Electrical Stimulation of Acupuncture Points and Blood Pressure Responses to Postural Changes: A Pilot Study

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Background Application of transcutaneous electrical stimulation over acupuncture points (Acu-TENS) facilitates heart rate recovery after exercise and restores hemodynamic stability after open heart surgery. The role of Acu-TENS on cardiovascular parameters in response to postural changes has not been reported.
Objective To investigate (1) the effect of Acu-TENS on blood pressure responses to -10° head-down postural change and (2) whether such effects were associated with modulation by the autonomic nervous system.
Method Sixteen healthy volunteers, mean age 22.8 (SD, 3.1) years, were subjected to a -10° head-down tilt from the supine position on 3 separate occasions and received in random order the following 3 intervention protocols for 40 minutes before the postural change: Acu-TENS (over bilateral acupuncture points, PC6), sham-TENS (TENS applied to the skin over the patellae), and control (no electrical output from the TENS device applied at PC6). Mean arterial pressure, large artery elasticity index, cardiac output, and heart rate were recorded and compared at different stimulation protocols in the supine and -10° head-down tilt positions. Spectral analysis of heart rate variability was used to determine any modulation by the autonomic nervous system.
Results Change in large artery elasticity index was observed only in the Acu-TENS group ($P < .05$) and mean arterial pressure appeared most stable during Acu-TENS. Autonomic nervous system modulation was not apparent with spectral analysis, irrespective of intervention. Sympathetic activity predominated in all positions.
Conclusion Acu-TENS seems to reduce blood pressure changes with -10° head-down tilt with concomitant changes in arterial vessel tone. (*American Journal of Critical Care.* 2011; 20:e67-e74)

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Hemodynamic stability during necessary interventions by intensive care nurses is essential in the management of critically ill patients. Patients with basal lung disease may require head-down positioning for gravity-assisted drainage and removal of secretions. Alternate side or even prone positioning for optimization of lung ventilation and prevention of pressure ulcers may be necessary. Patients with spinal cord injury often require postural change during their treatment and rehabilitation; however, postural change can be associated with complications. Low resting blood pressure is usually a feature of spinal cord injury, and a marked decrease in systolic blood pressure can occur with postural change.[1,2] Hypotension induces symptoms related to cerebral hypoperfusion, including light-headedness, restlessness, dizziness, blurred vision, and general fatigue.[3] These responses can have a marked negative effect on the provision of effective rehabilitation, as well as limiting the efficient completion of activities of daily living.[4] In many instances, the prevention of excessive orthostatic hypotension in response to an orthostatic challenge is accomplished via pharmacological intervention or avoidance of the provoking circumstances.[2] However, a postural change is often an unavoidable necessity for effective treatment of the patient, and pharmacological management can be contraindicated because of accompanying unwanted drug effects.[2]

Traditional acupuncture has been used for thousands of years in China, and its effect on hemodynamic responses has been reported.[5] Although acupuncture has demonstrated some beneficial effect on disease, it is an invasive procedure and carries some risks.[6,7] Application of transcutaneous electrical stimulation (TENS) over acupuncture points (thus termed Acu-TENS), a noninvasive means of acupoint stimulation, is effective in pain relief[8,9] and enhances heart rate recovery after exercise.[10] Recent reports suggest that Acu-TENS facilitates an earlier return to preoperative heart rate and maintains postoperative blood pressure at a lower rate pressure product in patients after open heart surgery.[11]

Despite these encouraging data, reports on the physiological effects of Acu-TENS are scanty. The effect of Acu-TENS on mean arterial pressure (MAP) during postural changes has never been reported. MAP is an important clinical sign and index of organ perfusion, often used to assist with therapeutic decision making. A noninvasive intervention that helps to stabilize MAP would be a useful adjunct to management of critically ill patients. For example, if Acu-TENS effectively modulates blood pressure change, it can be used before interventions that require postural alteration (eg, postural drainage for secretion removal) in critically ill patients with unstable or borderline blood pressure.

