EFFECT OF POSTURAL CHALLENGES ON NON-INVASIVE CARDIAC OUTPUT MEASUREMENT WITH IMPEDANCE CARDIOGRAPHY IN YOUNG HEALTHY ADULTS USING NEW HORIZONTAL ELECTRODE PLACEMENT METHOD

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Abstract

Background: Cardiac output is an important hemodynamic parameter of cardiovascular system and a significant indicator of autonomic function status of a person. It can be measured invasively as well as non-invasively. Imepdance cardiography (ICG) is a promising, new, noninvasive technique to measure cardiac output. There are no studies noninvasively measuring cardiac output in healthy subject by impedance cardiography using new horizontal method of electrode placement during postural challenges.

Objective: We observed effect of postural challenges on noninvasive cardiac output measurement using ICG by new horizontal electrode placement method.

Methods: Cardiac output (CO), stroke volume (SV) and cardiac index (CI), were measured non-invasively, before and after postural challenges namely Head Up Tilt (HUT) of 70^0 and Head Down Tilt (HDT) 20^0, in 38 healthy male subjects (mean age-28 yrs, range 22-34 yrs).

Results: After 70^0 HUT the values of CO, SV and CI decreased by 1.5±0.9 l/min (31%), 25.8±11.4 ml (37%), & 0.8±0.4 l/min/m^2 (27 %), respectively. HDT did not cause significant change in theses hemodynamic parameters.

Conclusion: ICG successfully detected physiological changes in cardiac output following postural challenges using new horizontal electrode placement method. The study underscores utility of this simple noninvasive tool for hemodynamic assessment after postural challenge using new horizontal electrode placement method.

Keywords: Noninvasive, Head up tilt, Head down tilt

1. Introduction

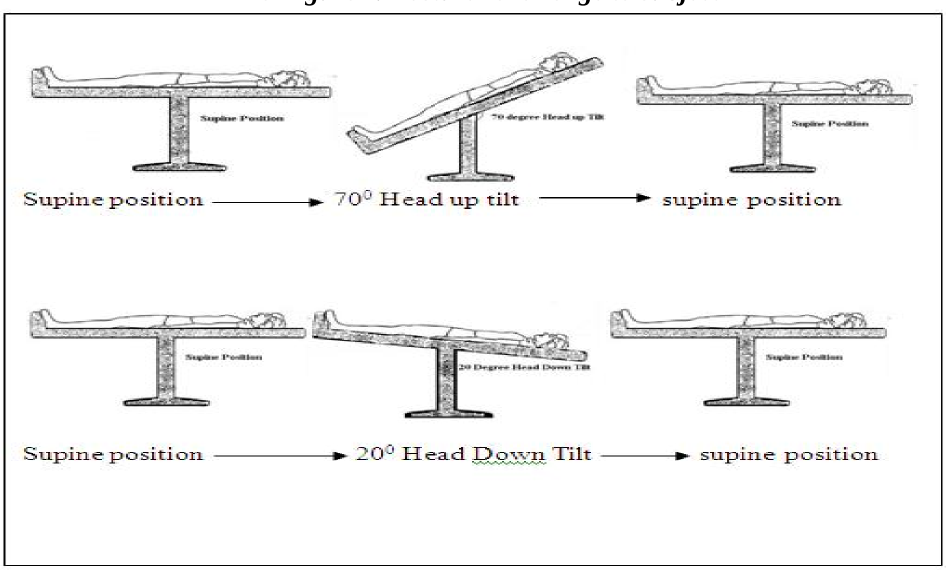
In clinical situation, Cardiac output (CO) is the functional expression of cardiovascular performance and can be used to confirm the need for, or efficacy of treatment. For many patients in ICU or in emergency medicine unit or those being investigated for some cardiovascular complaint, simply measuring heart rate (HR) and blood pressure does not provide adequate data on their hemodynamic state. Determination of cardiac output along with stroke volume and systemic vascular resistance is an important procedure in interventional cardiology and used in cardiothoracic surgery[1]. Similarly, demonstration of cardiac output measurement has been important skill to be acquired by postgraduate students in physiology laboratories.[2, 3] The postural challenge in the form of head up tilt or head down tilt leads change in hemodynamic parameters of the person[4]. To estimate CO in clinical practice, several invasive methods are available, like dye-dilution and thermo-dilution techniques or those based on echocardiography which requires a costly equipment and skilled manpower. Currently, thermo-dilution technique is used most commonly for measurement of cardiac output. These require catheterization of the patient which itself adds to morbidity and mortality of patient[5]. It gives only intermittent measurement of cardiac output of the patient.

