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Use of femoral vein catheters for the assessment of perfusion parameters

Utilização de cateter em veia femoral para avaliação de parâmetros de perfusão

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ABSTRACT

The use of central venous oxygen saturation ($SvcO_2$) and arterial lactate in the diagnosis of severe tissue hypoperfusion is well established, and the optimization of these parameters is currently under investigation, particularly in patients with severe sepsis/septic shock. However, the only place for deep venous puncture or the first choice for puncture is often the femoral vein. Although venous saturation obtained from blood sampling from this catheter, instead of $SvcO_2$, has already been used in the diagnosis of severe tissue hypoperfusion, little is known about the accuracy of the results. The venous lactate in place of arterial puncture has also been used to guide therapeutic decisions. We conducted this literature review to seek evidence on the correlation and concordance of parameters obtained by collecting femoral venous blood gases in relation to $SvcO_2$ and arterial lactate. Few studies in the literature have evaluated the use of femoral venous oxygen saturation ($SvfO_2$) or venous lactate. The results obtained thus far demonstrate no adequate agreement between $SvfO_2$ and $SvcO_2$, which limits the clinical use of $SvfO_2$. However, the apparent strong correlation between arterial and peripheral and central venous lactate values suggests that venous lactate obtained from the femoral vein could eventually be used instead of arterial lactate, although there is insufficient evidence on which to base this procedure at this time.

Keywords: Sepsis; Perfusion; Hemodynamics; Central venous pressure/physiology; Femoral vein; Oxygen/blood; Catheterization, central/methods

INTRODUCTION

In states of shock, cardiovascular changes cause an imbalance between the tissue supply and consumption of oxygen. Hemodynamic monitoring of patients in such conditions allows us to identify instability and assess responses to the introduced therapy.[1] Mixed venous oxygen saturation (SvO_2) obtained from the distal portion of the pulmonary artery catheter is a parameter that indirectly assesses the relationship between oxygen supply and demand. Changes in SvO_2 are associated with worse outcomes in various subgroups of patients,[1-3] including those with sepsis. [1,4,5] However, the use of a pulmonary artery catheter is not without risks and complications.[1-3,6] In septic patients, the delay in making decisions because of difficulties in inserting the catheter or in obtaining and interpreting values can be harmful to the patient.[1,6]

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Similarly to SvO_2, central venous oxygen saturation ($SvcO_2$), obtained by collecting blood from a venous catheter positioned in the superior vena cava or right atrium, has been used to detect tissue hypoxia, although values are not equal to those of SvO_2.[2,3] However, studies have demonstrated that there is a good correlation between $SvcO_2$ and SvO_2 and that they vary in parallel.[7-9] Compared to SvO_2, therefore, the use of $SvcO_2$ is a faster and more practical alternative in tissue hypoperfusion monitoring.

To date, the rationale of goal-directed therapy has been used in the management of septic patients,[10,11] but the use of $SvcO_2$ is not always satisfactory, as there are difficulties in the central venous catheter's insertion.[12-16] Moreover, in some cases, puncture of the internal jugular or subclavian vein may not be possible or may even be risky, leaving deep femoral vein access as the only alternative.[2,17] On several occasions, we have observed the clinical use of such parameters as surrogate values for central venous pressure (CVP) and $SvcO_2$. Although a few studies have demonstrate that in the absence of intra-abdominal hypertension, venous pressure measured in catheters in the femoral vein correlate well with CVP,[17] the use of the femoral vein for monitoring venous pressure and obtaining blood samples to verify venous saturation remains controversial.

In addition to the use of $SvcO_2$, the resolution of hyperlactatemia or lactate clearance has also been used for the assessment of the therapeutic response,[18] and lactate clearance has been considered as an alternative to $SvcO_2$.[19] To obtain lactate, patients are often subjected to multiple arterial punctures, a procedure that has been classified as an uncomfortable experience.[20] Furthermore, on some occasions, we are faced with patients with serious vasculopathies on whom we cannot perform catheterization of an artery to obtain invasive blood pressure and sample collection, including arterial lactate. In such cases, the use of lactate values obtained from blood collected from a femoral vein catheter could save the patient from a painful procedure and guide treatment.

Our objective was therefore to review the literature in search of evidence of the existence of a correlation between $SvcO_2$ and femoral venous oxygen saturation ($SvfO_2$) in critically ill patients and to explore the use of femoral venous lactate as a substitute for arterial lactate in assessing lactate clearance in critically ill patients.

METHODS

We performed a literature review focusing primarily on studies comparing the results obtained by measuring $SvfO_2$ to those obtained for $SvcO_2$ or SvO_2 only in critical patients and on studies that compared the values of arterial and femoral, central venous and peripheral venous lactate.