It is hypothesized that acupuncture and Acu-TENS affect the cardiovascular system via autonomic nervous system modulation.[12-14] Modulation of autonomic nervous system activity can be investigated by using spectral analysis of heart rate variability.[15] An increase in the high-frequency component represents an increase in parasympathetic activity, whereas an increase in the low-frequency component of the spectrum represents an increase in both the sympathetic and parasympathetic tone.[15] The interaction between the sympathetic and parasympathetic signals is expressed as a low-frequency to high-frequency ratio (LF/HF). A stable LF/HF ratio may suggest minimal alteration of autonomic neural activity.

The aim of this pilot study in healthy subjects is to determine whether Acu-TENS has an effect on MAP maintenance during postural change and explore a possible mechanism of action through evaluation of the large artery elasticity index (LAEI), a measure of the degree of propagation of blood flow within the artery[16-18] and LF/HF ratio.

About the Authors

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Method

Approval to conduct the study was obtained from the Departmental Research Committee of The Hong Kong Polytechnic University. University students were recruited by convenience sampling. Subjects were excluded if they had a history of cardiopulmonary, musculoskeletal, digestive, or abdominal organ dysfunction. The nature of the study was explained to the subjects, and informed consent was obtained before data collection. As studies of hemodynamic responses to postural changes in healthy subjects often adopt a sample size of 6 to 15 participants, a sample size of more than 15 was deemed appropriate for this study.

Subjects were invited to attend the cardiopulmonary laboratory on 3 separate days, 1 week apart, to receive, in random order, 3 different interventions described here. The temperature and humidity of the laboratory were maintained for all visits. All subjects were asked to refrain from food or fluid intake for at least 1 hour before arrival. Upon arrival, subjects were asked to rest in the sitting position for 30 minutes. Following this period of accommodation, the participant lay supine on a custom-designed tilt table for 10 minutes. Heart rate and cardiac output were measured continuously by the HIC-3000 Impedance Cardiograph System (Bio-Impedance Technology, Inc, Chapel Hill, North Carolina); blood pressure and LAEI were measured by the HDI/PulseWave CR-2000 Research Cardio-Vascular Profiling System (Hypertension Diagnostics, Inc, Eagan, Minnesota) at rest and at 5-minute intervals, using data taken at the fifth minute of the supine and head-down positions for comparison. Reliability of the HIC-3000 and HDI/PulseWave CR-2000 was established before the study with coefficients of variation of less than 10% on repeat measurements. Measurements were recorded and compared on 2 separate occasions an hour apart in 5 subjects. Measurements by using the HIC-3000 varied by 3.8% for cardiac output and 3.06% for stroke volume; measurements by the PulseWave CR-2000 varied by 0.29% for systolic blood pressure, 1.9% for diastolic blood pressure, and 3.68% for large artery elasticity.

TENS electrodes were placed either bilaterally over the patellae or over the acupuncture points PC6, Neiguan. These points are located 2 "cun" (the distance between the palmar skin creases circumscribing the interphalangeal joints of the middle finger) proximal to the distal crease of the wrist, between the palmaris longus and flexor carpi radialis tendons. The electrodes were attached to a TENS machine ITO ES-320 (ITO Co, Ltd, Tokyo, Japan). One of 3 different intervention protocols (described later) was adopted for 40 minutes, the order of the protocols was based on an allocation number concealed in an opaque envelope. After 40 minutes, the subject was placed in a -10° head-down position for 10 minutes and then returned to supine position for another 10 minutes (Figure 1). Before the intervention, parameter settings for the TENS units were verified by using a 100-MHz oscilloscope (MSO6014A; Agilent Technologies, San Diego, California).

