Pneumatic Lower Extremity Compression During Dobutamine Stress Echocardiography

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Background  Afterload is expected to increase with pneumatic compression of the lower extremities. There are left ventricular (LV) wall stress, which is the most important factor determining myocardial oxygen demand, will also increase, leading to an increase in the sensitivity of dobutamine stress echocardiography (DSE) or a shortened time to a positive response.

Methods and Results  In 40 patients who underwent DSE and were anticipating undergoing coronary angiography (CAG), the imaging was repeated with pneumatic compression (100 mmHg) of the lower extremities (DSEcomp) prior to CAG. The sensitivity and specificity of DSE and DSEcomp were determined based on the CAG findings. All patients tolerated pneumatic compression of the lower extremities during the tests. LV end-systolic volume (p=0.042) and end-systolic wall stress (p=0.036) were significantly greater with DSEcomp than with DSE. In 3 patients with false-negative results for DSE, DSEcomp gave a positive response, demonstrating a significant increase in sensitivity from 75% to 94% (p=0.045). Only 1 patient with a true negative result for DSE was interpreted as showing a positive response for DSEcomp, resulting in a decrease in specificity from 88% to 83% (p=NS). In 10 of 12 patients with true positive results for both DSE and DSEcomp, positive responses were seen at least 1 stage earlier with DSEcomp than with DSE.

Conclusions  Pneumatic compression of the lower extremities increases the sensitivity of DSE and shortens the time to a positive response.  (*Circ J* 2008; 72: 251–255)

Key Words:  Diagnostic accuracy; Dobutamine stress echocardiography; Pneumatic compression
sure and 12-lead ECG were recorded at baseline and at the end of every stage. The criteria for termination of the dobutamine infusion were attaining the target HR (>85% of the age-predicted maximum HR), new regional wall motion abnormalities, significant hemodynamic changes, significant arrhythmia, or severe adverse effects. The standard 16-segment model was used for wall motion analysis. A test was considered positive if a regional wall motion abnormality appeared in 1 or more segments. All echocardiograms were digitized online on optical disks and recorded on super-VHS videotape for subsequent offline analysis by another experienced observer. The presence and stage of the appearance of the regional wall motion abnormality were determined by consensus of 2 independent observers.

Assessment of LV Volume and Afterload

Of the 40 patients, 17 with negative results for both DSE and DSEcomp, normal coronary arteries, and adequate image quality for endocardial border detection on the apical views, were selected for the measurements of LV end-systolic and end-diastolic volumes using the modified Simpson’s method at each stage of DSE and DSEcomp. The smallest and largest LV cavity sizes determined from frame-by-frame inspection of the echocardiographic images were used to determine the end-systolic and end-diastolic volumes, respectively.

Systemic vascular resistance is reported to be an unreliable index of LV afterload, so to evaluate the cardiac effect of pneumatic compression of the lower extremities, we calculated the LV end-systolic wall stress at each stage of DSE and DSEcomp. One patient with inadequate image quality on the parasternal short-axis view was excluded, so 16 patients were included in the final analysis. End-systolic wall stress was estimated non-invasively using the measured blood pressure, LV dimension and wall thickness. The following formula was used for LV end-systolic wall stress measurement:

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\text{LV end-systolic wall stress} = \left( \frac{\text{Pes}}{(\text{Hes}) \left(1 + \frac{\text{Hes}}{\text{Des}}\right)} \right)^{0.34}
\]

where LV end-systolic wall stress is in g/cm², Pes, which stands for LV end-systolic pressure, is in mmHg, Des and Hes are in cm, and 0.34 is the factor for converting Pes from mmHg to g/cm². Because there were no subjects with aortic stenosis, Pes could be replaced with the non-invasively determined systolic blood pressure.

CAG

CAG was performed using either the femoral or radial approach, and stenosis >50% of the vessel diameter on quantitative CAG was defined as significant. Having at least 1 significant coronary artery stenosis was regarded as positive for CAG and the diagnostic accuracy of DSE and DSEcomp was then assessed according to the CAG findings.