A limited number of studies were found that evaluated the equivalence between values of venous saturations. The MedLine database (http://www.ncbi.nlm.nih.gov/pubmed) was consulted using the following descriptors: "femoral venous saturation AND (venous oxygen saturation OR central venous oxygen saturation)". This search generated 167 articles. Of these, only three papers dealt with the comparison between SfO_2 and $SvcO_2$ (Table 1).[2,3,21] A search was also conducted on the SciELO database with the keywords "femoral AND saturação (saturation)". No articles were found.

To search for articles that compared lactate values, we initially used the following descriptors on the MedLine database: "(femoral venous lactate) AND lactate clearance". This search resulted in 14 items; however, in the analysis of the abstracts, we found that none were related to our goal. Using the descriptors "(femoral venous lactate) AND arterial lactate", 150 articles in English were found, excluding experiments on animals and on the pediatric population, but the analysis of abstracts revealed no studies comparing arterial and femoral venous lactate. Likewise, using the descriptors "(critically ill) OR (intensive care) OR (critical care) OR (ICU) AND femoral venous lactate AND arterial lactate", we obtained eight articles, but the analysis of their abstracts indicated that none met the objective. Because we found no studies that compared the values of arterial and femoral venous lactate, we conducted a search for studies that compared arterial with both peripheral and central venous lactate values. This search was based on the need to check whether there is a rationale for the use of venous lactate in this context and thus a rationale to develop new studies that directly examine the validity of the lactate dosage obtained in the femoral vein. It is possible that this location is more appropriate in ascertaining systemic involvement, as it is a deep vein, especially considering that the catheter tip is most likely lodged in the common iliac vein. The blood content of the femoral vein therefore does not

Table 1 - Studies comparing the concordance between femoral venous saturation and central venous saturation

Author	Population	Number of sample pairs	Bias %	Concordance limits(%)
van Beest et al.[2]	100 cardiopathy patients	100	2.7	-12.9-18.2
van Beest et al.[2]	30 surgical patients	30 (T0)	-1.9	-20.0-16.3
		30 (T1)	-1.0	-30.2-28.3
van Beest et al.[2]	30 critically ill patients	30 (T0)	4.6	-23.5-32.6
Davison et al.[3]	39 critically ill patients	78	4.0	-18.4-26.4
Groombridge et al.[21]	43 critically ill patients	39	-3.21	-22.43-16.01

only reflect the skin, subcutaneous tissue and superficial muscles but also the deep muscles of the lower limbs and pelvis. We therefore used the following descriptors: "(critically ill) OR (intensive care) OR (critical care) OR (ICU) AND venous lactate AND arterial lactate". This search generated 382 articles. After excluding studies written in languages other than English, experiments on animals and the experiments on pediatric population, we obtained 186 articles. Four studies were reviewed in detail (Table 2). Furthermore, a comparison study between arterial and peripheral venous lactate identified through the references of articles found in the search was included in the review.

RESULTS

Comparative analysis between $SvfO_2$ and $SvcO_2$

The first comparison between $SvfO_2$ and $SvcO_2$ was published in 2010. Davison et al., in observing the preference for using access to the femoral vein in the emergency department and the possible use of $SvfO_2$ values to guide fluid resuscitation, investigated the frequency of use of the femoral vein by means of a questionnaire sent via the Internet.[3] In the same study, a unicentric prospective evaluation was performed exploring whether $SvcO_2$ and $SvfO_2$ values were interchangeable. Eight hundred questionnaires were sent to physicians who dealt with critical patients, and 150 responses were received. More than 35% of these professionals said that, in at least 10% of initial treatments, the femoral vein was the access method of choice, the principal reason being the impossibility of puncture at another site. To compare $SvcO_2$ and $SvfO_2$, the authors analyzed the values obtained from the blood gas collection of 39 patients who concurrently had catheters in central (jugular or subclavian vein, with position confirmed by radiography) and femoral veins (catheters 20 cm long) at time zero (T0) and 30 minutes after the first collection (T30). The mean value of femoral and central venous saturations differed significantly (73.1±11.6% for $SvcO_2$ and 69.1±12.9% for $SvfO_2$, p=0.002). In addition to having a weak correlation (r^2=0.35, p=0.01), concordance analysis using the Bland-Altman test revealed large differences between values, with mean bias of 4.0±11.2% and a confidence interval of 95% (CI95%) with concordance

Table 2 – Studies comparing the correlation and/or concordance between venous and arterial lactate