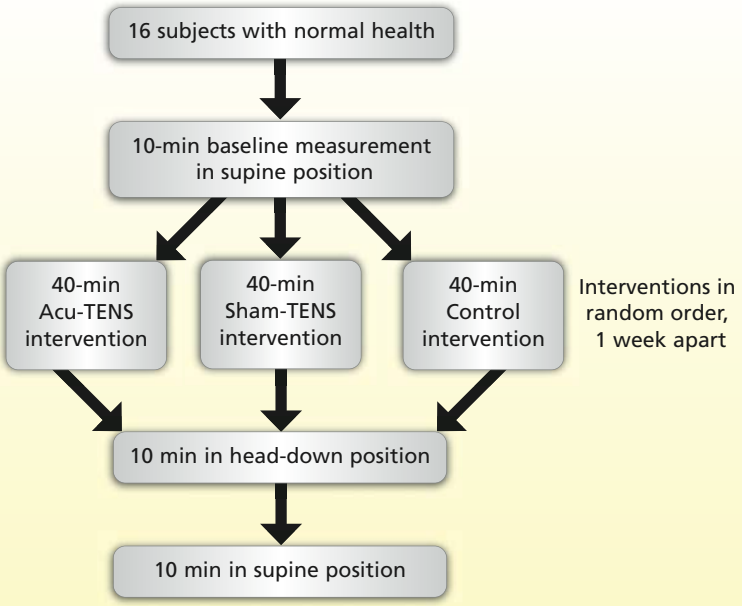

Figure 1 Flow chart of the study procedures.

Intervention Protocols

Acu-TENS Protocol. Electrodes were placed over acupuncture points PC6, and the electrical stimulation parameters were set at burst train mode, frequency 2 Hz, pulse width 200 μs, intensity at the maximal level that the subject could tolerate but short of muscle contraction. Those stimulation parameters were adopted on the basis of our previous experience with Acu-TENS.[11,19,20] A stimulation duration of 40 minutes was chosen, based on a previous study that demonstrated that stimulation for 40 minutes was necessary to induce optimal (analgesic) effect.[21]

Sham-TENS Protocol. Electrodes were placed on the skin over both patellae. Stimulation parameters were the same as the Acu-TENS protocol.

Control Protocol. Electrodes were placed over PC 6, but no electrical output was delivered from the TENS device. The output light, however, remained flashing. Subjects were told they were given electrical stimulation at a frequency that was beyond human perception.

