Evaluation and correlation of systolic time intervals (STI) with autonomic functions in young adults

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ABSTRACT

AIMS: The present study was conducted to evaluate systolic time intervals (STI) and autonomic functions in young healthy adults and to find out a correlation between STI and autonomic functions for assessment of cardiac performance in different autonomic status of different subjects.

METHODS: The Systolic Time Intervals namely QS2 (electromechanical systole), LVET (Left Ventricular Ejection Time), PEP (Pre-ejection Period), and LVET/PEP ratio were measured by simultaneous recording of ECG, Carotid Artery Pulse & Heart Sounds. Autonomic functions were assessed in the same subjects. Sympathetic functions were assessed by Hand Grip dynamometer Test & Cold Pressor Test while Parasympathetic functions were assessed thrh’ 30:15 ratio & Valsalva ratio.

RESULTS: All the STI’s and Autonomic Function Tests were found to be in normal range. QS2 and LVET both were found to have inverse and linear correlation with heart rate which was found to be statistically significant (p= 0.001 & p= 0.002 respectively). STI’s were corrected for heart rate to find out the correlation between STI’s and autonomic functions. No significant correlation between different STI’s and autonomic functions was observed.

DISCUSSION: The above results indicate that under normal range of functioning, autonomic functions and systolic time intervals could be independent predictors of normal cardiovascular function.

1. Introduction

Measurement of systolic time intervals of the left ventricle as reported by Weissler, Harris, and Schoenfeld (1968-69) is widely used for evaluation of cardiac functions (1,2). It is obtained from simultaneous recording of Electrocardiogram, Heart sounds and Carotid pulse. It constituted the first non invasive technique to assess cardiac functions. Three conventionally measured Systolic Time Intervals (STI) are: Total Electromechanical systole (QS2), Left Ventricular Ejection time (LVET) and the Pre-ejection Period (PEP) (3). QS2 is measured from onset of Q wave in electrocardiogram (ECG) to the first high frequency aortic component of the second heart sound (3). It is primarily used to measure PEP when the LVET values are known. QS2 has an inverse but linear relationship with heart rate (1). Shortening of QS2 is seen in acute MI (4,5). LVET is the time interval from the upstroke of the carotid pulse wave (indicates rise in aortic pressure) to its incisura (indicates aortic valve closure) (3). LVET has also an inverse but linear relationship with heart rate (1). Shortening of LVET in Heart failure and lengthening in aortic stenosis and aortic regurgitation is observed (2,5,6). PEP (QS2 - LVET). The pre-ejection period (measured as the time interval between Q wave in ECG and percussion wave of carotid pulse recording), extends from start of depolarization of left ventricle (LV) to the onset of ejection (3). PEP is only slightly affected by heart rate (2). A healthy ventricle has a short pre-ejection period (PEP) and a long ejection time (7). PEP/LVET ratio: The PEP/LVET ratio is less heart rate-dependent than the individual components and is used as a measure of left ventricular systolic function (2). The normal values are (mean±SD) 0.34±0.04, which increases in diseased ventricles (1). This ratio is maximum in patients with heart failure (7). Myocardial dysfunction greatly affects systolic time intervals. Some other factors like hemodynamics, electrical variables, posture, peripheral resistance, afterload and bundle branch block also have their influence on STIs (8).
homeostasis of body. The heart and great vessels receive a significant amount of autonomic innervation, and the control of heart rate and blood pressure through the baroreflex arc constitute an important part of the regulation of the cardiovascular system (9). Since many of the disorders of ANS function are manifested by effects on heart rate and blood pressure, several techniques have been devised for assessment of these functions. These include assessment of sympathetic function by hand grip test or cold pressor test and parasympathetic function by Valsalva ratio and 30:15 ratio.

Different studies measuring systolic time intervals during autonomic functions are reported in literature (10,11,12,13) but no study could be found in which correlation of various autonomic functions tests with different systolic time intervals has been studied. Therefore, the present study was planned to determine correlation between systolic time intervals and autonomic functions in young adults for assessment of cardiac performance in different autonomic status of different subjects.