Author	Population	Number of simultaneous samples	Results
Weil et al.[22]	12 critically ill patients	50 (arterial, central venous and mixed venous)	r=0.995 (arterial versus central venous) r=0.994 (arterial versus mixed venous)
	23 critically ill patients	104 (arterial and mixed venous)	r=0.998
Younger et al.[23]	48 ER patients (clinical, surgical or trauma)	48 (arterial and peripheral venous)	r=0.71 Bias: -0.18 (-0.372 e 0.012)
Lavery et al.[24]	375 ER patients (trauma)	221 (arterial and peripheral or femoral venous)	r=0.943
Réminiac et al.[25]	188 critically ill patients	673 (arterial and central venous)	Bias: -0.43 (-1.2-1.2) AUC for 2 mmol/L: 0.98 (cutoff: 2.1 mmol/L) AUC for 4 mmol/L: 0.98 (cutoff: 3.9 mmol/L)
Nascente et al.[26]	32 septic patients	238 (arterial, central venous and peripheral venous)	r=0.79 (arterial versus peripheral venous) Bias: -3.2 (-12.8- 6.4) r=0.84 (arterial versus central venous Bias: -0,8 (-12.5-10.8)

AUC - area under curve.

limits of -18.4% to 26.4%. Therefore, according to these data, $SvfO_2$ would not be an adequate substitute for $SvcO_2$.

In another unicentric prospective study published in 2011, Groombridge et al. compared venous pressure and oxygen saturation measurements in central venous and femoral catheters of 43 adult patients admitted to intensive care units (ICU), where catheters of both 20 cm and 24 cm long were used.[21] The analysis of 43 simultaneous measurements of venous pressure revealed discrepancies, with a mean difference between femoral and central venous pressure of 1.05 ± 2.42 mmHg with concordance limits (CI95%) of -3.79 to 5.89 mmHg. A single sample of blood was collected for comparison of central and femoral venous saturations in 39 of the patients studied. The mean difference obtained between $SvcO_2$ and $SvfO_2$ was -3.21, with concordance limits between -22.43 and 16.01, also suggesting poor concordance between the values. Believing that the length of the femoral catheter could have affected the results, the authors conducted a *post-hoc* analysis by dividing the sample according to the length of the femoral catheter. Although a smaller bias and smaller concordance limit intervals were found for venous pressure in the longer catheters, this effect was not observed for venous saturations, for which concordance limits remained elevated.

In 2012, van Beest et al. published a unicentric, prospective, observational study analyzing $SvfO_2$ in three groups of adult patients: a control group consisting of 100 stable cardiac patients with pulmonary artery catheters, a group of 30 high risk surgical patients and a group 30 critical patients consecutively admitted to the ICU because of septic or cardiogenic shock.[2] In the control group, samples were collected during femoral vein cannulation for passage of the pulmonary artery catheter. In the surgical group, samples were obtained simultaneously before placing sterile drapes (T0) and after the removal of the same drapes at the end of surgery (T1). In the clinical patients, collection was made in the first hour of resuscitation (T0) and after 6 hours (T1). In the two latter groups, the femoral sample was obtained by puncture of the same site. It should be noted that this form of collection can result in bias because with the use of a catheter, the blood collected most likely represents the contents of the iliac artery, whereas direct puncture accesses the contents of the femoral vein.

Analysis of the one hundred paired samples obtained in the control group revealed a lower median $SvfO_2$ value compared with both SvO_2 (66.3% versus 68.9%; p=0.03) and with $SvcO_2$ (66.3% versus 69.2%; p<0.01). The saturations exhibited a weak but significant correlation, with r_s=0.57 (p<0.001) for SvO_2 and $SvfO_2$ and r_s=0.55 (p<0.001) for $SvcO_2$ and $SvfO_2$. The Bland-Altman analysis revealed extended intervals of concordance limits: 2.1% bias with limits between -13 and 17.5% for SVO_2 and $SvfO_2$, and 2.7% with limits between -12.9 and 18.2% for $SvcO_2$ and $SvfO_2$. The values found in the analysis of 60 paired samples in the group of surgical patients were -1.9%, with limits of -20 to 16.3% at T0, and -1%, with concordance limits of -30.2 to 28.3% at T1. In both instances, $SvcO_2$ and $SvfO_2$ exhibited no significant correlation (p=0.23 at T0 and p=0.06 at T1). The correlation between $SvcO_2$ and $SvfO_2$ was significant, although weak, at both sampling times in clinical patients with r_s=0.46 (p=0.01) at T0 and r_s=0.55 (p=0.002) at T1. Concordance analysis at T0 exhibited a bias of 4.6%, with concordance limits between -23.5 and 32.6%, and at T1 the bias was 3.3%, with concordance limits between -18.5 and 25.1%.

