Assessment of Stress-Induced Hemodynamic Responses Using Multipurpose Non-invasive Continuous Cardiovascular Monitoring System

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Abstract—**In order to develop a simple and reliable assessment method of the stress induced psychosomatic and hemodynamic responses against various stress situations, especially for evaluating of the effectiveness of stress reduction methods, a multipurpose non-invasive continuous cardiovascular monitoring system was developed. The monitoring system could measure beat-by-beat finger blood pressure (SBP, MBP, DBP based on the volume-compensation method), cardiac output (CO, electrical admittance method), total peripheral resistance (TPR=MBP/CO), and the other hemodynamic related parameters (e.g. RR-interval, respiratory rate, pulse wave velocity, etc.). As controlled stress conditions, the human subjects would be exposed to the various stresses such as flash video display, electrical stimulation and so on. In this study, after 5 minutes resting, the stress induced hemodynamic responses were measured during 10-min presentation of floating vertical stripes image using 5 healthy subjects. The image presentation was discontinued when the subject gave his/her self-assessment due to considerable discomfort. The results showed that although BP increased during the presentation in all the subjects, there observed two types of cardiovascular responses; one is a type of increase in CO (or of almost unchanging or decrease in TRP), and the other of increase in TPR. These results strongly suggested that the detection of the change in TPR might be an important factor for the evaluation of stress conditions. Further investigations would be required for the reasons why these two types were observed in the same stressful condition.**

I. INTRODUCTION

It is a common observation that hemodynamic changes, especially arterial blood pressure, as part of the physiological response to stressful conditions. This observation has drawn many to the conclusion that stress factors contribute to hemodynamic disorder, arterial hypertension, lifestyle-related diseases and so on [1,2]. In this study, to assess the degree of the stress-induced hemodynamic responses especially for the prevention of the hemodynamic disorder, a portable multipurpose noninvasive continuous cardiovascular monitoring system was developed.

The overall goals of this study are to find some simple indexes for the assessment of the degree of the stress conditions using hemodynamic parameters and treat ourselves by appropriate stress reduction methods using various noninvasive stress assessment systems. At the present, for finding some simple indexes for the assessment of the stress conditions, we investigated the acute hemodynamic responses to the stress of sensory conflict known as the motion sickness using floating vertical stripes image presentation.

II. MATERIALS AND METHODS

Portable multipurpose noninvasive continuous cardiovascular monitoring system

The portable multipurpose noninvasive continuous cardiovascular monitoring system (Fig.1) can offer beat-by-beat index finger arterial blood pressure (SBP, MBP, DBP based on the volume-compensation method), instantaneous cardiac output (CO, electrical admittance method), total peripheral resistance (TPR=MBP/CO), and the other hemodynamic related parameters such as inter-beat interval (RR interval), respiratory rate, pulse wave velocity, etc. The index finger arterial blood pressure was converted to the heart-level blood pressure with the hydrostatic pressure sensor in the portable unit. For more comfortable and absolute value measurement, we are now studying about the optimal position of the tetra-polar spot electrodes method for CO measurement. However, in this study, the tetra-polar band electrodes method was employed due to its performance well investigated. The more detail descriptions of the measurement principles and performances were cited elsewhere [3,4,5].

Sensory conflict stress, Motion sickness

As a sensory conflict stressor, the floating vertical stripes image was presented to the human subjects. The visual perception conflict is well known as the motion sickness. The motion sickness symptoms are often experienced by individuals in moving vehicles, vehicle simulations, virtual reality environments, and zero gravity conditions. Although the constellation of the symptoms will vary, motion sickness symptoms can include headache, dizziness, pallor, bodily warmth, drowsiness, nausea, retching, and vomiting. Although its causes are far from understood, current theories of the motion sickness are centered on sensory conflict [6].