2. Material And Methods:

The study was conducted in the Department of Physiology in a tertiary care institute. 58 young healthy male volunteers in the age group of 18-45 years were selected for the study. The plan of the study was approved by the ethical committee of the institute. Consent from each subject was obtained as per guidelines of Helsinki modified according to test protocol. Systolic Time Intervals were measured and Autonomic Function Tests were performed as follows:

**Systolic Time Intervals:**

The duration of Total Electromechanical Systole (QS2), Pre-ejection Period (PEP), and the Left Ventricular Ejection time (LVET) was measured by simultaneous recording of electrocardiogram (ECG), carotid arterial pulse (CAP), and phonocardiogram (PCG) on four channel recorder (Polyrite: INCO) at a paper speed of 25 mm/sec. The synchronisation of the ECG, carotid arterial pulse and phonocardiogram was adjusted at the beginning of each session and checked at intervals during the experiment. ECG recording was done through Lead II. The phonocardiogram was obtained by placing the microphone over the third intercostal space about 3cm to the left of the mid line. The microphone was lightly held in place by a rubber strap. The right carotid pulse was recorded by placing a pick up device at the point of maximum carotid pulsation just below the angle of the jaw at the level of thyroid cartilage, which in turn was connected through a plastic tube to a volume transducer (T-303, VT-1532). The amplified carotid pulse, ECG and phonocardiogram were recorded and monitorized on the 4 channel polyrite. Then Systolic time interval was calculated, LVET was measured from point of onset of sudden upstroke of carotid artery pulse (CAP) to trough of incisura. QS2 was measured from the onset of QRS deflection of ECG to first high frequency vibration of aortic component of second heart sound. PEP was calculated from the difference between QS2 and LVET. These systolic time intervals were corrected for heart rate and age by using Weissler's regression equation (2).

Weissler’s regression equations: (19-65 years)

\[
QS2 = QS2 + 2.1 \text{ HR} \\
\text{LVET} = \text{LVET} + 1.7 \text{ HR} \\
\text{PEP} = \text{PEP} + 0.4 \text{ HR}
\]

**AUTONOMIC FUNCTION TESTS**

Following Autonomic Function Tests Were Performed:

**Hand Grip Test (HGT):**

This test depicts Blood pressure response to isometric exercise. The baseline systolic and diastolic blood pressure is recorded. The subject is asked to perform maximal voluntary contraction (MVC) by gripping the handgrip dynamometer, as hard as possible for few seconds and the maximum force exerted is noted down. After giving rest for a few minutes, the subject is made to perform isometric exercise at 30% of the maximal voluntary contraction to the point of fatigue. Systolic and diastolic blood pressure recordings is taken at intervals of each minute during the period of exercise. The maximal values of systolic and diastolic BP achieved during exercise is noted down. The response is taken as the difference between maximum blood pressure (SBP/DBP) achieved during exercise and baseline reading. The value of more than 15mmHg rise in BP is taken as normal response; 11-15 mmHg as border line; and 10 mmHg or less is taken as abnormal, an indicator of sympathetic insufficiency (14).

**Cold Pressor Response (CPR):**

The subject is made to sit comfortably for about thirty minutes before performing the test. The baseline BP is recorded. Then right hand of the subject is immered up to the wrist in cold water at a temperature of 4°C for 1 minute. Blood pressure is recorded at 30 seconds and 1 minute of submersion of the hand. After taking out the hand, blood pressure is recorded after every minute, till it returns to the baseline. The increase in blood pressure from the baseline value to maximal value, known as the range or response, is obtained. The response of 15-20 mmHg in increase in systolic BP and diastolic BP by 10 mmHg is considered as normal response to cold pressor test. In any condition if there is deficient sympathetic outflow, the cold pressor test will be expected to show a smaller rise in BP below 10 mmHg (hyporeactors). A stronger pressor response above 20 mm Hg to a cold stimulus selects hyperreactive subjects having a higher risk of later development of hypertension (15).

