Correlation between right atrial venous blood gasometry and cardiac index in cardiac surgery postoperative period

Correlação entre gasometria atrial direita e índice cardíaco no pós-operatório de cirurgia cardíaca

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Abstract

Objective: To determine, even during the postoperative period, the reliability of the cardiac index correlated with the data provided by a central atrial venous blood gasometry in patients who underwent cardiac surgery.

Methods: From the sample of arterial and venous blood of right atrium gathered in postoperative period of cardiac surgery, it was determined the hemoglobin concentration and the gasometric study through what was observed of the venous oxygen saturation ($SvO_2$) and the partial pressure of oxygen from venous blood gathered in right atrium ($PvO_2$), add to the calculation of artery-venous difference of the oxygen content - radial artery / right atrium ($C(a-v)O_2$). Afterwards, these parameters were compared with the cardiac index determined by thermodilution.

Results: There was a good correlation between $SvO_2$, $C(a-v)O_2$ of the venous right atrial blood and cardiac index measured by thermodilution method, with sensibility and specificity good and high positive predict value and negative predict value. The $PvO_2$ demonstrated poor sensibility in the estimation of low output.

Conclusion: In cardiac surgery postoperative, the $SvO_2$ and the $C(a-v)O_2$ were safe parameters correlated with low cardiac output. The $PvO_2$ showed poor sensibility in the diagnosis of low output in postoperative cardiac surgery.


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Resumo

Objetivo: Determinar a confiabilidade em se correlacionar o índice cardíaco com os dados fornecidos pela gasometria do sangue venoso atrial direito em pacientes submetidos à cirurgia cardíaca, durante o período pós-operatório.

Métodos: A partir das amostras de sangue arterial e venoso do átrio direito, colhidas no período pós-operatório de cirurgia cardíaca, foram determinados os parâmetros de oxigênio do sangue venoso e arterial, e comparados com o índice cardíaco determinado por termo-diluição.

Resultados: Houve uma boa correlação entre $SvO_2$, $C(a-v)O_2$ do sangue venoso atrial direito e o índice cardíaco determinado por termo-diluição, com sensibilidade e especificidade boas e alto valor predictivo positivo e negativo. O $PvO_2$ demonstrou baixa sensibilidade na estimativa de baixo fluxo cardíaco.

Conclusão: No pós-operatório de cirurgia cardíaca, o $SvO_2$ e o $C(a-v)O_2$ foram parâmetros seguros correlacionados com baixo fluxo cardíaco. O $PvO_2$ mostrou baixa sensibilidade na diagnóstico de baixo fluxo cardíaco no período pós-operatório.

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individuals who had other concurrent diseases, such as chronic obstructive pulmonary disease, hematological disorders, and liver and kidney diseases have been excluded. the existence of anatomical abnormalities that would provide a mixture of intracardiac blood and moderate and/or severe tricuspid insufficiency was also an exclusion criterion.

one hour prior to the surgical procedure, a swan-ganz® catheter was inserted in each patient in the right pulmonary artery, at wedge zone ii, and a central venous catheter was inserted in the right atrium, both positioned with the assistance of radioscopy. a plastic catheter was also introduced in the radial artery in order to obtain continuous monitoring of mean arterial pressure and arterial blood samples for arterial blood gasometry study. all patients underwent cardiac surgery (four mitral valve repairs, one implantation of aortic valve prosthesis, and five implants of mitral valve prostheses) performed by the same team of the cardiovascular surgery service from the university hospital at federal university of mato grosso do sul. cardiopulmonary bypass support with similar technique and apparatus was used in all the cases.

in the postoperative period, the patients were initially kept under mechanical ventilation with a multiprocessor pressure-controlled respirator. they were also monitored by pulse oximetry, capnography, and ekg. bedside chest radiography confirmed the correct placement of catheters. arterial and right atrium blood samples were collected simultaneously from each patient, according to the need of hemodynamic and blood gasometry assessment. a total of ten samples from each patient were collected. the following parameters were determined: plasma hemoglobin (hb) concentration, arterial oxygen saturation (sa02), right atrium mixed venous oxygen saturation (sv02), partial pressure of arterial oxygen (pa02), and partial pressure of right atrium venous oxygen (pv02).

