High Incidence of ST-T Changes in Women During Tilt-Table Testing

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Abstract:

Introduction: We have observed electrocardiographic (ECG) changes primarily in women during tilt table testing.

Methods: We reviewed 12 lead ECGs during tilt studies between 2012-2016 for changes in ST segments and T waves during tilt table testing. Patients with distinctly abnormal baseline ECGs were excluded.

Results: Of the 180 tilt studies, 117 (65%) were in women. There were 32 patients with ECG changes during tilting. Of these, 28 (87.5%) were in women with an average age of 45 years. None had a history of CAD or exertional chest pain. Echocardiograms were available in 21 of the 28 women with tilt induced ECG changes and all were normal. ECG changes during tilt table testing were found in 4/64 (6.25%) of men. The occurrence of ST-T wave changes during tilt testing was significantly higher among women compared to men, with a p value of 0.008.

Of the 28 women with ECG changes during tilt, 11 had T wave inversions alone. ST segment depression alone was noted in 7 women. There were 10 women who had both ST segment depression and T wave inversions. Changes occurred immediately upon tilting in 6. In the remaining, they occurred at an average of 4.8 ± 4 minutes after tilting. The slight increase in heart rate in patients with ECG changes was similar to that in the patients without new ECG changes. The ECG changes were not related to the presence of syncope.

Conclusions: ECG changes during the testing was observed at a relatively high incidence primarily in women. The clinical significance of these repolarization changes during tilt testing is unknown. These ECG changes during tilt testing may correlate with the high incidence of false positive ECGs in women during exercise testing but do not necessarily indicate the presence of ischemic coronary disease. Additional research is needed to explain this phenomenon.

Key Words

1. Tilt table testing
2. 12-Lead ECG
3. Repolarization changes
4. Young women
5. Postural variations
6. Autonomic imbalance

Introduction:

Passive head upright tilt table (HUTT) testing is frequently performed to assist in the diagnosis and cause of syncope. Kenny et al (1) first reported tilt table testing in 1986 in fifteen patients with unexplained syncope. Since then, several protocols with varying sensitivity and specificity have been proposed and provocative agents are used to improve the diagnostic utility of this test (2). The European Society of Cardiology recommends tilt table testing for patients with unexplained syncope in a high risk situation or recurrent syncope in the absence of organic heart disease (3). It is also recommended in patients with syncope who have organic heart disease, after cardiac causes of syncope have been thoroughly excluded.

The test is performed on a tilt table which can move the patient from a supine to an upright position. The patient is secured to the table with restraints and a foot board. The study is done following a 4 hour fast. A standard tilt protocol (3) consists of a resting supine phase that lasts for 5-20 minutes, followed by a passive tilt phase. The initial tilt phase may last for 20-45 minutes at an inclination of 60-70°. Provocative agents such as intravenous isoproterenol at incremental doses (usually < 3mcg/min) to increase the average heart rate by approximately 20-25% (4) or sublingual nitroglycerin at a dose of 300-450 mcg (5) are then used to unmask abnormal postural reflexes. The patient is then returned to the supine position. Throughout the test, noninvasive blood pressure and an ECG are recorded.

The occurrence of syncope or presyncope and simultaneous hemodynamic changes such as reflex hypotension/bradycardia or symptomatic orthostatic hypotension are necessary to

consider the test as positive (3). The diagnosis of postural orthostatic tachycardia syndrome and psychogenic pseudosyncope can also be made using the tilt table study (3).

At our institution, 12 lead ECG's are recorded every minute during the tilt table studies. We have observed ECG changes during the tilt studies, predominantly in young women. These changes may not be recognized if single lead ECG's are used during tilt studies. This study evaluated the frequency of the ECG changes during tilt testing.

Materials and methods:

After obtaining IRB approval, we performed a retrospective chart review of all tilt studies that were done at our institution between 2012-2016. We reviewed the medical charts for age, gender, echocardiograms, stress test findings when available, and tilt test results for each patient. We examined the 12 lead ECGs during tilt studies for ST segment depression and T wave inversion during rest, tilting and recovery. Patients with bundle branch block, or those who had an abnormal ECG as defined by the presence of T wave inversions or ST segment abnormalities prior to tilting were excluded. We considered T wave flattening as nonspecific and not an abnormality. ECG abnormalities were then classified as T wave changes, ST segment changes or both. The leads in which these changes were seen were noted.

