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Femoral venous oxygen saturation and central venous oxygen saturation in critically ill patients ☆

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ABSTRACT

Objectives: To investigate the relationship between central venous oxygen saturation ($ScvO_2$) and femoral venous oxygen saturation ($SfvO_2$) in a large group of critically ill patients.
Design: Observational study.
Patients: A group of unselected critically ill patients with central line placed into superior vena cava were included.
Setting: A 26-bed intensive care unit in a tertiary referral hospital.
Interventions: None.
Measurements and main results: Venous blood samples of superior vena cava and femoral vein were collected within an interval of 5 to 15 minutes and analyzed with blood gas/electrolyte analyzer immediately. Although $SfvO_2$ was significantly correlated with $ScvO_2$ ($r = 0.493$, $P < .001$; Pearson correlation, 2 tailed), the limits of agreement were wide (up to 61% to −41%) between the 731 pairs of blood samples collected from 357 patients. The fit line of scatter diagram $ScvO_2$ vs $SfvO_2$ had a large intercept (48.68%) and a low slope (0.2978); $ScvO_2$ was still around 50% while $SfvO_2$ was nearing 0%. The distribution of blood flow, measured with Doppler ultrasound, had a similar trend in 237 patients and 412 measurements. The ratio of femoral artery flow over common carotid artery flow varied widely (from 0 to 7.13). Blood flow was not distributed in a fixed ratio to the superior vena cava–drained organs and tissues.
Conclusions: Central venous oxygen saturation was not representative of the whole systemic circulation in critically ill patients. Central venous oxygen saturation alone might be misleading in goal-directed therapy.

A significant number of patients in emergency department (ED) and intensive care unit (ICU) are hemodynamically unstable, so hemodynamic optimizing becomes an important work of ED and ICU [1]. To achieve hemodynamic optimization, blood volume status should be accurately assessed. Arterial blood pressure, heart rate, central venous pressure, urine output, and blood lactate are widely used parameters in evaluating blood volume status. Because goal-directed therapy has been widely accepted and practiced, the value of venous oxygen saturation (SvO_2) is increasingly appreciated [2-6].

Measurement of mixed SvO_2 is technically difficult for most EDs or ICUs, so central SvO_2 ($ScvO_2$) is frequently used as a surrogate of SvO_2 clinically. Compared with $ScvO_2$, femoral SvO_2 ($SfvO_2$) can be easily and safely obtained in almost all clinical settings. However, in previous studies [7,8], the limits of agreement between values of $SfvO_2$ and $ScvO_2$ were found to be wide. Based on these studies, one might conclude that $SfvO_2$ was useless in assessing blood volume status and guiding fluid therapy in critically ill patients. However, the sample sizes of these studies were relatively small, the true relationship between $SfvO_2$ and $ScvO_2$ might not be detected, and the value of $SfvO_2$ might have been overlooked. More importantly, was $ScvO_2$ a reliable reference at all? So we set forward to find out the relationship between $SfvO_2$ and $ScvO_2$ in a larger series of critically ill patients.

1. Methods

We conducted this observational study in Emergency Intensive Care Unit (EICU) of Sichuan Provincial People's Hospital. This EICU had 12 beds before 2014; it became a 26-bed setting in 2014. The sampling of femoral venous blood for gas analysis was done together with withdrawal of blood for routine test, renal and hepatic function tests, and other. The blood sampling carried no additional risk. The ethical committee at Sichuan Provincial People's Hospital approved the study protocol. The informed consents were obtained from the patients or their close relatives.

The central venous catheters were inserted when there were clear indications, for example, need of vasopressor administration, intravenous administration of hypertonic solution, and aggressive fluid therapy. Those patients who had catheters placed via subclavian or internal jugular vein into superior vena cava entered this study.

The study population was composed of almost all disease entities admitted to this EICU. Because the majority of surgical patients were hemodynamically stable and venous gas analysis was not strongly indicated in these cases, only a small number of surgical patients entered

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this study; in this way, surgical patients were not proportionally represented by this study.

Subclavian vein or internal jugular vein was catheterized with the Seldinger method. Double lumen catheters were used to avoid interruption of vasopressor administration. Right subclavian vein was preferred. During blood samplings, the following maneuvers were avoided: changing ventilator parameters/inspired oxygen fraction, adjusting vasopressor dosage, changing patient's position, suctioning sputum, fluid challenge, and blood transfusion. The above maneuvers would reduce the comparability of these samples. Active massive bleeding would lead to drastic changes in blood contents, so blood sampling was avoided during active massive bleeding. The interval between withdrawal of central venous blood and that of femoral venous blood was 5 to 15 minutes. The withdrawals of blood took place in an unspecified order; either superior vena cava or femoral vein might come first. Either right or left femoral vein was chosen; the prerequisite was that the lower limb from which blood was withdrawn was grossly healthy (no trauma, no infection). The samples were collected with syringes containing a minimal amount of heparin. Before withdrawing central venous blood, 1 to 2 mL of blood in the catheter was removed. The blood samples were analyzed with GEM Premier 3000 blood gas/electrolyte analyzer (model 570; Instrumental Laboratory, Lexington, MA) in the ward without delay. The blood gas analyzer was calibrated once a month, and the performance of the analyzer was monitored by an on-site service engineer.

Blood flows in common carotid artery and femoral artery were measured with Doppler ultrasound in a group of patients. Femoral artery was measured immediately distal to the inguinal ligament. Either right or left femoral artery was chosen; the prerequisite was that the examined side was grossly healthy (no trauma, no infection). Either right or left common carotid artery was examined. Blood flows in common carotid artery and femoral artery were measured with Acuson X300 Premium Edition (Siemens Medical Solutions USA, Mountain View, CA). Maximal diameter and mean centerline velocity (Vmean) were measured separately. They were measured in duplicate and represented as averages. When measuring Vmean, at least 3 cardiac cycles were counted. r (radius) = maximal diameter/2. Blow flow was calculated with the following equation: $Q = \pi r^2 Vmean/2$.