The currently available studies therefore suggest that $SvfO_2$ does not appropriately reflect the behavior of $SvcO_2$.

Comparative analysis of arterial and venous lactate values

Weil et al. studied 50 simultaneous samples of arterial, central venous and pulmonary artery lactate obtained from pulmonary artery catheters in 12 critically ill patients.[22] In addition, the authors retrospectively analyzed 104 samples collected simultaneously from the pulmonary artery and arterial blood of 23 critically ill patients. The authors also compared lactate values using linear correlation, finding in the first case a good correlation between arterial and central venous lactate levels (r=0.995, p<0.01) and between arterial and pulmonary lactate (r=0.994) and in the latter case a good correlation between pulmonary and arterial lactate (r=0.998, p<0.0001). Therefore, the authors concluded that the blood samples obtained from central venous and pulmonary artery sites could be used to measure lactate.

Because the collection of arterial lactate requires technical skill and can be even more difficult in hypotensive patients, Younger et al. evaluated the relationship between arterial lactate and peripheral venous values in 48 pairs of blood samples collected from patients admitted to the emergency department of a university hospital.[23] Peripheral venous lactate was an effective marker of elevated arterial lactate, such that an abnormal venous lactate value had a sensitivity of 100% and a specificity of 86% in predicting arterial hyperlactatemia. The correlation between the two values was 0.71, with $p<0.001$, and the Bland-Altman concordance analysis revealed a mean difference of -0.18 mmol/L (CI95% of -0.372 - 0.012). However, the study had a small sample size, and only 13 of the 48 patients evaluated had arterial hyperlactatemia. The correlation analysis may therefore be limited and should be interpreted with caution.

In a unicentric prospective study, Lavery et al. evaluated the use of venous lactate in screening trauma patients in an emergency department.[24] Arterial (collected from the femoral or radial artery) and venous (collected from the femoral vein or veins of the upper limbs, with or without the use of tourniquet) blood samples were obtained within 10 minutes of the patients' arrival for blood gas and lactate analysis. Approximately 221 paired samples were analyzed. The mean values of arterial and venous lactate exhibited no significant differences, with arterial lactate of 3.11 mmol/L (standard deviation - SD 3.45, CI95% 2.67-3.55), and venous lactate of 3.43 mmol/L (SD 3.41, CI 95% 2.96-3.9). The correlation between arterial and venous samples was strong, with $r=0.94$, $p<0.0001$, with no significant difference regarding the use of the tourniquet in the collection of venous lactate. The correlation remained high regardless of the sample collection site (radial or femoral artery and femoral or peripheral vein). The increase in lactate was consistently associated with severity of injury as measured by the Abbreviated Injury Score (AIS). Both arterial and venous lactate and base deficits were able to discriminate patients with AIS ≥4 from patients with a maximum AIS score of 3 ($p<0.01$). As in patients with arterial lactate ≥2 mmol / L, patients with venous lactate ≥2 mmol/L had increased risk of exhibiting an Injury Severity Score (ISS) of ≥13, which corresponds to people with severe lesions with considerable morbidity and increased probability of death. Furthermore, venous lactate was able to predict with greater accuracy than the institution's standard screening criterion patients with ISS ≥13, those who required ICU admission and those with length of stay of >2 days. Thus, the authors concluded that the use of lactate could improve screening for trauma patients and that venous lactate, the collection of which is less costly, would be just as effective as arterial lactate.

Using a retrospective study, Réminiac et al. evaluated the ability of central venous lactate and its clearance to predict the same variables when harvested arterially in 673 paired samples obtained from 188 critical patients.[25] The number of samples from the same patient may be viewed as a limitation of the study. For the first pair of samples from 188 patients, the bias between central venous and arterial lactate was -0.07 mmol/L, with a concordance interval between -1.4 and 1.3. To evaluate the power of venous lactate to predict arterial lactate, the authors determined the area under the curve (AUC) to be 0.98, with a cutoff of 2.1 mmol/L with 98% sensitivity and 89% specificity, to predict arterial lactate of >2 mmol/L. For arterial lactate >4 mmol/L, the AUC was 0.97, with a cutoff of 3.8 mmol/L (90% sensitivity and 98% specificity). Analyzing the 673 pairs of samples, arterial lactate values varied from 0.6 to 2.6 mmol/L, and venous lactate values varied from 0.6 to 22.8 mmol/L. The bias between lactates was -0,043 mmol/L, with concordance limits between -1.2 and 1.2 mmol/L. The AUC of the ability of central venous lactate to predict the values of arterial lactate >2 and >4 mmol/L were 0.98 with cutoff of 2.1 (sensitivity of 95% and specificity of 93%) in the first case and 0.98 with cutoff of 3.9 (sensitivity of 90% and specificity of 99%) for the latter value. Approximately 171 paired samples were collected from the same patients within an interval of 4 to 6 hours to assess lactate clearing. The AUC for the ability of central venous lactate to detect arterial lactate clearing of <10% or >10% was 0.93 and 0.94, respectively. These results demonstrated that central venous lactate can estimate the value of arterial lactate.