Statistical Analysis

All values are expressed as mean ± SD or as percentage. The Z test was used to compare the sensitivity and specificity of DES and DSEcomp. To compare the effect of pneumatic compression in addition to dobutamine infusion, we used repeated measures analysis of variance (ANOVA) on the LV end-systolic and end-diastolic volumes, and the end-systolic wall stress. Where appropriate, comparisons of the 2 arms (DSE vs DSEcomp) at each stage were conducted using the unpaired t-test. SPSS 13.0 statistical package (SPSS Inc, Chicago, IL, USA) was used and p<0.05 was considered statistically significant.
Results

Effects of Compression on LV Volume and Afterload

In the 17 patients with normal CAG and negative findings for both DSE and DSEcomp, there was a significant difference between the DSE and DSEcomp in LV systolic volume (p=0.042). The LV volumes were significantly larger during 40 μg·kg⁻¹·min⁻¹ dobutamine infusion and with the addition of atropine in DSEcomp compared with the same stages in DSE (Fig 1). In 16 patients in whom LV end-systolic wall stress was obtained, there was no significant difference between DSE and DSEcomp in the blood pressure responses (Fig 2); however, the LV end-systolic wall stress was significantly different between DSE and DSEcomp (p=0.036). LV end-systolic wall stress was significantly higher during 30 and 40 μg·kg⁻¹·min⁻¹ dobutamine infusion, and with the addition of atropine in DSEcomp compared with the same stages in DSE (Fig 3).

Effects of Compression on the Results for DSE

There were 16 true positive cases among the 40 patients. In 3 patients with false-negative results for DSE, DSEcomp showed a positive response, thereby increasing the sensitivity of the test from 75% to 94% (p=0.045). Only 1 patient with a true negative result for DSE showed a positive response for DSEcomp, decreasing the specificity from 88% to 83% (p=NS). In 12 patients with true positive results for both DSE and DSEcomp, positive responses were seen 2 stages earlier in 3 and 1 stage earlier in 7 during DSEcomp (Figs 4, 5).

Discussion

The concept of therapeutic pneumatic compression of the lower part of the body was introduced to clinical practice as early as 1903 and its application has been investigated in aerospace and emergency medicine. Among the hemodynamic changes associated with its use, systemic vascular...
resistance is reported to be increased, which may affect LV afterload. Theoretically, increasing the afterload during DSE can increase the sensitivity of the test and, among the loading conditions used in echocardiography, sustained hand-grip exercise has been used to increase afterload. However, this maneuver cannot be adequately performed for a prolonged period of time and has only been used in cases when loading manipulation is necessary for a short period of time, such as during evaluation of dynamic obstruction of the LV outflow tract. Therefore, applying pneumatic compression to the lower part of the body may be a good option for providing a sustained increase in afterload during DSE. For the convenience of patients and to allow easy changing of the patient's position during the examination, in the present study we limited the pneumatic compression to the lower extremities. All the patients who participated in our study tolerated 100-mmHg compression of the lower extremities from the beginning to the end of the study. Because of the concerns regarding the unreliability of systemic vascular resistance as an index of LV afterload, we measured end-systolic wall stress to investigate the effect of compression of the lower extremities on LV afterload and we found a significant increase when pneumatic compression was used. Three patients with false-negative results for DSE, showed a positive response for DSEcomp. A more pronounced effect of pneumatic compression of the lower extremities was earlier achievement of a positive response. In all, 83% (10/12) of the patients with the true positive results for both DSE and DSEcomp showed a positive response at an earlier stage of DSEcomp than for DSE. One of the major obstacles for the wide-spread use of DSE in clinical practice is that it is a time-consuming test. gaining a positive response at an earlier stage not only shortens the test time but also shortens the time to restoration of the baseline HR and, therefore, the time to discharge of the patient from the laboratory.

Study Limitations
It should be noted that our study was limited by the small number of patients. Repeating the same test was the main
obstacle in recruiting more patients and the results of our study should be validated in a large-scale multicenter study.

Our study is also limited by not being performed in consecutive patients. Only 40% (16/40) of the patients had significant coronary artery stenosis. In order to repeat the DSE, patients in whom CAG had been performed on the day of admission were excluded and therefore, patients with atypical chest pain or false-positive results based on other stress tests or coronary computed tomography angiography were more likely to be included.

Conclusions

The present results suggest that using pneumatic compression of the lower extremities during DSE may reduce both false-negative test results and the time needed to obtain a positive result.

References