



Original article

## Lower limb peripheral NIRS parameters during a vascular occlusion test: An experimental study in healthy volunteers



### Évaluation dynamique de la NIRS tissulaire périphérique : une étude expérimentale chez le volontaire sain

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#### ABSTRACT

**Objectives.** – The aim of the study was to compare NIRS parameters in combination with a vascular occlusion test (VOT) at a proximal (leg) and a distal (foot) site in male and female.

**Study design.** – A prospective experimental study in healthy subjects.

**Patients and methods.** – Twenty volunteers (10 male, 10 female,  $28 \pm 4$  years) were investigated during 4 experimental steps: baseline, ischemia, reperfusion, and baseline. For each volunteer, 3 NIRS optodes were placed on right and left calves and the left arch of the foot. Blood pressure, heart rate and peripheral pulse oxymetry were monitored.

**Results.** – Significant differences were observed at baseline between regional oxygen saturation ( $rSO_2$ ) values according to the site of measurement (proximal  $rSO_2$   $81 \pm 9\%$  vs distal  $rSO_2$   $60 \pm 5\%$ ,  $P < 0.001$ ) but not according to gender. Both decreases in proximal and distal  $rSO_2$  during ischemia and increases over baseline values during reperfusion depended on group membership (male or female). NIRS parameters during the VOT were significantly higher in male when compared with female at the proximal site: desaturation rate 5.6% (IQR: 5.5) vs 2.5% (IQR: 0.8),  $P = 0.001$ ; resaturation rate 40.7% (IQR: 6.6) vs 21.7% (IQR: 5.4),  $P = 0.003$ ; and  $\Delta rSO_2$  10.0% (IQR: 7.0) vs 5.5% (IQR: 6.0),  $P = 0.041$ .

**Conclusions.** – Values of  $rSO_2$  at the lower limb varied according to the anatomical site of measurement. A VOT induced major changes in  $rSO_2$  that differed between male and female. These results should be taken into account in further clinical studies.

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#### R É S U M É

**Objectifs.** – Comparer les paramètres de NIRS tissulaire périphérique lors d'un test d'occlusion vasculaire (TOV) chez l'homme et la femme aux niveaux proximal et distal.

**Type d'étude.** – Étude prospective expérimentale.

**Patients et méthodes.** – Vingt volontaires sains (10 hommes, 10 femmes,  $28 \pm 4$  ans) ont été étudiés lors de 4 phases expérimentales : contrôle, ischémie, reperfusion, contrôle. Pour chaque volontaire, 3 optodes de NIRS étaient placées sur les mollets droit et gauche et sous la voûte plantaire gauche. La pression artérielle, la fréquence cardiaque et la saturation artérielle en oxygène étaient monitorées.

**Résultats.** – Des différences étaient observées entre les valeurs d'oxygénation tissulaire périphérique ( $rSO_2$ ) au temps contrôle selon le site de mesure ( $rSO_2$  proximale  $81 \pm 9\%$  vs  $rSO_2$  distale  $60 \pm 5\%$ ,  $p < 0,001$ ) mais pas selon le sexe. La baisse des  $rSO_2$  proximale et distale pendant l'ischémie et leur augmentation pendant la reperfusion dépendaient du sexe des volontaires. Les paramètres de NIRS obtenus lors du TOV étaient significativement plus élevés chez l'homme que chez la femme au niveau proximal : vitesse de désaturation 5,6 % (EIQ : 5,5) vs 2,5 % (EIQ : 0,8),  $p = 0,001$ ; vitesse de resaturation 40,7 % (EIQ : 6,6) vs 21,7 % (EIQ : 5,4),  $p = 0,003$ ; et  $\Delta rSO_2$  10,0 % (EIQ : 7,0) vs 5,5 % (EIQ : 6,0),  $p = 0,041$ .

##### Mots clés :

NIRS

Oxygénation tissulaire périphérique

Test d'occlusion vasculaire

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**Conclusions.** – Les valeurs de rSO<sub>2</sub> tissulaire périphérique varient selon le site anatomique. Un TOV induit des modifications importantes de rSO<sub>2</sub> qui diffèrent selon le sexe. Ces résultats devront être pris en compte lors des futures études cliniques.

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## 1. Introduction

Near-infrared spectroscopy (NIRS) is a continuous and non-invasive technology using algorithms that translate measured changes in light attenuation to physiologic changes in oxyhemoglobin and desoxyhemoglobin concentrations and regional tissue oxygen saturation (rSO<sub>2</sub>) [1]. Initially marketed for cerebral oxymetry, Food and Drug Administration-approved devices also have been developed commercially to monitor peripheral tissue perfusion [1]. Since, numerous sites of rSO<sub>2</sub> measurements have been tested. rSO<sub>2</sub> can be considered as a meta-parameter influenced by oxygenation, ventilation, hemoglobin, regional perfusion, and metabolism [2]. Whatever the site of measurement, a normal value of rSO<sub>2</sub> would suggest adequacy between oxygen supply and consumption at the regional level. Values of rSO<sub>2</sub> and sensitivity to effort or ischemia-reperfusion are, however, expected to strongly differ among various regional vascular beds, emphasizing the potential clinical interest of a multisite monitoring. Furthermore, previous physiological studies reported a differential tolerance to effort and ischemia in female when compared with male subjects [3–6].