Our tilt protocol (5) consists of recording heart rate, blood pressure and a 12 lead ECG while the patient is supine, followed by 20 minutes of passive head upright tilt at 60°. The test is continued for 15 minutes after the administration of 400 mcg of nitroglycerin by sublingual

spray. 12 lead ECGs are recorded every minute during the study. The most common indication for the tilt test was syncope of unknown etiology (in 50% of these patients); other indications being dizzy spells (34%) and near syncope (16%). All the studies were supervised by the senior author of this paper. (Dr. Marcus)

The study was deemed positive if symptoms of syncope or presyncope were associated with hemodynamic abnormalities such as hypotension and or bradycardia. A positive test was then subclassified into either type I (mixed), type 2 (cardioinhibitory) or type 3 (vasodepressor) (6).

Results:

Of the 180 tilt studies performed between 2012-2016, 117 (65%) were in women. There were 32 individuals (18%) who had ECG changes during tilting. Twenty-eight (87.5%) of these were in women with an average age of 45 years. The remaining 4 (12.5%) were in men. None of the 32 patients had a history of CAD or exertional chest pain. Therefore, ECG changes during tilt testing for syncope was observed in 24% of women and in 6% of men. Tilt test positivity among those with ECG changes during the tilt was 50%.

Baseline supine ECGs were normal in 29 of the 32 patients, of whom 25 were women. There were 3 women with flat T waves at baseline. Echocardiograms were available in 25 patients with ECG changes of whom 21 were women. They were all normal.

Of the 28 women with new ECG changes during tilt, 11 had isolated T inversions and 7 had only ST segment depression. Two of the 11 had T wave inversions in precordial leads, one in limb leads and the remaining 8 in both precordial and limb leads. One had ST segment depression in limb leads, one in precordial leads and the remaining 5 in both precordial and limb leads. There were 10 women who had both ST segment depression and T wave inversions. An example is shown in Figure 1. ECG changes occurred immediately upon tilting in six individuals. In the remaining, they occurred at an average of 4.8 ± 4 minutes after tilting. The average baseline heart rate was 88 ± 18 beats per minute. Although the heart rate increased by an average of 15 beats per minute in 18 individuals, the mean change in heart rate was similar in individuals with and without tilt related ECG changes.

A total of 10 patients had persistent ECG changes during recovery. The ECG changes reverted to baseline during recovery after an average of 5.2 ± 4.9 minutes. When the ECG changes reverted to baseline, a decrease in heart rate occurred at an average of 9 beats per minute.

Discussion:

This study showed that ST/T changes on the ECG occurred in 18% of patients during tilt table testing of whom 87.5% were women. None had a history of ischemic heart disease. The changes were unrelated to the results of the tilt study. ECG changes resolved in the majority (64%) of the patients immediately upon assuming the supine position.

An analysis of ECG changes during tilt in 150 patients was reported by Mayuga et al from the Cleveland Clinic (7). It is difficult to compare their results of ECG changes with ours because their protocol was different. They recorded ECGs during supine resting, at 30° tilt for 2 minutes, at 45° tilt for 2 minutes and at 30° tilt for 45 minutes followed by 5 minutes in the supine position. In V5, the T wave became negative in 32 patients. Another difference from our study is that the postural orthostatic tachycardia syndrome is found in 67 of their patients but was present in only 2 patients of our patients. We found ECG changes in 18% of the patients including 24% in women undergoing the tilt study. Fifty percent of patients with ECG changes had tilt test positively.

The question arises of whether ST/T wave changes occur in relation to change in posture. Madias et al (8) compared standing and supine electrocardiograms and standing, sitting and supine stress electrocardiograms. They reported ECG recordings in the supine and standing positions in 10 patients using standard electrode placement and in the sitting, standing and supine positions in 16 patients using the Mason-Likar electrode system. They concluded that the standard ECGs recorded in patients in the supine and standing positions and stress ECGs in the sitting, standing and supine positions were interchangeable.

Postural changes have been linked to false positive repolarization abnormalities. Murayama et al (9), analyzed exercise electrocardiograms in women in the standing and supine positions. The study included 26 women with non-ischemic ST depression and 14 patients with typical angina pectoris. Maximal ST depression in false positive tests occurred immediately after onset of

exercise and showed rapid resolution in early recovery. ST depression persisted or even worsened in late recovery as long as the subjects remained standing. Interestingly, ST depression returned to baseline when their position was changed to supine after exercise. This pattern was not observed in true positive tests. They concluded that changing posture while recording the post exercise electrocardiograms could assist in differentiating false positives from true ischemic responses. However, it should be noted that this study was performed in Japanese population, who may have different repolarization pattern compared to Caucasians.

Variations of the 12 lead ECG with changes in posture have also been observed (10-12). ST/T depression during standing has been reported and the changes have been attributed to differences in heart position or increased sympathetic tone. Bergman et al (13) evaluated the 12 lead ECGs in the supine and 60-degree head-up position in 58 hospitalized patients. The study population included patients with coronary artery disease, non-ischemic dilated cardiomyopathy, valvular heart disease and those with structurally normal hearts. The head upright position was found to decrease voltage in the lateral precordial leads, could influence the accuracy of pathological Q waves and impair the diagnostic accuracy of the ECG for left ventricular hypertrophy.