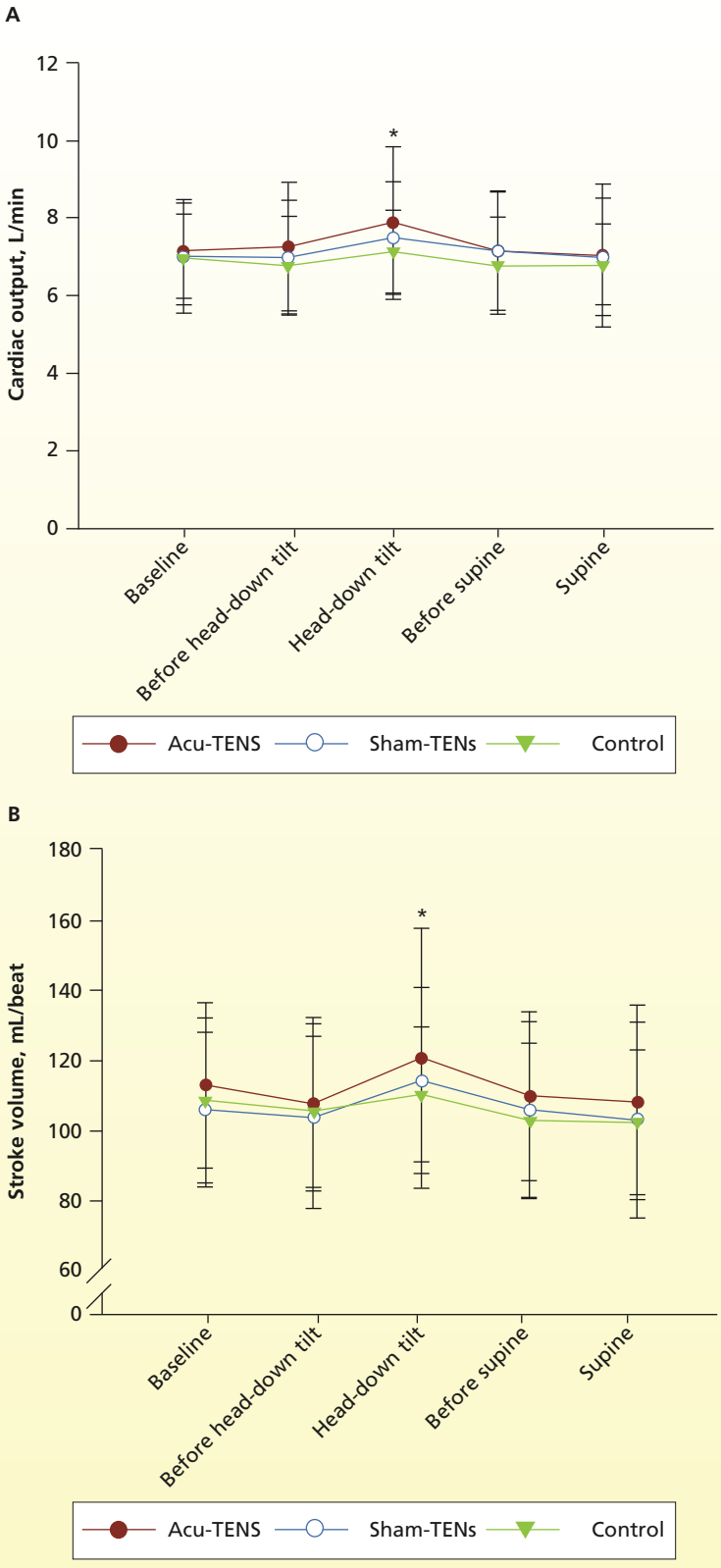

Figure 2 (A) Cardiac output and (B) stroke volume recorded with subject in different positions.

* Significant main effect for time ($P < .05$).

Data Analysis

Repeated measures analysis of variance was used to compare changes in parameters (heart rate, cardiac output, stroke volume, MAP, LAEI, LF/HF) recorded with different interventions and in different body positions. Post-hoc analysis was applied to any significant changes. Alpha was set at 0.05 and the Statistical Package of Social Science (SPSS Inc, Chicago, Illinois) for Windows Version 14 was used for statistical analysis.

Results

Sixteen participants (9 men and 7 women) were enrolled in this study (mean [SD]: age, 22.8 [3.1] years; height, 167.7 [7.1] cm; weight, 60.6 [6.0] kg).

Cardiac Function

Our data showed that cardiac output and stroke volume increased significantly during the head-down tilt. However, the change in cardiac output and stroke volume in response to the position change was not significantly different between the intervention protocols (Figure 2). Heart rate increased when the subjects resumed the supine position after the head-down tilt during the sham-TENS and control interventions, but remained stable during the Acu-TENS intervention (Figure 3).

Changes in MAP

Position change from supine to head-down did not induce any within-group or between-group differences in MAP irrespective of the stimulation protocols (Figure 4A). A significant decrease in MAP (mean [SD], -3.00 [3.77] mm Hg; $P = .02$) occurred in the sham-TENS group when the subject returned from head-down tilt to the supine position.

Changes in LAEI

LAEI increased by a mean of 1.55 (SD, 1.98) mL/mm Hg x 10 ($P = .02$) from supine to head-down and decreased by a mean of 2.38 (2.58) mL/mm Hg x 10 ($P = .008$) from head-down to supine during Acu-TENS intervention (Figure 4B). No change in LAEI was observed during the other 2 stimulation protocols.

Changes in Autonomic Nervous System Contribution (LF/HF Ratio)

No significant changes in LF/HF ratio were observed in any positional change or with any of the interventional protocols. The LF/HF ratio, however, remained greater than 1 in all positions (Figure 5).

Discussion

This study is the first to evaluate the effect of Acu-TENS on cardiovascular parameters in response to a positional change. Positional change is an intervention that is known to disturb hemodynamic status,[22,23] particularly in patients who are critically ill. A body position cycle of supine to -10° head-down and return to supine position was used to induce a cardiovascular challenge in this study. Gravity has a significant effect on the physiological response of the cardiopulmonary system,[24] and an increase in gravitational forces can markedly affect cardiac output and respiratory work.[25,26] Usually, when a person's position is changed from supine to head-down, venous return to the heart will initially increase in response to the hydrostatic effect and subsequently stroke volume, cardiac output, and blood pressure increase.[27] When body position is returned from head-down to supine lying, stroke volume, cardiac output, and blood pressure will decrease because of a decrease in venous return and ventricular filling. These expected changes were confirmed in the current study.

Prolonged immobility in the supine-lying position, often a scenario for patients in critical care, leads to autonomic and physiological deconditioning and is associated with orthostatic intolerance.[28] An understanding of the effect of body position on circulatory hemodynamics is integral to appropriate clinical management of orthostatic intolerance.