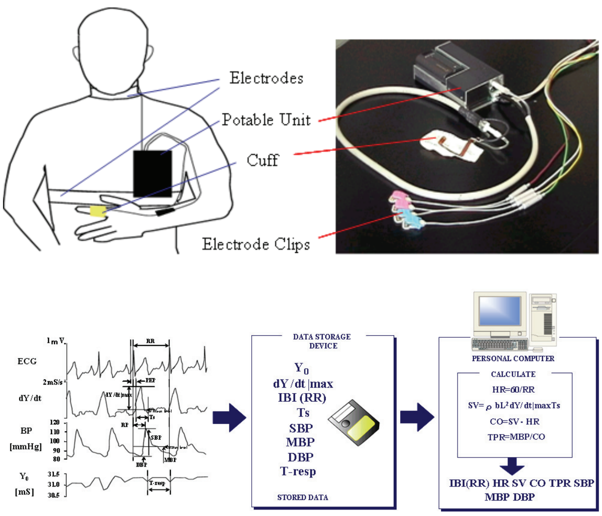

Fig. 1 The portable multipurpose noninvasive continuous cardiovascular monitoring system and its measurement parameters

Procedure

The healthy adult subjects (20-24 yrs, n=12) sat in front of the image projection screen. After 5 minutes resting, the 10-min floating strips image was presented. The image presentation was discontinued when the subject gave his/her self-assessment due to considerable discomfort, motion sickness symptoms. The floating speed of the stripes was adjusted initially as fast as he/she could track using nystagmograph.

During the experiments, the portable multipurpose noninvasive continuous cardiovascular monitoring system was stored in the shirt pocket of the subject and the continuous arterial blood pressure (SBP, MBP, DBP), inter-beat interval (IBI), stroke volume (SV), cardiac output (CO) and total peripheral resistance (TPR) were measured simultaneously.

III. RESULTS

The results showed that the blood pressure increased initially and the inter-beat interval (IBI) decreased during image presentation in all subjects. However, two different types of the cardiovascular responses were observed during the image presentation (typical recordings were shown in Fig. 2, 3).

The one is the type of increase in CO (or of almost unchanging or decrease in TPR), and the other of increase in TPR (or increase in MBP). These results strongly suggested that the detection of the change in TPR might be an important factor for the evaluation of stress conditions. The results of the hemodynamic reactive during the high level of the self-assessment of discomfort (3 or 4) are summarized in the table 1. All of the subjects gave the high level (3 or 4) of the self-assessment of the discomfort during 10-min image display.

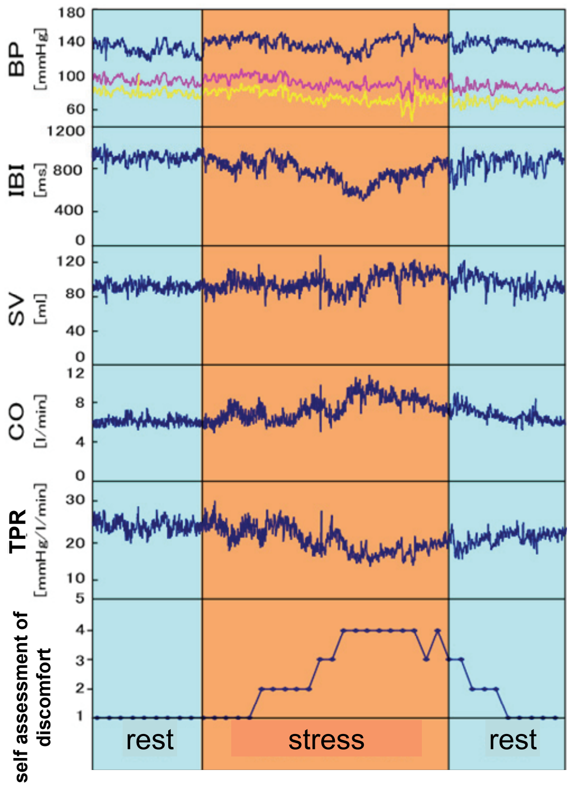

Fig. 2 Typical recording of a type of increase in CO (decrease in TPR)