Alternatively, the method of Impedance Cardiography with its several advantages is a promising method to measure cardiac output. The existing impedance based cardiac output monitors operate by emitting a very low voltage (2.5 to 4 mA), high frequency (50 to 100 kHz), and alternating electrical current through the thorax using band electrodes or standard ECG surface electrodes[5, 6, 7]. The electrical impedance changes according to changes in the volume and velocity of the blood flow, in the thoracic aorta are detected by sensing electrode as pulsatile decreases in impedance (dZ), which can be further expressed as its derivative (dZ/dt). This derivative has been shown to be proportional to stroke volume. The waveform shows two prominent waves namely, C-wave (ventricular systole) and O-wave (ventricular diastole). The onset of C-wave is marked by point-B, which corresponds to the opening of aortic valve[9]. It is marked in successive ten cycles, which then averaged and gives stroke volume. Now, the stroke volume multiplied by heart rate gives us CO of the patient. There is change in cardiac output due to postural challenge[4]. This becomes physiological tool to assess a technique, which is proposed to measure it. As measured by various other methods directly and indirectly, the cardiac output (CO) decreases[11] on an average by 25% and stroke volume (SV) decreases by 40% during the 70^0 head up tilt (HUT). However, from the supine position to 20^0 head down tilt (HDT), the CO and SV did not change significantly[10]. We have non-invasively measured the CO and SV during postural challenge with indigenous ICG equipment to test its ability to detect these changes on postural challenges. There are two methods for putting electrodes on the thorax for ICG measurement, namely new horizontal electrode placement method with old vertical electrode placement method[12]. Earlier study, comparing these two methods in supine position has shown concordance and new horizontal electrode placement has advantage of reduced cost and is easy to use. It is important to know the ability of ICG to noninvasively detect the changes in cardiac output as well as to document the changes in cardiac output before and after a postural challenge which are not measured so far using new horizontal method of electrode placement.

2. Methods

Using an ICG equipment (BARC, Mumbai), we measured CO in 38 healthy male subjects (mean age-28 yrs, range 22-34 yrs), in supine position followed by HUT of 70^0. Similarly CO measurement was done in supine position followed by 20^0 HDT (Figure-I). The measurements were done separately using new horizontal method of electrode placement.[12] For HUT, subjects were allowed to rest in supine position for ten minutes and cardiac output was measured non-invasively by ICG using horizontal electrode placement method. Then 70^0 head up tilt was given with help of a motorized table within 8 seconds. The cardiac output was measured immediately after HUT. The change in cardiac output was calculated. Similarly for HDT, subjects were allowed to rest in supine position for ten minutes. Cardiac output was measured non-invasively by ICG using horizontal electrode placement method. Then 20^0 head down tilt was given with help of a motorized table within 3 seconds. The cardiac output was measured immediately after HDT. The change in cardiac output was calculated.

The Figure I: Postural challenge to subject



[Figure I: *shows the sequence of postural changes given to subject, during which cardiac output was measured by horizontal method of electrodes placement. Initially in supine position five successive recordings at five minutes interval. After postural challenge, first recording was done immediately after the tilt. This was then followed by four recording in tilted position. Then subject was brought back to supine position in which five successive recordings were taken.*]

While all the recordings, the value of basal impedance was kept around '28±3 Ω ' by ensuring proper electrical contact of electrodes with body surface, and also by adjusting the inter electrode distance for the sensing electrodes. The data analysis was done using SAS 8.0 statistical package. Descriptive statistics has been calculated for both the postural challenges at each point time. The above study was approved by medical ethics committee of All India Institute of Medical Sciences, New Delhi - 110 029.