A trend of decreasing heart rate and increasing blood pressure was observed in patients who received daily Acu-TENS for 5 days after open heart surgery.[11] However, the heart rate remained higher and blood pressure lower in patients who received placebo-TENS (electrodes attached to acupuncture points PC6 but with no electrical output) and in the control group (who received no intervention at all). The same study also showed that postoperative rate pressure product and the dose of metoclopramide (Maxolon) required (for symptoms of nausea and vomiting) were lower in the Acu-TENS group. The authors postulated that Acu-TENS induced endogenous cerebrospinal fluid β-endorphin, which leads to reduced symptoms of nausea and vomiting; the lowering of heart rate suggested possible vagal nerve modulation.[11,13] Researchers in that study concluded that Acu-TENS facilitates early recovery of hemodynamic variables, thereby providing useful adjunctive therapy when optimizing postoperative cardiac rehabilitation.

We have previously shown that Acu-TENS facilitates recovery of exercise heart rate.[10] The effect of acupuncture on the cardiovascular system is believed to involve activation of both sympathetic and parasympathetic nerves.[28-30] Our hypothesis, therefore, was that Acu-TENS increased parasympathetic neural activity. This current study, however, showed no change in the LF/HF ratio, suggesting that the acute change in heart rate variability induced by Acu-TENS was minimal. In other words, acute modulation of the autonomic nervous system activity by Acu-TENS was not demonstrated in this study. This result could be a false-negative finding due to the small sample size and a position change that was insufficient to induce significant changes in the heart rate variability in a healthy cohort. The LF/HF ratio, however, remained greater than 1 in all positions, suggesting sympathetic activity predominated as the main determinant of blood pressure maintenance.

This study demonstrated that Acu-TENS appears to have a stabilizing effect on MAP during position changes. A more obvious fluctuation was observed in the other 2 groups, and the change of MAP in sham-TENS was statistically significant. Interestingly, this study also showed that significant fluctuation of LAEI was observed only in the Acu-TENS group. We therefore postulate that Acu-TENS enhanced elastic recoil and arterial compliance, facilitating blood propagation, and lowered blood flow resistance when the posture was changed from supine to

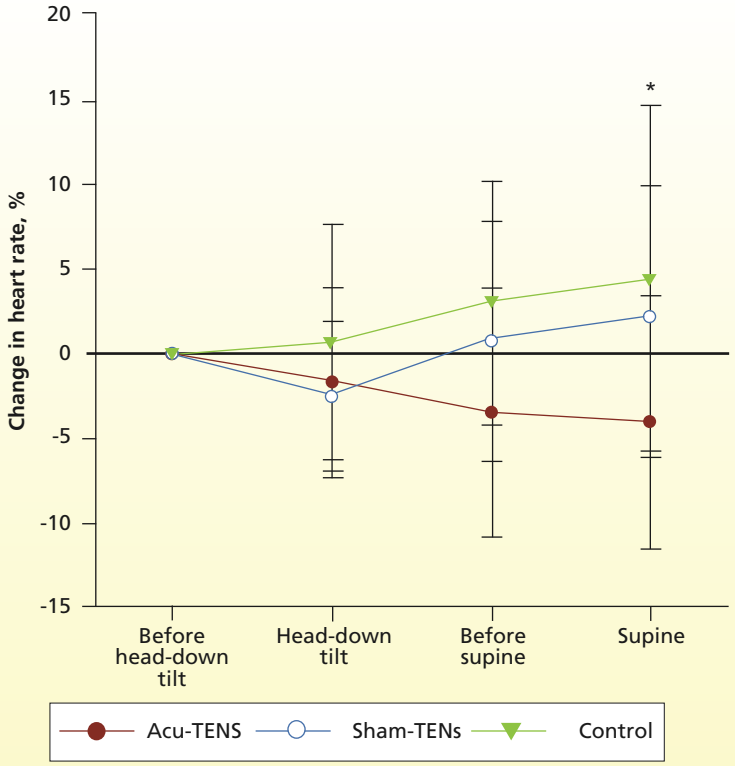

Figure 3 Percentage change in heart rate from before head-down tilt to resumption of supine posture.

* Significant interaction effect for time x condition ($P < .05$).