The unique characteristics of the NIRS technology explain why cerebral and peripheral NIRS parameters during a vascular occlusion test (VOT) - i.e. baseline and peak values of rSO<sub>2</sub>, desaturation and resaturation rates [7] - are being increasingly used in many clinical settings to detect hypovolemia [8–10], to conduct goal-directed therapy [11,12] or to predict adverse outcomes [13–17]. Several limits to the NIRS technology, however, exist and could justify why it is not yet adopted as a clinical standard of care. Furthermore, there is no well-established reference values for rSO<sub>2</sub> according to the site of measurement. No previous study compared NIRS parameters during a VOT at the lower limb according to the peripheral anatomical site of measurement and gender of subjects.

Therefore, the objectives of the present experimental study conducted in healthy volunteers were to compare NIRS parameters during a VOT at two different lower limb peripheral anatomical sites in male and female subjects. We hypothesized that numerical values of rSO<sub>2</sub> and desaturation and resaturation rates would differ between both anatomical site of measurement and gender of healthy subjects.

## 2. Methods

Twenty healthy volunteers (10 men, 10 women) were consecutively investigated at the Teaching University Hospital of Caen (Caen, France). Institutional approval was obtained from the Ethical Committee (Comité de Protection des Personnes Nord-Ouest III, CHU, Caen, France) and all volunteers gave written previous informed consent (ID-RCB n° 2011-A00203-38). All subjects underwent a medical history and a physical examination before inclusion in the study. Inclusion criteria were an age between 18 and 50 years. Exclusion criteria were pregnancy, a body mass index greater than 30 kg.m<sup>-2</sup>, a history of respiratory and/or cardiovascular disease, a history of acute or chronic anemia, any cardiac treatment and any abnormality in physical examination. At the time of the study, all volunteers were comfortable, resting in the 45° semi recumbent position in a quiet, dimly light

and temperature controlled room (21 °C to 22 °C), and breathed spontaneously.

### 2.1. Measurements

A non-invasive blood pressure cuff was applied to the left arm, a peripheral pulse oximeter (SpO<sub>2</sub>) was placed on the right index finger and heart rate was obtained continuously from the five-lead electrocardiogram monitoring (Dash 4000, GE Healthcare, Milwaukee, WI). After rubbing and cleaning the skin with an alcohol swab, three NIRS optodes SomaSensor SAFB-SM (Covidien, Troy, MI) were carefully placed on different anatomical sites:

- over the skeletal muscle in the medial part of both calves allowing measurements of proximal right and left leg rSO<sub>2</sub>;
- under the left arch of the foot allowing measurements of distal left foot rSO<sub>2</sub>.

The proximal right leg rSO<sub>2</sub> was used to verify the absence of spontaneous changes in rSO<sub>2</sub> value over time. The optodes were attached to the skin of participants with adhesive stickers so the angle and position of the optodes were kept constant. The optodes were connected to the two-wave-length INVOS 5100C (Covidien, Troy, MI) monitor via a four-channel reusable sensor cable RSC-4 (Covidien, Troy, MI). NIRS signals were sampled every 4 seconds. All rSO<sub>2</sub> values were recorded continuously and stored on a hard drive for off-line analysis. An automated pneumatic cuff inflator (Spengler Electronics, S.A.S. Spengler, Antony, France) was positioned at the upper extremity of the left lower limb. After the placement of these devices, a 20-min stabilization period was allowed before recording baseline measurements of blood pressure, heart rate, as well as SpO<sub>2</sub> and proximal and distal peripheral rSO<sub>2</sub> values.

### 2.2. Study protocol

After completion of a baseline set of measurements for each volunteer, a rapid arterial occlusion of the left lower limb was provoked by inflation of the pneumatic cuff at 50 mmHg above the resting systolic arterial pressure, up to the proximal left leg rSO<sub>2</sub> value decreases to 40% or for a maximal period of 10 minutes, and measurements were repeated (ischemia data set). The arterial cuff was then rapidly deflated to initiate reperfusion and measurements were repeated at the peak of the proximal left leg rSO<sub>2</sub> value (reperfusion data set). Finally, measurements were repeated after 10 minutes of reperfusion (final data set). The duration of the overall protocol for each volunteer was nearly 60 minutes.

### 2.3. Statistical analysis

The number of subjects was fixed empirically as it was impossible to estimate a difference between anatomical sites and/or gender a priori. Data are presented as mean ± standard deviation or median (interquartile range) for non-normally distributed variables (Kolmogorov-Smirnov test). The desaturation rate was calculated as (baseline – ischemia) rSO<sub>2</sub>/time of ischemia and expressed in %.min<sup>-1</sup>. The resaturation rate was calculated as (reperfusion – ischemia) rSO<sub>2</sub>/time of reperfusion and also expressed in %.min<sup>-1</sup>. ΔrSO<sub>2</sub> was calculated as peak rSO<sub>2</sub> minus baseline rSO<sub>2</sub>.

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