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Evaluation of Peripheral Circulation in Critically Ill Patients by Pulsed Doppler Ultrasonography

Shunji Kasaoka, Yoshikatsu Kawamura, Takeshi Inoue, Ryosuke Tsuruta, Daikai Sadamitsu, Tsuyoshi Maekawa

Abstract

Object: **Because critically ill patients often have peripheral circulatory disturbance, it is very important to evaluate the status of peripheral circulation as well as cardiac function. We evaluted peripheral circulation in critically ill patients by pulsed Doppler ultrasonography.**

Methods: **The subjects were 5 critically ill patients with the cold extremities. All of them were on mechanical ventilation in the intensive care unit. We measured the blood flow velocity of the radial artery before and during reactive hyperemia, which was induced by a 3-minute occlusion of the brachial artery by a tourniquet. Normal controls used for comparison were 10 healthy volunteers.**

Results: **Skin temperature of the examined upper extremity in the patient group was significantly lower than that in the control group (26.1 ± 2.4°C versus 33.8 ± 1.6°C, p<0.0001). Before reactive hyperemia, the mean blood flow velocity of the radial artery in the patient group was significantly lower than that in the control group (0.05±0.03 m/sec versus 0.27 ± 0.11 m/sec, p=0.0011). Pulsatility index and resistance index in the patient group were significantlly higher than those in the control group (9.3 ± 4.4 versus 3.1 ± 1.7, 1.4 ± 0.3 versus 0.9 ± 0.3, respectively). The baseline blood flow in all of the patient group had the reverse flow. The mean velocity of the reactive hyperemic blood flow in the patient group was significantly increased, compated witth that at baseline (0.05 ± 0.03 m/sec to 0.21 ± 0.11 m/sec, p<0.05), while pulsatility index and resistance index were significantly decreased. The increase rate of the mean flow velocity in reactive hyperemia was similar for both groups.**

Conclusion: **The peripheral blood flow in criticallly ill patients with the cold extremities is significantly decreased, however the peripheral vascular responsiveness is maintained.**

Introduction

The monitoring of pulmonary arterial pressure and cardiac output by Swan-Ganz catheter is useful for the evaluation of circulatory system in critically ill patients [1]. Because critically ill patients often have peripheral circulatory disturbance, it is very important to evaluate the status of peripheral circulation in these patients [2]. However, the study of the peripheral circulation in critically ill patients is not still satisfactory. Post-occlusive reactive hyperemia is a local phenomenon that occurs after temporary occlusion of the blood supply, and the reactive hyperemia response of the peripheral circulation in critically ill patients by pulsed Doppler ultrasonography, which is noninvasive method to measure the peripheral blood flow.

Methods

The study protocol was approved by the ethics committee of Yamaguchi University Hospital and all patients gave informed consent for their participation before the study.

The subjects were 5 critically ill patients with the cold extrremities (4 men and 1 woman, aged 24 to 72 years, mean age 49±19 years). All of the patients were on mechanical ventilation in the intensive care unit (ICU). The causes of admission to the ICU were acute

From the Advanced Medical Emergency and Critical Care Center, Yamaguchi University Hospital, Japan (Drs. Shunji Kasaoka, Yoshikatsu Kawamura, Takeshi Inoue, Ryosuke Tsuruta, Daikai Sadamitsu and Tsuyoshi Maekawa).

Address request for reprints to:
Shunji Kasaoka, MD, Advanced Medical Emergency and Critical Care Center, Yamaguchi University Hospital, 1-1-1 Minami-Kogushi, Ube 755-8505 Japan
Fax: +81-836-22-2344. E-mail: skasa-ygc@umin.ac.jp

myocardial infarction, epilepsy, trauma and hanging. Normal controls used for comparison were 10 healthy volunteers (10 men, aged 23 to 29 years, mean age 26 ± 2 years).