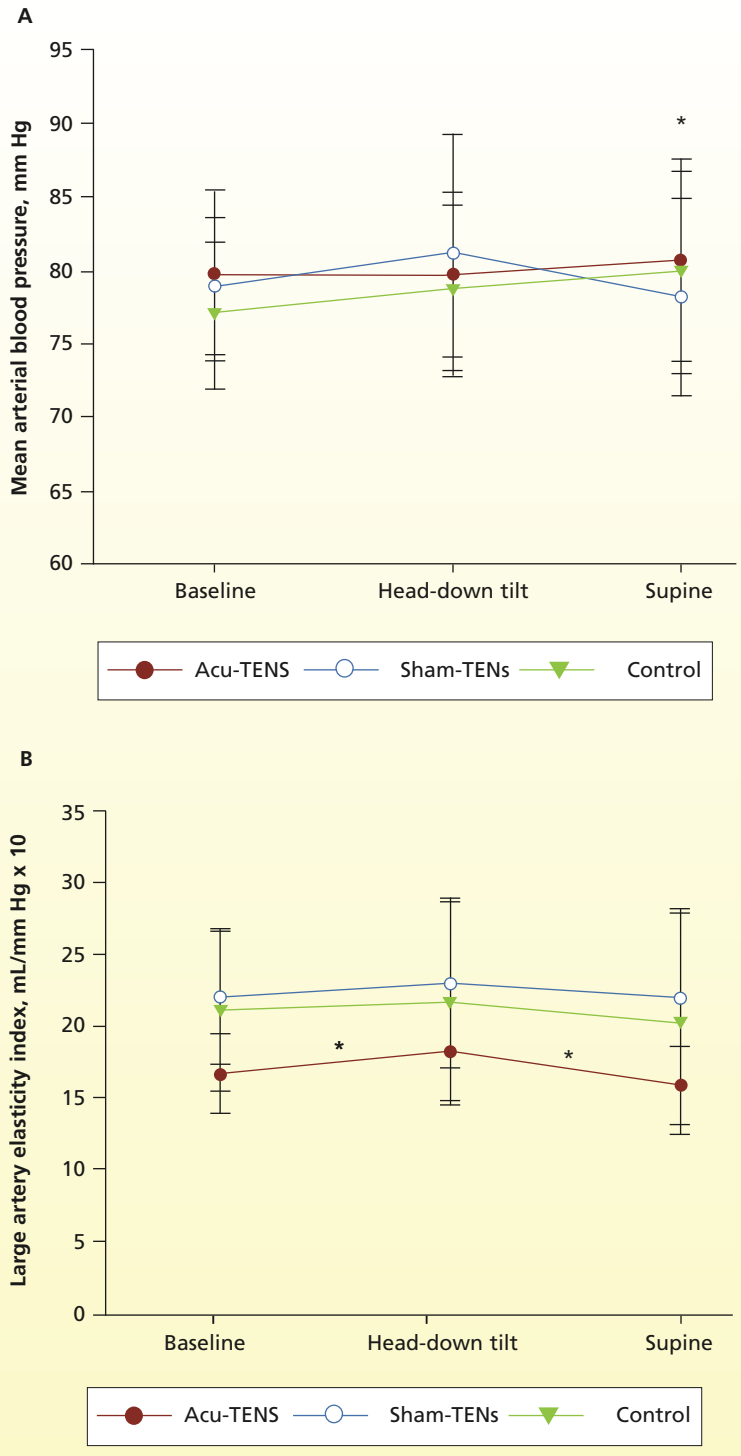

Figure 4 (A) Mean arterial pressure and (B) large artery elasticity index recorded at different positions.

* Significant main effect for time ($P < .05$).

head-down. LAEI, however, decreased when the position returned from head-down to supine, maintaining the blood pressure with a decrease in cardiac output. This phenomenon was not observed with sham-TENS or control interventions, suggesting that LAEI was associated with a specific acupoint effect, rather than a response to electrical stimulation.

In traditional Chinese medicine, Neiguan PC6 is the most commonly selected acupoint for management of cardiovascular problems.[29,30] In patients with hypertension, stimulation of PC6 for 30 minutes reportedly reduced systolic blood pressure by 11%.[31] In a canine hemorrhagic model, stimulation of PC6 attenuated hypotension and improved stroke volume.[32] It is possible that Acu-TENS had a bidirectional influence on MAP with postural change such that blood pressure fluctuation was minimized by LAEI compensation.