**Valsalva Manoeuvre:**

Forced expiration against a closed glottis is valsalva maneuver. Each subject performs the valsalva maneuver for 15 seconds by blowing against a closed glottis through a mouthpiece attached to an aneroid manometer and maintaining a pressure of 40 mm Hg for 15 sec. A continuous ECG is recorded starting 1 min before the maneuver (resting period), during the maneuver (strain period, 15 sec) and 60 seconds subsequent to the strain period. The valsalva ratio is calculated as the ratio of the maximum R-R interval after the strain to that of the shortest R-R interval during the strain. A ratio of greater than 1.45 is considered normal: 1.20 to 1.45 as border line: and less than 1.20 as abnormal (autonomic dysfunction) (16).
**30:15 Ratio:**

Each subject lies quietly for 3 minutes, then stand up and remains motionless while a continuous ECG is recorded and a point is marked to identify the point of standing. The 30:15 ratio is calculated by taking the ratio of the R-R interval at beat 30 and at beat 15 after standing (16). The values are interpreted as follow.

- Normal: >1.04
- Borderline: 1.01-1.04
- Abnormal: <1.00

**Statistical Analysis:**
The statistical analysis was done by using Pearson’s correlation coefficient.

**3. Result**

The correlation to analyze the degree of association between the systolic time intervals and autonomic function tests variables were made by the calculation of Pearson coefficient \( r \). Two-tailed \( p \) values <0.05 were retained for statistical significance.

The Mean S.D value of QS2, LVET, PEP were 48632.13 msec, 293.16 msec, 19320.5 msec respectively. When these STIs were corrected for heart rate by using Weissler’s regression equation, the Mean S.D value of QS2, LVET, PEP came out to be 636.6842.21 msec, 421.6942.68 msec and 221.8728.95 msec respectively. All the values of systolic time intervals in subjects were within the accepted normal range.

An inverse and linear correlation of QS2 and LVET with heart rate was observed and it was statistically significant \( (r = -0.432, p=0.001; r = 0.406, p=0.002) \) as shown in Fig.1 and 2. PEP was also found to have inverse correlation with heart rate though its statistically insignificant \( (r=0.120, p=0.368) \), the slope of PEP being lesser than that of LVET (Fig. 3). PEP/LVET ratio was found to increase with heart rate though not significant statistically \( (r= 0.140, p= 0.291) \) [Fig. 4].

As regards results of Autonomic function tests performed, the Mean S.D value of valsalva ratio was 1.750.35 and that of 30:15 ratio was 1.140.18. The mean values of change in Systolic blood pressure \( (\Delta SBP) \) and Diastolic blood pressure \( (\Delta DBP) \) for Hand grip test came out to be 12.52166 and 16.381.69 respectively. The mean values of \( \Delta SBP \) and \( \Delta DBP \) for Cold pressor test were 14.381.78, 13.532.94 respectively. All the values were found to be within normal range.

The correlation of systolic time intervals with each of the autonomic function test was made by the calculating Pearson correlation coefficient \( (r) \). No statistically significant correlation of QS2 was found with Valsalva ratio \( (r= 0.822) \), 30:15 ratio \( (r=0.967) \), \( \Delta SBP \) and \( \Delta DBP \) for HGT \( (r=0.333, r=0.573) \), and \( \Delta SBP \) and \( \Delta DBP \) for CPT \( (r=0.946 r=0.334) \) [Table-1].

Similarly LVET, PEP and PEP/LVET ratio was not found to have statistically significant correlation either with valsalva ratio, 30:15 ratio, \( \Delta SBP \) and \( \Delta DBP \) for HGT, or with \( \Delta SBP \) and \( \Delta DBP \) for CPT [Table-1].