The patients were at rest for 5 minutes before initiation of the examination. The resting heart rate, blood pressure, body temperature, and skin temperature of the examined upper extremity were measured. We measured the blood flow velocity of the radial artery before and during reactive hyperemia using the ProSound SSD-5500 (ALOKA, Tokyo, Japan) with a 7.5 MHz linear probe. Reactive hyperemia was induced by a 3-minute occlusion of the brachial artery by a tourniquet. The radial artery Doppler flow signal was recorded on a videotape, and then maximum velocity, minimum velocity and mean velocity were measured with a personal computer (Power Macintosh G3, Apple, USA). Pulsatility index (PI) and resistance index (RI) were calculated by the following equations:

PI= (Maximum Velocity-Minimum Velocity) / Mean Velocity

RI= (Maximum Velocity - Minimum Velocity) / Maximum Velocity

Both parameters have been reported to be associated with the regionall vascular resistance [4]. Echocardiography was performed using the same system with a 3.5 MHz transducer for left ventricular dimensions and stroke volume. Systemic vascular resistance (SVR) was determined by the following equation:

80 x mean arterial pressure / [heart rate x stroke volume] (dyne•sec•cm^{-5})

Venous blood was obtained from all of the patients and healthy volunteers before occlusion of the brachial artery. Plasma total homocysteine concentration was determined by high performance liquid chromatography with a electrochemical detector (EICOM Co, Kyoto, Japan).

Data are expressed as mean±standard deviation. Differences were evaluated by Student's test. A level of $P<0.05$ was considered statistically significant.

Results

As shown in Table 1, mean age in the patient group was significantly older than that in the control group. Skin temperature of the examined upper extremity in the patient group was significantly lower than that in the control group (26.1 ± 2.4 °C versus 33.8 ± 1.6 °C, $p<0.0001$). Stroke volume evaluated by echocardiography in the patient group was significantly lower than that in the control group, while mean blood pressure and systemic vascular resistance were not significantly different between the two groups. Plasma homocysteine concentration was similar for both groups.

Doppler ultrasonographic variables at baseline and during reactive hyperemia were shown in Table 2. At baseline, the mean flow velocity of the radial artery in the patient group was significantly lower than that in the control group (0.05±0.03 m/sec versus 0.27±0.11 m/sec, $p=0.001$). PI and RI in the patient group were significantly higher than those in the control group (9.3±4.4 versus 3.1±1.7, 1.4±0.3 versus 0.9±0.3, respectively). . The baseline radial artery diameter was not signifiicantly different between the two groups. During reactive hyperemia, the mean flow velocity of the radial artery in the patient group was significantly lower than that in the control group (0.21 ± 0.11 m/sec versus 0.48 ± 0.20 m/sec, $p=0.016$) while PI was not

Table 1 *Baseline clinical characteristics*

	Patient group (n=5)	Control group (n=10)	p value
Age (years)	48.6 ± 19.2	25.6 ± 2.1	0.002
Body temperature (°C)	35.9 ± 0.9	36.7 ± 0.4	0.025
Skin temperature (°C)	26.1 ± 2.4	33.8 ± 1.6	<0.0001
Heart rate (beats/min)	86.4 ± 23.8	60.3 ± 9.6	0.009
Mean blood pressure (mmHg)	89.0 ± 12.9	83.7 ± 6.6	ns
Stroke volume (ml)	49.4 ± 17.1	74.6 ± 15.4	0.013
SVR (dyne•sec•cm^{-5})	1916 ± 745	1562 ± 344	ns
Homocysteine (nmol/ml)	17.2 ± 24.7	10.3 ± 3.1	ns

SVR, systemic vascular resistance

Table 2 *Doppler ultrasonographic variables at baseline and during reactive hyperemia*

	Patient group (n=5)	Control group (n=10)	p value
BASELINE			
Maximum velocity (m/sec)	0.31 ± 0.14	0.84 ± 0.46	0.027
Minimum velocity (m/sec)	-0.13 ± 0.09	0.09 ± 0.16	0.012
Mean velocity (m/sec)	0.05 ± 0.03	0.27 ± 0.11	0.001
Pulsatility index	9.31 ± 4.44	3.14 ± 1.67	0.002
Resistance index	1.43 ± 0.25	0.92 ± 0.26	0.003
Radial artery diameter (mm)	4.0 ± 0.9	5.2 ± 1.4	ns
REACTIVE HYPEREMIA			
Maximum velocity (m/sec)	0.37 ± 0.25	0.82 ± 0.30	0.013
Minimum velocity (m/sec)	0.09 ± 0.08*	0.33 ± 0.14**	0.004
Mean velocity (m/sec)	0.21 ± 0.11*	0.48 ± 0.20*	0.016
Pulsatility index	1.56 ± 0.98*	1.09 ± 0.29**	ns
Resistance index	0.75 ± 0.18**	0.61 ± 0.07**	0.043
Radial artery diameter (mm)	4.5 ± 0.9*	5.8 ± 1.3*	ns