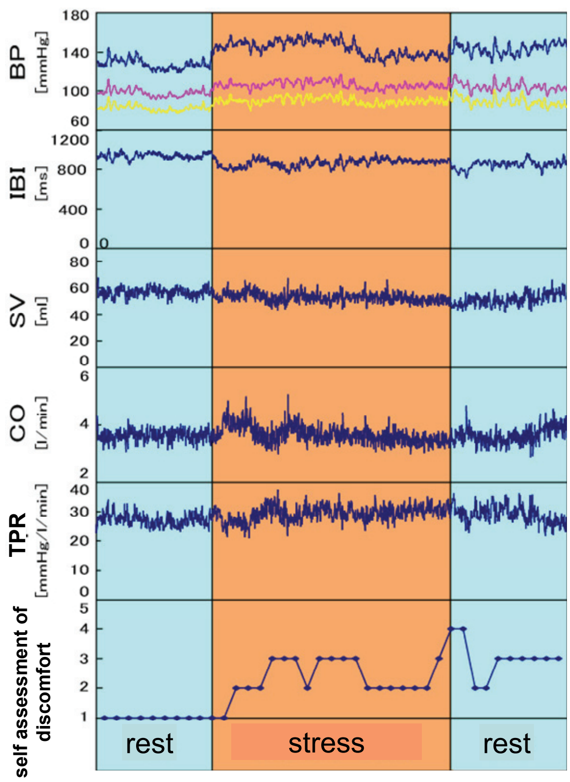

Fig.3 Typical recording of a type of the increase in TPR

TABLE 1

The results of the acute hemodynamic reactive during the high level (3 or 4) of the self-assessment discomfort.

The types of the hemodynamic reactive were categorized by the subjects of increase in TPR (or MBP) (blue shadowed) and the other (almost unchanging or decrease in TPR).

p<0.05

Subject	MBP	IBI	SV	CO	TPR
A	+	−	−	NS	+
B	+	−	−	−	+
C	+	−	−	NS	+
D	+	−	−	NS	+
E	+	−	−	−	+
F	+	−	−	+	+
G	+	−	−	NS	+
H	−	−	+	+	−
I	−	−	+	+	−
J	NS	−	NS	+	−
K	NS	−	+	+	NS
L	−	−	−	+	−

IV. DISCUSSION AND CONCLUTION

As shown in the results (Fig.2,3), the initial changing hemodynamic parameters, such as increases in blood pressure, during the image presentation were recognized as anxiety reaction to the experiments. The acute hemodynamic responses against the anxiety reaction were in the similar in all subjects.

For the sensory conflict stress conditions, the detection of the change in TPR suggested that the important index for the evaluation of the stress conditions. From the point of the autonomic nerve activity, the TPR has been recognized as mainly regulated by the sympathetic nerve activity to maintain the bodily demanded blood pressure. So the change in TPR is directly concerned with the change of the balance of the autonomic nerve activity.

However, the types of changing TPR during the image presentation were categorized by two groups such as increase and decrease type. The type of increase in TPR would be recognized as the reinforcement of the vascular (more peripheral) response and the type of decrease as of the myocardial (more central) response from the TPR=MBP/CO. The response of the increase in TPR has been observed in the cold pressor task (passive task) and the response of the decrease also in the mental arithmetic task (active task) [7]. The differences of the TPR responses against stresses might differ from the passive or active reaction. So the individual differences of the hemodynamic responses in this study might be from the mixed or one-sided stress responses of the passive and/or active reaction. We are now planning to take further investigations of the stress-induced hemodynamic response measurements against various stresses.

On the other hand, the noninvasive assessment methods of the autonomic activity using heart rate variability (HRV) or blood pressure variability (BPV) are widely used in various situations [8,9,10]. However, these methods are hardly distinguished sympathetic and parasympathetic nerve activity due to its double innervations. From the present results, another noninvasive autonomic activity analysis method such as TPR variability (TPRV) will be useful for the assessment of the only sympathetic nerve activity. The analyses of the HRV, BPV and TPRV against various stress-induced hemodynamic responses are also currently ongoing to evaluate the stress conditions and the effects of the stress reduction methods.

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