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Short Report

The Relationship between Inferior Vena Cava Distensibility and Arterial Blood Pressure

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Abstract

The purpose of this study was to clarify the relationship between the inferior vena cava distensibility and blood pressure. Six Japanese healthy males volunteered to participate in this study. We measured the cross-sectional area of inferior vena cava (CSAivc) and blood pressure at rest and during passive leg raising in supine position. We calculated the change rates of each parameter, based on the value at rest in supine position. We observed a negative correlation between the change rate of CSAivc and systolic blood pressure ($P<0.05$). These results suggest that the inferior vena cava distensibility affects partially systolic blood pressure.

Introduction

The venous vasculature, called the capacitance vessel [1], has the main capacitive function as approximately 70% of the total blood volume is contained within the venous compartment [2, 3]. The veins, especially splanchnic veins, deep limb veins and cutaneous veins, are capable of active and passive changes in capacity that serve to modulate the filling pressure of the heart by adjusting the central blood volume [4]. In previous studies, we clarified that while passive leg raising (PLR), which was the model accelerating purposely venous return to heart, increased the cross-sectional area of inferior vena cava (CSAivc), stroke volume (SV) during PLR at rest saw no change [5]. Moreover, while the CSAivc in standing position with water immersion (water level: trochanter major) increased, compared to that in standing position on land, SV saw no change [6]. These results suggested that the inferior vena cava might be the organ that is not just a pool of blood, but controls the volume of venous return to heart as well as veins and venules.

We hypothesized that the structure and the function of inferior vena cava (i.e. the inferior vena cava distensibility) affected the preload and the afterload of the heart. In this study, we investigated the relationship between the changes in CSAivc and BP with PLR, based on the results in a previous study [5].

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Methods

Subjects

Japanese healthy males (n=6) volunteered to participate in this study. The means of their age, height and body weight were 20 years, 172.1 ± 6.8cm and 64.0 ± 6.7kg, respectively. All subjects were non-smokers. None of them were taking any medications or had current or past evidence of any cardiovascular disease. We informed each subject of the procedures to be utilized as well as the purpose of this study. All subjects signed informed consent forms prior to participation in this study. All procedures of this study were approved by the ethics board at Kawasaki University of Medical Welfare.

Experimental procedures

The CSAivc, systolic and diastolic blood pressure (SBP and DBP) at rest and during PLR in supine position of each subject were measured. The posture during PLR in each subject was set at the hip joint flexion position of 30 degrees in supine position (Fig.1). We prescribed that each subject abstains from caffeine, intensive exercise and drinking on the night before the test, and fasted for at least 3 hours before the test.

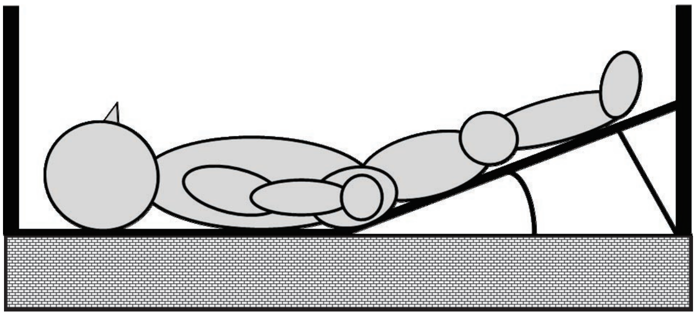

Fig. 1 Passive leg raising

The measurement of CSAivc and blood pressure

We created the cross-sectional image of inferior vena cava for a minute at the 12th thoracic vertebra level, using ultrasound B-mode (180PLUS, SonoSite, INC., WA, USA), and retrieved these images to a personal computer via digital-video converter (ADVC-300, Canopus, Co, LTD., Kobe, Japan). We sampled the five cross-sectional pictures of inferior vena cava during expiration, which is reproducible [7], from recorded image, and calculated the cross-sectional area of each pictures, using the image analysis software (NIH image 1.63, NIH., USA). Then, we calculated the average value of those, and defined the average value as CSAivc in each condition.

SBP and DBP were measured, using aneroid sphygmomanometer. SBP and DBP during PLR in supine position were measured within a minute of the raising legs.

Statistical analysis

SBP and DBP were presented as means ± standard deviation (SD). Mean differences of SBP and DBP were examined using Student's paired t-test. We calculated the change rates of each parameter with PLR, based on the value at rest in supine position. The Pearson's correlation coefficients were calculated to test for significance of the linear relationship between the change rates of CSAivc and the change rates of SBP and DBP.

$P<0.05$ was considered to be statistically significant.

Results and Discussion

There were no condition differences in SBP and DBP (Table 1). We observed the significant negative correlation between the change of CSAivc and the change of SBP (P<0.01, r=-0.95, y= -0.22x + 130.53. Fig.2). However, there was no significant correlation between the change of CSAivc and the changes of DBP (N.S., r=-0.15. Fig.3).

Table 1 Systolic and diastolic blood pressure in supine position and during passive leg raising
Data were mean ± SD. Not significant.