**P<0.05, **p<0.01 versus baseline*

significantly different between the two groups. The mean velocity of the reactive hyperemic flow in the patient group significantly increased, compared with that at baseline (0.05 ± 0.03 m/sec to 0.21 ± 0.11 m/sec, $p<0.05$), while PI and RI significantly decreased. The increase rate of mean flow velocity in reactive hyperemia was not significantly different between the two groups. The radial artery in the patient group was significantly dilated in reactive hyperemia (4.0 ± 0.9 mm to 4.5 ± 0.9 mm, $p<0.05$). Figure 1 shows representative pulsed Doppler waveforms at the radial artery in each group. The baseline blood flow in all of the patients had the reverse flow as shown in Figure 1.

Discussion

We recognize the cold extremities as a sign of peripheral circulatory disturbance [5]. It is not uncommon to see the cold extremities in critically ill patients in the ICU. However, the status of peripheral circulation in critically ill patients with the cold extremities has not been sufficiently clarified. Therefore, we assessed the status of peripheral circulation in critically ill patients by pulsed Doppler ultrasonography.

The radial arterial blood flow in critically ill patients with cold extremities was significantly decreased, and regional vascular resistance was significantly increased. The increased regional vascular resistance and decreased peripheral blood flow may cause the cold extremities. The causes of the former were thought to be the decreased stroke volume owing to impaired cardiac function and/or the effect of some vasoactive mediators increased in the peripheral arteries. In addition, we thought that the reverse blood flow at baseline (**Figure 1**) might be a characteristic flow pattern in critically ill patients with the cold extremities. The mean flow velocity of the radial artery may be correlated with aging, however, we thought that the cause of the decreased mean velocity at baseline in the patient group was not aging alone.

In the present study, we assessed blood flow velocity at baseline in the patient group was significantly lower than that in the control group (Table 2). However, the mean blood flow in the patient group as well as the control group was significantly increased in reactive hyperemia. In addition, the increase rate of the mean flow velocity was not significantly different between the two groups. These findings suggest that the peripheral vascular responsiveness in critically ill patients with the cold extremities is maintained.

The vascular response to reactive hyperemia was reported to attenuate in patients with congestive heart failure [6] and with cardiogenic shock [7]. This obser-