Different results were reported by Nascente et al.[26] In a unicentric, analytical, cross-sectional study, the authors evaluated the association between lactate values obtained from different puncture sites (arterial, central venous and peripheral venous) in patients with severe sepsis/septic shock, with an emphasis on the impact of these values on clinical management. Two hundred and thirty-eight lactate measurements were performed. The correlation between peripheral and arterial lactate was moderate ($r=0.79$, $p<0.0001$), whereas the correlation between central and arterial lactate was stronger ($r=0.84$, $p<0.0001$). However, the Bland-Altman concordance limits were large for both comparisons: a bias of -3.2

with concordance limits between -12.8 and 6.4 for arterial and peripheral lactate and bias of -0.8 with concordance limits between -12.5 and 10.8 for arterial and central lactate. To evaluate concordance in clinical management, lactate values were analyzed along with other hemodynamic parameters by an intensivist who was unaware of the lactate collection site. Only three results were discordant for central lactate, meaning that in 96.3% of cases, the therapeutic measures taken would be the same using either arterial or central venous lactate. This concordance was lower for peripheral lactate, where the procedure would be the same in 87% of cases and different in ten cases. Central venous lactate could therefore replace arterial lactate with good correlation and lead to similar clinical procedures, although the Bland-Altman concordance is low. Peripheral lactate would not be recommended because it could lead to unnecessary therapeutic intervention.

Analyzing the above studies, we can see that venous lactate, especially central venous lactate, could be used instead of arterial lactate in the evaluation of perfusion parameters in critically ill patients. In one study, some samples were obtained by puncture of the femoral vein, but it was not the objective of the study to separately analyze the correlation between femoral venous and arterial lactate. However, the same study using a large sample was able to demonstrate that even peripheral lactate values exhibited good correlation and concordance with arterial lactate. These results suggest that the venous lactate obtained from the femoral vein could reflect hypoperfusion states and guide treatments.

FINAL CONSIDERATIONS

There are few studies in the literature evaluating the use of femoral venous oxygen saturation = as a substitute for central venous oxygen saturation = in patients where catheterization of the central vein is not possible. The results obtained thus far are not favorable. By contrary, the apparently strong correlation between the values of arterial and peripheral and central venous lactate suggests that venous lactate obtained from the femoral vein could eventually be used instead of arterial lactate, although there is insufficient evidence on which to base this procedure at this time. Further studies are therefore needed to provide a proper analysis of this role.

RESUMO

A utilização da saturação venosa central de oxigênio ($SvcO_2$) e do lactato arterial no diagnóstico de hipoperfusão tecidual em doentes graves já está bem estabelecida, e a otimização desses parâmetros é buscada principalmente em pacientes com sepse grave/choque séptico. Contudo, em diversas ocasiões, o único sítio para punção venosa profunda ou a primeira escolha para punção é a veia femoral. Embora a saturação venosa obtida da coleta de sangue desse cateter, em substituição a $SvcO_2$, já tenha sido utilizada, pouco se sabe a respeito da acurácia de seus resultados. A utilização do lactato venoso, em substituição da punção arterial, também tem norteado decisões terapêuticas. Realizamos esta revisão de literatura buscando evidências sobre a correlação e a concordância desses parâmetros, obtidos pela coleta de gasometria venosa femoral, em relação à SvcO2 e ao lactato arterial. Existem poucos estudos na literatura avaliando a utilização da saturação venosa femoral de oxigênio ($SvfO_2$) ou de lactato venoso. Os resultados até então obtidos mostram não haver concordância adequada entre $SvfO_2$ e $SvcO_2$, o que limita sua utilidade clínica. No entanto, a aparente correlação forte entre os valores de lactato arterial e venoso, tanto periférico como central, sugere que o lactato venoso obtido da veia femoral poderia, eventualmente, ser utilizado em substituição do lactato arterial, embora não haja evidências suficientes para basear essa conduta no momento.

Descritores: Sepse; Perfusão; Hemodinâmica; Pressão venosa central/fisiologia; Veia femoral; Oxigênio/sangue; Cateterismo venoso central/métodos

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