concurrently, with the collection of blood samples, the cardiac index was measured by thermodilution method.

introduction

the cardiac output monitoring has been incorporated into clinical practice, from studies by swan et al. [1] in 1970, with the idealization of a pulmonary artery catheter, which allowed the measurement of cardiac output by thermodilution after improvement in their structure, described by forrester et al. [2] in 1972. however, many criticisms have arisen about the risks and complications of using this apparatus, and that its use would increase the morbidity and mortality for patients [3]. but according to some recently published trials, effective studies are needed to determine the correct protocols to be followed and the groups of patients who may benefit from the use of swan-ganz® catheter [4-6].

new parameters have emerged as alternatives to cardiac function monitoring, such as the oxygen saturation of mixed venous blood, which according to studies by krauss et al. [7] and perner et al. [8] are well correlated with the values of cardiac output. because of the greater difficulty in obtaining the blood samples from the pulmonary artery, the blood collected from the right atrium has been used with good correlation with mixed venous blood [9].

objective

this study aims to determine the reliability to correlate low cardiac output with the data provided by gasometry of venous blood collected from the right atrium in patients undergoing cardiac surgery during the postoperative period.

methods

ten patients with heart valve disease referred for heart surgery were selected for the study, six males and four females, age ranging from 30 and 70 years (mean = 50.4 years). on echocardiography, these patients presented signs of both heart failure and ejection fraction lower than 40% (mean = 36.2% ± 4.2).

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using Swan-Ganz® catheter, and considering as the final value, the average of three consecutive measurements, since there were no differences greater than 10% between them. The measurement of this parameter during the period of mechanical ventilation was performed in the final phase of expiration.

Data provided by the analysis of the collected blood samples allowed the calculation of the arteriovenous difference of oxygen content \( (C(a-v)O_2) \), according to the equations represented as follows:

\[
\begin{align*}
CaO_2 &= SaO_2 \times Hb \times 1.39 + 0.0031 \times PaO_2 \\
CvO_2 &= SvO_2 \times Hb \times 1.39 + 0.0031 \times PvO_2 \\
C(a-v)O_2 &= CaO_2 - CvO_2
\end{align*}
\]

Where: \( CaO_2 \) represents the oxygen content of the arterial blood, and \( CvO_2 \) the oxygen content of venous blood of the right atrium. The value 1.39 represents the amount of oxygen in milliliters that can be delivered by one gram of hemoglobin, and 0.0031 is the solubility of oxygen in the plasma.

The results were statistically analyzed using the linear correlation coefficient \( (r) \) and the Student’s \( t \)-test, and \( p \) equal to 5% was considered significant. Diagnostic tests in relation to the gold standard (thermodilution) were applied to assess the capacity of a given parameter to estimate the cardiac index \( (CI) \). It was assumed that \( SvO_2 < 60\% \), \( PvO_2 < 28 \) mmHg, \( C(a-v)O_2 = 7.0 \) mL/\%, and \( CI < 2.0 \) L/min/m² represented a low cardiac output clinical situation.

The study was approved by the Ethical Committee of the UFMS University Hospital, and the free informed consent was obtained from each patient.

RESULTS

The \( SvO_2 \), \( PvO_2 \) and \( C(a-v)O_2 \) showed a linear correlation \( (r) \) with the \( CI \) of 0.80, 0.79, and -0.84, respectively, all values of \( P < 0.05 \).

Table 1 shows the comparison between \( SvO_2 \), \( PvO_2 \) and \( C(a-v)O_2 \) with \( CI \), considering the linear correlation \( (r) \) and Student’s \( t \)-test.

Figures 1, 2, and 3 represent graphically these correlations.