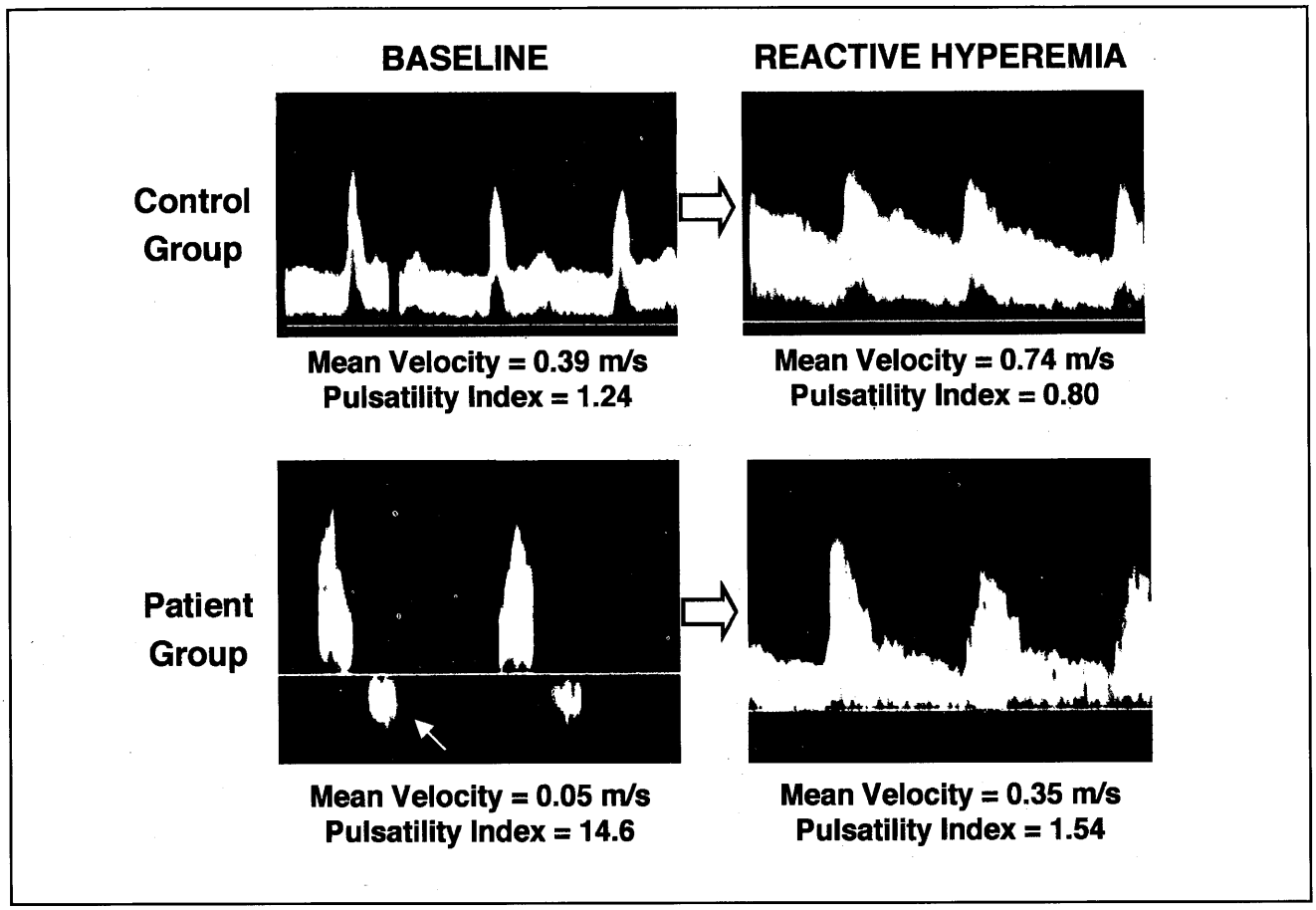

Figure 1. *Representative recordings of radial arterial blood flow velocity at baseline and during reactive hyperemia. In the control group, the mean blood flow velocity increased from 0.39 m/sec to 0.74 m/sec, while the pulsatility index decreased from 1.24 to 0.80. In the patient group, the mean blood flow velocity increased from 0.05 m/sec to 0.35 m/sec, while the pulsatility index decreased from 14.6 to 1.54. Arrow indicates the reverse flow.*

vation may reflect the severe reduction in cardiac output that occurs in cardiogenic shock. It has been reported that reactive hyperemia was significantly reduced in patients with septic conditions and the absence of reactive hyperemia might suggest poor clinical prognosis [8,9]. Provocation of reactive hyperemia may be useful for detection of high-risk patients who subsequently develop multiple organ failure. In the present study, 3 of the five patients died in the ICU, however they had the response of reactive hyperemia. We thought that the response of reactive hyperemia might not be a good predictor of clinical prognosis in the non-septic patients.

Reactive hyperemia after temporary interruption of blood flow is thought to result from an interplay between physical and local metabolic factors [10]. Of the metabolic factors, prostaglandins, adenosine, nitric oxide (NO), and ATP-sensitive potassium channels play an important role in reactive hyperemia [11,12]. Homocysteine is a sulfur-containing amino acid that is derived from dietary methionine. It has been reported that elevated plasma homocysteine is a risk factor for atherosclerosis and hyperhomocysteinemia may decrease the bioavailability of nitric oxide [13,14]. We measured plasma total homocysteine concentration to assess the effect of homocysteine on the status of peripheral circulation in critically ill patients with the cold extremities. Plasma homocysteine level in the patient group was not significantly increased and was not significantly associated with the Doppler ultrrasonographic variables.

In conclusions, the peripheral blood flow in critically ill patients with the cold extremities is significantly decreased, however the peripheral vascular responsiveness is maintained. The Doppler ultrasonography is useful for the evaluation of peripheral circulation in critically ill patients in the ICU.

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