Acupuncture reportedly maintains body homeostasis,[33] and its effect may not be measurable if the homeostatic disturbance is small. A -10° head-down tilt was adopted in this study because it was believed that this amount of tilt was a sufficient provocative stimulus, particularly for critical care patients. Furthermore, based on the work of Williamson and colleagues,[34] who used -6° head-down tilt for 4 hours, a significant decrease in plasma volume and peak oxygen consumption and an increase in heart rate and mean arterial pressure was demonstrated. A head-down tilt of -10° for 10 minutes may have been insufficient to significantly effect changes in blood pressure homeostasis in our young healthy subjects. In a clinical setting, hemodynamic homeostasis is more likely to be disturbed, particularly in critically ill patients, as a head-down position adopted for secretion clearance often lasts for 15 to 20 minutes. Nevertheless some effect of Acu-TENS on heart rate was evident, and results of this study suggest that the role of Acu-TENS on MAP in critically ill patients warrants further investigation.

Although studies of Acu-TENS are limited, some evidence indicates that Acu-TENS exerts a vagal inhibitory effect on heart rate after exercise.[10,11] Results of this study suggest that Acu-TENS may have a stabilizing effect on blood pressure during postural changes. Therefore, when positional changes are necessary for treatment interventions, such as gravity drainage or postural rehabilitation training for patients with spinal cord injury, application of 40 minutes of Acu-TENS before the maneuver may be a useful adjunct to assist stabilization of blood pressure in patients who are critically ill. Future work should investigate the role of Acu-TENS on blood pressure changes in a cohort of critically ill patients.

Limitations of the Study

A major limitation of this study was that healthy subjects were used instead of critically ill patients.

It is essential, however, for a pilot study to demonstrate an effect of Acu-TENS on hemodynamics before assessment in a critical care cohort. Another limitation of this study was the small sample size. Our sample size in the present study was, however, sufficient to demonstrate the potential benefits of Acu-TENS.

The duration of head-down changes was probably too short to induce a sufficient body stress in healthy individuals to properly determine any stabilizing effect of Acu-TENS.

Conclusion

This study showed that Acu-TENS may have a positive effect on LAEI and could possibly maintain MAP during a head-down tilt positional change in healthy subjects. It may be possible that Acu-TENS can be considered as an adjunct in maintenance of MAP when changes in a patient's body position are necessary for treatment intervention. This study supports further investigation of the role of Acu-TENS in maintaining cardiovascular stability in patients who require postural changes for treatment.

FINANCIAL DISCLOSURES
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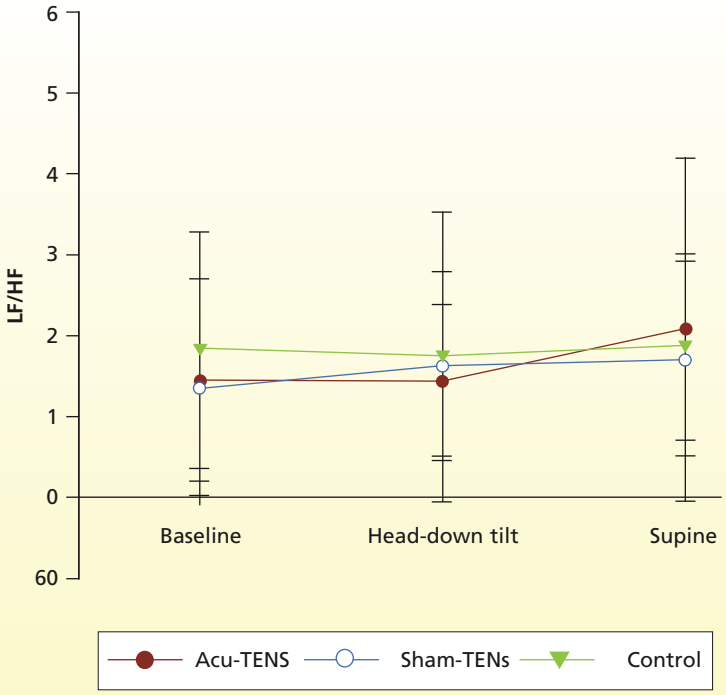

Figure 5 Low-frequency to high-frequency spectral ratio (LF/HF) deduced from heart rate analysis with subject in different positions.

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