We observed that new ST/T changes were seen immediately upon tilting in only 6 patients. There was an average delay time of 4.8 ± 4 minutes in others. We also noticed a small increase in heart rate upon tilting, which may be explained by increased sympathetic tone. However, these minor changes in heart rate were not different from those who did not have

new repolarization changes during the tilt, possibly indicative of a heart rate independent mechanism. Our study was not adequately powered to detect such differences due to heart rate dependent mechanism.

Although there was a reduction in heart rate upon resumption of the supine position, increased sympathetic tone during tilting could not explain the orthostatic changes in our patients since only 10 of the 33 patients showed resolution of ECG changes immediately after being placed in the supine position during recovery. One of our patients, an 18-year-old female, developed ST/T changes during an exercise stress test in the anterior and inferior leads upon standing from a supine position. The changes resolved during stage 3 of the Bruce protocol. Similar orthostatic changes were seen one year later during tilt table testing that was performed due to recurrent syncope.

Reflex syncope is common among younger patients. Imbalance of autonomic tone has been implicated in patients with reflex syncope. Alterations in autonomic tone also affect ventricular repolarization leading to changes in the morphology of ST/T waves and length of the QT interval (14-16). Friesinger (16) first described electrocardiographic changes related to posture by using a term “vasoregulatory abnormalities” and attributed these changes to an abnormal autonomic response. Studies have supported the existence of a “cardiac cortical rhythm control site” within the territory of the middle cerebral artery or anterior cingulate cortex (17, 18). The autonomic nervous system is extensively interconnected and receives neural inputs from different parts of the cerebral cortex, hypothalamus and brainstem (19).

Sudden stress from awakening due to an alarm call resulted in changes in the repolarization pattern in healthy physicians (20). Sudden shift toward sympathetic dominance in the autonomic nervous system has been speculated to be the reason for this change in ST/T waves. Whether sympathetic dominance led to repolarization changes noted in our group of young patients is a matter of speculation. ST/T wave changes can also be detected during regular daily activities in healthy individuals during ambulatory ECG monitoring (15, 21, 22).

Lewis et al (14) studied 350 normal adults following brief hyperventilation. T wave inversions in 2 or more precordial leads were observed in 37 subjects and they called it latent “juvenile pattern”. Psychiatric evaluation of these patients showed them to be tense, immature and emotionally disturbed. It is unclear if our patients who had repolarization changes had any psychiatric or emotional instability. Neurocirculatory asthenia, or the so called Da Costa’s syndrome is more common among young women (23). Respiratory symptoms and cardiac symptoms (including palpitations, chest discomfort, dizziness, faintness and fatigue) are frequent among these patients. Resting ECGs also showed ST/T wave changes in these patients that resolved with intravenous propranolol (24). However, our patients with ECG changes during tilt were predominantly young women, had normal ECGs at baseline and the ECG changes developed only during tilting.

Conclusion:

A high incidence of ECG changes suggestive of myocardial ischemia was observed during tilt table testing, predominantly in women. The reason and significance of these repolarization changes is unknown. Additional research is needed to explain this phenomenon. These ECG changes during tilt testing may correlate with the high incidence of false positive ECGs in women during exercise testing (25). Although this finding does not necessarily indicate the presence of ischemia, more data will be needed to determine the cause of these ECG changes.

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FIGURE 1A: Resting supine ECG in an 18 year old woman with a history of multiple episodes of syncope associated with change in position from sitting to standing. Her BP at the time of the ECG was 102/56 and HR was 52 bpm.

FIGURE 1B: ECG obtained during tilt testing when the patient was at 60° upright tilt for 9 minutes. Her BP was 110/60 and her HR was 68 bpm. Note diffuse T wave inversions.

FIGURE 1C: ECG 4 minutes after sublingual nitroglycerin administration. Her BP was 97/73 and HR was 110 bpm. There is diffuse ST depression. Soon thereafter, she developed symptoms consistent with impending syncope and was placed in a supine position with immediate relief of her symptoms.

Table 1: Baseline characteristics of patients with ECG changes during tilt table testing.

Age (overall), in years (N=33)	49+/-23
Age (females), in years (N=28)	46+/-23
Age (males), in years (N=4)	62+/-7
CAD	0
Hypertension	11 (34%)
Diabetes	1 (3%)
Hyperlipidemia	7 (22%)
Indications for tilt test	
Syncope	16 (50%)
Dizzy spells	11 (34%)
Near syncope	5 (16%)