<table>
<thead>
<tr>
<th></th>
<th>VALSALVA RATIO</th>
<th>30:15 RATIO</th>
<th>HGT(ΔSBP)</th>
<th>HGT(ΔSBP)</th>
<th>HGT(ΔSBP)</th>
<th>CPT(ΔDBP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QS2-Pearson Correlation coeff.</td>
<td>.030</td>
<td>.005.009</td>
<td>.129</td>
<td>.076</td>
<td>.009</td>
<td>.129</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.822</td>
<td>.967.946</td>
<td>.333</td>
<td>.573</td>
<td>.946</td>
<td>.334</td>
</tr>
<tr>
<td>LVET-Pearson Correlation coeff.</td>
<td>.071</td>
<td>-.101.001</td>
<td>.211</td>
<td>.179</td>
<td>-.001</td>
<td>.201</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.598</td>
<td>.452.993</td>
<td>.111</td>
<td>.178</td>
<td>.993</td>
<td>.130</td>
</tr>
<tr>
<td>PEP-Pearson Correlation coeff.</td>
<td>.106</td>
<td>.112.072</td>
<td>-.111</td>
<td>.078</td>
<td>.072</td>
<td>.112</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.426</td>
<td>.403.592</td>
<td>.409</td>
<td>.561</td>
<td>.592</td>
<td>.401</td>
</tr>
<tr>
<td>PEP/LVET-Pearson Correlation coeff.</td>
<td>.058</td>
<td>.156.067</td>
<td>-.223</td>
<td>-.030</td>
<td>.067</td>
<td>-.011</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.665</td>
<td>.241.616</td>
<td>.093</td>
<td>.822</td>
<td>.616</td>
<td>.932</td>
</tr>
</tbody>
</table>

Correlation is significant at the .05 level (2-tailed).
The present study was planned to find out a correlation between the systolic time intervals and autonomic function and to see whether a deviation in autonomic functioning produces a similar disturbance or change in systolic time intervals. It is now a well-established fact that heart rate, peripheral resistance, ventricular filling, myocardial contractility and stroke volume all affect Systolic Time intervals independently (1, 8). In our study, QS2 and LVET were found to be inversely and linearly related to heart rate which was statistically significant. PEP was also inversely and linearly related to heart rate though statistically not significant. The negative slope of PEP was lesser than that of LVET. All these findings are in line with the studies by Weissler (1,2) the results being attributed to adrenergic influences that affects both HR and myocardial contractility. Our results on PEP/LVET ratio which was found to increase with heart rate also corroborate the finding of Cokkinos et al (17) to which they have suggested that this ratio should be corrected for heart rate if it is to be taken as an index of cardiac contractility.

There have been quite a few studies in which Systolic Time Intervals have been assessed during the testing of autonomic functions (10,11,12,13). In one of these studies, Stafford et al. (1970) analysed the effects of graded increments of passive head-up tilt on the duration of the systolic time intervals, and observed that head-up tilt caused a prolongation of the pre-ejection period and a shortening of the left ventricular ejection time, while total electromechanical systole diminished minimally (10). In another study, the effect of gradual head up tilt on systolic time intervals was observed by Tuckman and Shillingford which showed prolongation of PEP and shorten the duration of left ventricular filling. These effects were attributed to increased sympathetic stimulation consequent to increased baroreceptor activity as a result of sudden postural change (18).

In our study, in all the subjects, autonomic functions as well as systolic time intervals were found to be in normal range. No significant correlation was observed between different autonomic functions and systolic time interval parameters. This implies that under normal range of functioning, autonomic functions and systolic time intervals could be independent predictors of normal cardiovascular function. The reason for this might be a dual control of heart function, one being automatic and other being through autonomic nervous system and only a significant alteration in autonomic function might have an effect on STI parameters. Hence it is inconclusive to predict presently whether any deviation from normal autonomic function will affect systolic time intervals or not. For this, study on a larger sample size with more homogenous population could be an area for research.

5. References


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