Oxygen saturations and oxygen partial pressures of central venous blood ($ScvO_2$ and $PcvO_2$) femoral venous blood ($SfvO_2$ and $PfvO_2$) were recorded, and scatter diagrams were plotted with Microsoft excel. Blood flows in common carotid artery and femoral artery were also recorded, and scatter diagrams were plotted with Microsoft excel. Data were expressed as mean ± SD or range. Pearson correlation analyses were carried out with SPSS 13.0 for Windows.

2. Results

From May 2012 through August 2014, 731 pairs of blood samples, collected from 357 critically ill patients, were analyzed with blood gas analyzer (Table 1).

Central lines were placed via right subclavian vein (328/357 cases), right internal jugular vein (17 cases), left internal jugular vein (6 cases), and left subclavian vein (6 cases). The positions of central lines were verified by chest x-ray or computed tomography in 343 of 357 cases.

At first glance, the difference between $ScvO_2$ and $SfvO_2$ was large, ranging from 61% to −41% (Fig. 1). However, they were significantly correlated ($r = 0.493$, $P < .001$; Pearson correlation, 2 tailed). Microsoft excel gave a linear equation, $ScvO_2 = 0.2978 \times SfvO_2 + 48.68\%$. Notably, the intercept was large, and the slope was low. When $ScvO_2$ was lower, $SfvO_2$ might be much lower than $ScvO_2$.

Oxygen partial pressures of central venous and femoral venous blood were also significantly correlated ($r = 0.409$; $P < .001$) (Fig. 2). The linear equation given by Microsoft excel also had a large intercept ($PcvO_2 = 0.2696 \times PfvO_2 + 3.7343$).

Table 1
Demographic characteristic of subjects

	Cases undergoing SvO_2 analyses	Cases undergoing arterial blood flow measurements
Age (y)	58 ± 19 (17-90)	62 ± 20 (16-98)
Male/female	225/132	148/89
No. of measurements	1-9 (median, 2)	1-6 (median, 1)
Principal diagnosis		
Severe sepsis/septic shock	131	87
Trauma	13	19
Massive bleeding/ hemorrhagic shock	43	30
Severe acute pancreatitis	59	6
Cardiac arrest/post–cardiac pulmonary resuscitation	15	7
Elective surgery	29	10
Others	69	78

To test whether a similar tendency existed in the relationship between blood flow of common carotid artery (an important source of central venous blood) and that of femoral artery (the source of femoral venous blood), blood flows were measured by Doppler ultrasound in a group of 237 critically ill patients. From May 2014 through December 2014, 412 pairs of data were collected (Table 1). The measurements in one patient lasted 20 to 30 minutes.

A similar trend was detected in the distribution of blood flow (Fig. 3). The ratio of common carotid artery flow over femoral artery flow varied widely (Fig. 4). However, these blood flows were significantly correlated ($r = 0.421$; $P < .001$). The fit line also had a large intercept and a low slope. When common carotid artery flow was lower, femoral artery flow were markedly reduced, and when common carotid artery flow increased, femoral artery flow became much higher than common carotid artery flow.

3. Discussion

As we know, SvO_2 is a function of cardiac output, hemoglobin content, arterial oxygen saturation, and oxygen consumption (VO_2). When cardiac output decreases, more oxygen molecules dissociate from hemoglobin, and SvO_2 decreases. Cardiac output is related to blood volume; in fluid responders, cardiac output increases after fluid challenges. In this way, mixed SvO_2 has become an important “goal” in goal-directed therapy. Because of technical difficulty, SvO_2 is not easily obtained, and $ScvO_2$ is frequently used as a surrogate of SvO_2 clinically.

Blood samples can be easily and safely obtained from femoral veins. However, in a study in which 39 critically ill patients were enrolled, $SfvO_2$ was found to be significantly different from $ScvO_2$ (26.4% to −18.4%). More than 50% of $ScvO_2$ and $SfvO_2$ values diverged by more than 5% [7]. In another study in which 100 stable cardiac patients, 30 surgical patients, and 30 critically ill patients were enrolled, although significant correlation between values of $SfvO_2$ and $ScvO_2$ was detected, the limits of agreement were wide (−23.5% to 32.6%) [8]. Based on the above 2 studies, one might conclude that $SfvO_2$ was useless in assessing blood volume status and guiding fluid therapy in critically ill patients. However, the sample sizes of the aforementioned studies were relatively small, the true relationship between $SfvO_2$ and $ScvO_2$ might not be detected, and the value of $SfvO_2$ might have been overlooked. Moreover, the accuracy of $ScvO_2$ as a reference was not self-evident. When SvO_2 reached 65%, $ScvO_2$ might be much lower or higher than 70% in critically ill patients. So we set forward to find out the relationship between $SfvO_2$ and $ScvO_2$ in a larger series of critically ill patients.

In the present study, $SfvO_2$ and $ScvO_2$ were found to be significantly correlated. However, limits of agreement were even wider. More importantly, the line fitted on the $SfvO_2$-vs-$ScvO_2$ scatter diagram had a large intercept and a low slope. When $ScvO_2$ was lower, $SfvO_2$ might be much lower than $ScvO_2$, and when $ScvO_2$ became higher, $ScvO_2$ might be much higher than $SfvO_2$. The reason for this finding was that not a fixed