3. Results

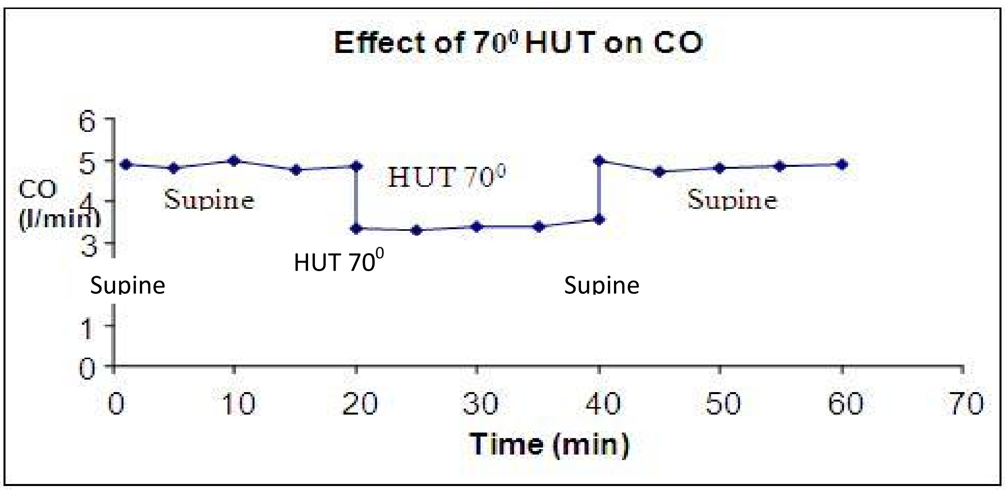
After 70^0 HUT, the values of CO, SV and CI decreased by 1.5±0.9 l/min (31%), 25.8±11.4 ml (37%), & 0.8±0.4 l/min/m2 (27 %), respectively (Table-1). The trend in values of cardiac output seen during supine position followed by 70^0 HUT, and then back to supine position shows a characteristic pattern (Graph1). After 20^0 HDT, there was non-significant decrease in the values of CO, SV by 0.3±0.5l/min (6%) & 3.4±18.0 ml (4.8%), respectively (Table-2). The trend of cardiac output values over a period of time also shows no significant change (Graph-3)

Table-I: changes in hemodynamic parameter following postural challenge HUT 70^0

	Supine CO	HUT CO	ΔCO	Supine CI	HUT CI	Δ CI	Supine SV	HUT SV	Δ SV
H	4.84±.68	3.34±.88	1.5±0.9	2.8±.06	1.9±.05	0.76±0.4	68±12	41±9	25.8±11

[*TABLE-I Shows the mean (M±SD) decrease in cardiac output, CO (l/min), cardiac index, CI (l/min/m^2) and stroke volume, SV (ml) after giving postural challenge of head up tilt of 70^0 to subject who was initially resting in supine position by using, horizontal electrodes placement (H) , (n=38)*]

The Graph – 1 Characteristic curve showing changes in CO following HUT 70^0



[***Graph I**: postural challenge, 70^0 HUT, results in the changes in cardiac output (CO) as measured by non-invasive ICG using horizontal spot electrodes placement. Each dot represents cardiac output value. Inter-recording interval is five min. except those recordings, which were taken immediately after postural challenges. Sequence was initially supine, then 70^0 HUT, then again back to supine position. After HUT, the CO value decreased and after bringing subject back to supine position, the CO value restored*]

Table-II: changes in hemodynamic parameter following postural challenge HDT 20^0

	Supine CO	HDT CO	ΔCO	Supine CI	HDT CI	Δ CI	Supine SV	HDT SV	Δ SV
H	4.87±0.4	5.15±0.6	0.28±0.5	2.8±0.6	3.6±0.6	0.1±0.3	68±12	73±17	3.4±1

[***Table-II** Shows the mean (M±SD) increase in cardiac output, CO (l/min), cardiac index, CI (l/min/m^2), and stroke volume, SV(ml) after giving postural challenge, 20^0 head down tilt to subject who was initially resting in supine position. H, horizontal electrodes placement (n=38)*]

4. Discussion

Postural challenge is associated with the change in cardiac output is a well-documented fact. After head up tilt, 300-500 ml of blood pools in the venous capacitance vessels of the lower extremities. If no compensatory cardiovascular changes occurred, the reduction in cardiac output due to pooling on standing would lead to a reduction of cerebral flow of this magnitude, and consciousness would be lost. In this study we used posture related physiological response to check the ability of ICG using new, convenient, horizontal electrode placement method to detect these physiological responses. The ICG equipment successfully measured the change in cardiac output and stroke volume using horizontal electrode placement method. Our result confirms the findings of Van Lieshout JJ *et al*, 2005; Harms MP, 1999 and Critchley LA, 1997 [10, 13, 14] that the stroke volume and cardiac output decreases on head up tilt by value almost by 40% of its supine value as measured by invasive and other methods. With our noninvasive easy to use method, we found this change as 36%, which is similar to it. Thus, ICG equipment can be used to measure changes in CO and SV due to postural challenge using convenient horizontal electrode placement method. This can be a test for assessment of reactivity of cardiovascular system in response to postural challenge along with measurement of change in HR, BP. The interplay between the CO, SV, HR, BP, and peripheral vascular resistance could be a good functional tool to assess the integrity of cardiovascular response in conditions like postural syncope or orthostatic hypotension. Similarly, this postural challenge test can also be a noninvasive tool for early recognition of decreased cardiovascular performance during diseases like hypertension and heart failure. Limitation of our studies includes small sample size, lack of repeated measurements in same test subjects on different occasions. Further studies with large sample size and different of age groups with variety of conditions, are needed to explore and establish its utility in assessment of hemodynamic functions.

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