All patients over 18 years old with sequential organ failure assessment (SOFA) or quick SOFA (qSOFA) scores of more than two were included in this study. The parameter of lung oxygenation used in this study was PaO2/FiO2 ratio which PaO2 obtained from arterial blood gas analysis. All measurements were performed within the 1st h of ICU admission. The demographic data, CVP, CPP, MAP, PaO2/FiO2 ratio, and GCS were analyzed. The GCS of intubated patients were evaluated with a method that was developed by Brennan et al., which can be seen in Figure 1 [10].

Table 1: Characteristics of subjects

| Characteristics     | Descriptive (n = 62) |
|---------------------|----------------------|
| Gender              |                      |
| Male                | 31 (50%)             |
| Female              | 31 (50%)             |
| Intubated patients  | 16 (25.8%)           |
| Age, (mean ± SD)    | 54.84 ± 13.25 years  |
| MAP, (mean ± SD)    | 96.23 ± 19.78 mmHg   |
| CVP, (mean ± SD)    | 8.15 ± 2.75 mmHg     |
| CPP, (mean ± SD)    | 88.1 ± 20.46 mmHg    |
| GCS, median         | 12 (10–14)           |

Table 2: Correlation of MAP, CVP, CPP, PF ratio, and GCS

| Variables           | p value |
|---------------------|---------|
| MAP × GCS           | 0.546   |
| CVP × GCS           | 0.886   |
| CPP × GCS           | 0.569   |
| PF ratio × GCS      | 0.716   |

Table 3: Correlation of MAP, CVP, CPP, PF ratio, and level of consciousness

| Level of consciousness | Mean rank | p value |
|------------------------|-----------|---------|
| Compos mentis          | n = 11    |         |
| Somnolence             | n = 29    |         |
| Sopor                  | n = 14    |         |
| Coma                   | n = 8     |         |
| MAP                    | 28.41     | 0.352   |
| CVP                    | 25.09     | 0.560   |
| CPP                    | 29.45     | 0.401   |
| PF ratio               | 35.68     | 0.359   |

Discussion

In sepsis patients, the brain function may be affected by several systemic disturbances such as abnormal glucose level, hypotension, hypoxemia, and organ dysfunction, for example, high ammonia or urea. Aside from these metabolic effects, inflammation itself also plays a key role in managing cerebral homeostasis [4].

Severe hypotension was found to be the only predictor of sepsis-associated delirium in a multiple logistic regression analysis. MAP tends to be lower in severe sepsis and septic shock patients. Accordingly, the level of CPP is low as well. When MAP drops...
significantly, blood flow won’t be able to perfuse cerebral tissues and, therefore, causes loss of consciousness and probably neuronal death. Based on the formula below, we can conclude that CPP is directly proportional to MAP [11], [12], [13].

\[
\text{CPP} = \text{MAP} - \text{ICP} \\
\text{CPP} = \text{Cerebral Perfusion Pressure} \\
\text{MAP} = \text{Mean Arterial Pressure} \\
\text{ICP} = \text{Intracranial Pressure}
\]

In our patients, MAP was controlled very tightly, sometimes with vasopressor or fluid, explaining why we did not find an association between MAP and GCS. The concept of inadequate cerebral perfusion as one contributor to brain damage in sepsis is supported by earlier work showing reduced CBF in patients with sepsis utilizing the xenon-133 clearance technique [11].

Near infra-red spectroscopy (NIRS) is an increasingly used non-invasive tool to assess cerebral oxygenation. The tissue oxygenation index has been satisfactorily validated, and recent work has confirmed that it is not influenced by external factors such as hemoglobin concentration or skull thickness. The use of NIRS and transcranial Doppler (TCD) in detecting CPP has shown excellent results [6].

CVP is also used to estimate a patient’s preload. It is considered one of the indices of IVS (Intravascular Volume Status) and cardiac function. Based on Frank Starling Law, vascular resistance should match CO as determined by CVP gradient. Changes of CO will affect blood pressure and, thus, affect MAP. Changes in CO that is associated with CVP are very crucial concerns in treatment of critically ill patients (Table 4) [14], [15].

New evidence suggests no absolute direct correlation between CVP and the total blood volume present in the circulation. CVP was found to be a poor predictor of fluid responsiveness. Another reason is that the measurement of CVP may vary from one person to another. A survey reported that 75% of respondents made an error in the measurement of CVP [16], [17].

One of the limitations of this study was our inability to determine CPP using the method of TCD or NIRS in measuring CPP. Instead, we obtained CPP from the subtraction of MAP with CVP. This method was more inferior than NIRS and TCD. A few subjects in this study were also mechanically ventilated and sedated. Therefore, sedation may cause bias in GCS and level of consciousness.

Conclusion

In this study, we found no correlation between CVP, MAP, CPP, PF ratio, and GCS with the level of consciousness in ICU sepsis patients. Further study is required to investigate this correlation with a better approach (NIRS or TCD) and larger subjects.

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