	Supine position	Passive leg raising
Systolic blood pressure (mmHg)	115 ± 4	112 ± 5
Diastolic blood pressure (mmHg)	63 ± 5	60 ± 3

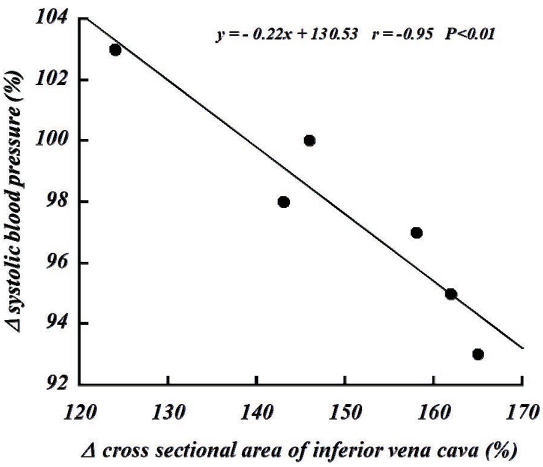

Fig. 2 Correlation between the change rates of cross sectional area of inferior vena cava and systolic blood pressure with passive leg raising, based on the value at rest in supine position

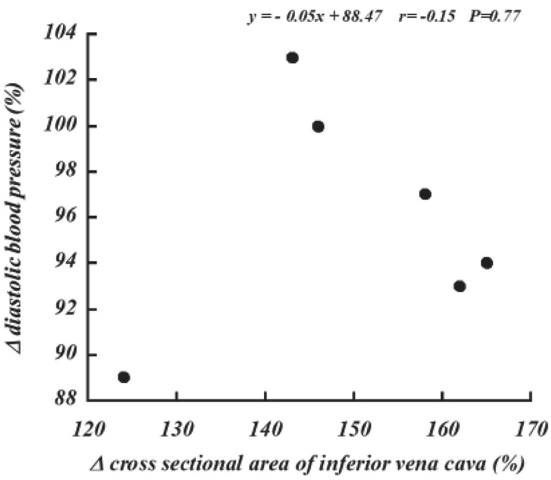

Fig. 3 Correlation between the change rates of cross sectional area of inferior vena cava and diastolic blood pressure with passive leg raising, based on the value at rest in supine position

The main finding of this study was that a negative correlation was observed between the change of CSAivc and the change of SBP. These results suggested that the inferior vena cava distensibility might affect SBP.

We considered that there were two possible mechanisms responsible for the distensibility of inferior vena cava. One was the functions, which regulated inferior vena cava. In previous study, we reported that the inferior vena cava might be the organ that is not just a pool of blood, but controls adequately the volume of venous return to heart [5] and the vascular capacitance of inferior vena cava might be regulated by the neurohumoral system and regional factor as well as veins and veinules because the increase of CSAivc during PLR at rest disappeared after high intensity exercise [8]. Regulation of the venous system was dominated by the baroreceptor reflex systems (baroreflex), which were the neurocardiovascular reflexes that operated in a negative feedback system [9], mediated sympathetic nerve system [3]. Thus, we suggest that the changes of venous tone, which are evoked by the baroreflex mediated sympathetic nerve system, caused the changes of CSAivc during PLR. The arterial baroreflex sensitivity related to the compliance of an artery in which artery baroreceptors are located [10]. In young men, whereas the differences in arterial compliance between the sedentary men and endurance trained men [11], resistance training reduced arterial compliance [12]. In this study, the inferior vena cava distensibility in a subject who had resistance training habits tended to be lower than the other subjects. We considered that if the venous tones of inferior vena cava were modulated via baroreflexes, the decrease of arterial baroreflex sensitivity, induced by resistance training, affected the decrease of inferior vena cava distensibility. The other possible mechanism was the structures of inferior vena cava. Miyachi et al. [12] suggested that the changes of the arterial structure and/ or the arterial load-bearing properties of collagen and elastin might cause the decrease of arterial stiffness with resistance training. The previous study of inferior vena cava reported that the increase of CSAivc was induced by high intensity endurance training [13]. These findings suggested that the habitual exercise and lifestyle might alter the structures of inferior vena cava as well as artery because the major components of veins are the smooth muscle and the fibrous proteins, collagen and elastin as well as arteries [9] while the veins have more collagen, but less elastin and smooth muscle than arteries [4]. However, there were no data available to support adequately these mechanisms.

The correlation between the change of CSAivc and the changes of DBP was not significant in this study. There was a negative correlation between muscle sympathetic nerve activity, which contributes the control of vascular resistance, and DBP [14]. We implied that the vascular resistance, rather than the volume of venous return, might affect DBP.

This study had several limitations. First, we measured each parameter within a minute after the change of posture. Therefore, the changes of each parameter over time were not made clear. The vasoconstriction responses to the change in posture were relatively quick, whereas the changes in venous tone occurred much more slowly [15]. We considered that venous tone responded within 20-30 seconds after the changes in posture [5]. We implied that we might obtain findings which differ from the results obtained in this study if we evaluated continuously the parameters soon after the changes in posture. Second, this study was the cross-sectional study. Therefore, we must confirm the suggestions, which were obtained in this study, in future studies focusing on the relationship between inferior vena cava distensibility and the other factors (aging, habitual exercise, and so on). However, we emphasized that the finding in this study was availability to hypothesize the relation of inferior vena cava distensibility and the other factors.

In conclusion, a negative correlation was observed between the change of CSAivc and the change of SBP with PLR.

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