Table 2 shows the results of diagnostic tests performed for each parameter studied in relation to the thermodilution method, considered the gold standard for determination of cardiac index.

\( SvO_2 < 60\% \) presented 8% of the false positive results and 2% of the false negative results, and consequently, lower specificity; however, \( SvO_2 < 55\% \) as an indicator of low cardiac output presented a better diagnosis profile, as shown in Table 3, with only 2.6% and 2% of false positive and false negative results, respectively.

### Table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>( R )</th>
<th>( P )</th>
</tr>
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<tbody>
<tr>
<td>( SvO_2 \times CI )</td>
<td>0.80</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>( PvO_2 \times CI )</td>
<td>0.79</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>( C(a-v)O_2 \times CI )</td>
<td>-0.84</td>
<td>&lt; 0.05</td>
</tr>
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DISCUSSION

The use of oxygen saturation in the blood of the right atrium (SvO2 RA) as a substitute for mixed venous blood (SvO2PA) has been used to estimate the tissue oxygenation in the cardiac output due to the greater facility to obtain it. Martin et al. [10] studying patients in septic shock, reported that the values of oxygen saturation of venous blood collected in the central superior vena cava (SvO2svc) and SvO2PA were not overlapped. According to Stone et al. [11] and Smith et al. [12], the redistribution of blood flow in favor of cerebral perfusion under conditions of low cardiac output would be responsible for the difference found among the values of SvO2cs and SvO2AD, and the estimate of SvO2AP. Thus, the oxygen saturation of blood from the superior vena cava would have become greater than the blood of the inferior vena cava due to the reduced perfusion of splanchnic organs; therefore, the values of SvO2AD would better represent the values of SvO2AP compared with the data provided by SvO2cs. These data explain the findings by Scheinman et al. [13] in 1969, studying patients with acute myocardial infarction, who reported a greater difference between the mean values of SvO2cs and SvO2AP for patients with clinical evidence of left ventricular failure or shock, different from that observed in patients clinically stable.

Martin et al. [14] suggested the maintenance of SvO2AP values greater than 60% would be an important parameter to guide therapy in critically ill patients from the hemodynamic standpoint.

In relation to the cardiac index, which in the final analysis, could express the hemodynamic status of the patient, the literature shows large discrepancies in the correlations between this parameter and the oxygen saturation of central venous blood.

Krauss et al. [7] reported a good correlation (r = 0.78) between mixed venous oxygen saturation and cardiac index in patients undergoing cardiac or pulmonary surgery. Waller et al. [15], studying patients undergoing coronary artery bypass grafting, through continuous monitoring of SvO2AP using fiber optic catheters, reported good correlation between changes in values of SvO2AP and CI, with r = 0.69, when there was a variation increase or decrease of 5% or more in SvO2AP value.

Jamieson et al. [16], studying patients undergoing cardiac surgery, showed a good correlation between the CI and SvO2AP, with r = 0.95, and SvO2AP values greater than 65% corresponded to a satisfactory cardiac index. Other authors have presented different results, in which they had obtained little correlation between the extent of SvO2AP and CI [17-19].

Jain et al. [20] attributed the high variability of results reported in the literature to different metabolic and hemodynamic profile of the patients studied. As these authors described, the correlation between SvO2AP and cardiac output does not occur linearly as suggested by the authors mentioned above. These authors showed that in the group of patients with CI < 2 L/min/m2 and SvO2AP < 55%, the correlation was good (r = 0.87), differing from the lowest correlation (r = 0.42) found in the most hemodynamically stable group of patients with CI > 2 L/min/m2 and SvO2AP > 55%. These authors also considered
During this period, the variability of oxygen consumption (VO2), as an important factor responsible for the hemodynamic instability, was higher. However, the threshold value of 60% of VO2 determined almost 8% of false positive results, which was reduced to only 2.6% when considering SvO2 less than 55% as indicative of low output, promoting improvement in sensitivity and especially in specificity, with greater positive predictive value. This diagnostic profile of SV02 certifies its routine use in the postoperative period as an additional and important parameter in the hemodynamic analysis of patients, and it may guide procedures, such as drug weaning process and infusion volumes, slowing, or even preventing in some cases, the use of Swan-Ganz® catheter.

Sommers et al. [21], studying patients undergoing coronary artery bypass grafting, most specifically the first eight hours postoperatively, reported better correlation between Pvo2AP and CI, with a mean value of r = 0.6502, compared to the SvO2AP and CI with r = 0.424. These results were attributed to the instability of the patients during the immediate postoperative period and the likely variability of oxygen consumption (VO2) by the patient during this period.

Kandel et al. [22] reported that it would be preferable to use SvO2AP instead of Pvo2AP to monitor tissue oxygenation, once changes in SvO2AP can be used to identify disturbances in oxygen transport in an earlier stage, thus allowing a better response to disso, a SvO2AP seria determinada apenas pelos componentes do sistema de transporte de oxigênio, ou seja, DC, Hb, SaO2 e VO2, enquanto a Pvo2AP pode ser alterada na presença de qualquer fator que cause desvios na curva de dissociação da hemoglobina sem necessariamente existir distúrbios no transporte de oxigênio. In addition, SvO2AP would be determined only by the system components of oxygen transport, i.e., CO, Hb, SaO2, and VO2, while Pvo2AP can be altered by any factor that causes deviations in the dissociation curve of hemoglobin without having necessarily disturbances in oxygen transport.

In our study, despite the good correlation found between the PVO2 and CI (r = 0.79), this parameter was less sensitive (sensitivity of 65.7% ± 15.7) in diagnosing low cardiac output compared to SvO2, agreeing with the results of Kandel et al. [22].

Theoretically, the arteriovenous oxygen content difference (C(a-v)O2) has a better performance when correlated to the cardiac output, compared to SvO2, because to its calculation it is used a measure of two other determinant factors (SaO2 and Hb) of the oxygen transport. This argumentation was corroborated by the studies of Buheitel et al. [23]. When examining children in the postoperative period of congenital cardiac surgery, they found a better correlation between cardiac index and CaO2/C(a-v)O2 ratio, in comparison to SvO2AP.

Valentine et al. [24], studying patients suffering from acute myocardial infarction, showed that the average C(a-v)O2 was higher, 7.2 mL/100 mL in patients who had radiological signs of pulmonary edema when compared with the 6.6 mL/100 mL in the group that did not present these radiological changes. Of the 19 patients studied by these authors, five died, and of these, only one did not have C(a-v)O2 greater than 7.5 mL/100 mL.

Tahvanainen et al. [25] described a good relationship between the oxygen arteriovenous difference, considering the blood from the right atrium and pulmonary artery, as r = 0.89 and p <0.001, as well as Furqan et al. [26], but in a group of postoperative pediatric patients for congenital heart disease repair.

The arteriovenous oxygen content difference (C(a-v)O2) showed the best diagnostic profile among the parameters studied, showing a correlation of -0.84 with the cardiac index, specificity of 100%, sensitivity of 94.1% ± 7.9, and accuracy of 98.7 ± 1.9%. The positive predictive value was 100% and the negative predictive value of 95.9% ± 4.0%, showing no false positive results and only 1.33% of false negative results, thus consisting in the most efficient blood gasometry parameters correlated to low cardiac output.

CONCLUSIONS

The blood gasometry from the right atrium can be useful in evaluating the hemodynamic status of patients in the postoperative period of cardiac surgery. SvO2 < 55% and C(a-v)O2 > 7.0 mL/100mL reflect a state of low cardiac output and due to a good sensitivity, specificity, and accuracy its use can be widely applied without establishing further risks to the patients. This is a simple method to be applied in the postoperative cardiac surgery routine and together with the clinical examination may safely guide therapeutic procedures, such as weaning of inotropic drugs and fluid replacement, especially in those patients with hemodynamic instability.

REFERENCES


