U - Wave Amplitude Increases During Exercise in Persons without Cardiovascular Disease

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Abstract

U wave is the wave between T wave and P wave of electrocardiogram. Inverted U waves during stress test are considered to correlate with critical disease of left anterior descending coronary artery. There is no literature regarding effect of exercise on U wave in normal persons. We retrospectively evaluated U wave changes during treadmill stress test in 25 normal persons without cardiovascular risk factors and with negative treadmill stress test. U wave amplitude increased with increasing heart rate during exercise and decreased with decrease in heart rate during recovery. Clinical significance of this observation needs further evaluation.

Keywords

Trade mill stress test; U-wave.

Introduction

U wave is the wave between T wave and P wave of electrocardiogram. There is no consensus of opinion about its genesis. Prolonged repolarization of myocardial M cells is considered to be responsible for genesis of U-wave. It is not clearly visible in all persons. When clear, it can be identified in all the leads but is usually most apparent in leads V2 to V4. Normally, the polarity of U wave is same as that of T wave1. Therefore U wave is negative in lead aVR and at times in V1. It is positive in other leads.

There is no literature about effect of exercise on U-wave in persons without cardiovascular disease [1-3]. This is probably because of several reasons. Firstly, ‘U’ wave is a low amplitude wave which is not clearly visible in all persons. Secondly, vibrations occurring during treadmill stress testing prevent identification of ‘U’ wave. Thirdly, clinicians, in their busy OPD, are inclined to see the averaged ECGs rather than the raw ECGs recorded throughout stress testing. Averaged ECGs include interval from terminal part of P wave to
the end of T wave and do not include ‘U’ wave (Figure 1). Further, conventional reporting of treadmill stress test does not include changes in ‘U’ wave.

We frequently observed that in persons without cardiovascular disease, ‘U’ wave was more prominent during early exercise and during early recovery when the heart rate was faster than the resting heart rate and there was still a clear space between T and P wave. These observations gave us a clue that amplitude of ‘U’ wave could be increasing with increasing heart rate during exercise stress test.

**Figure 1:** Showing averaged ECGs recorded during treadmill stress test. ECGs include period from terminal part of P wave to end of T wave. U wave is not included.

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**Aim of Study**

To study effect of exercise induced tachycardia on U wave of surface electrocardiogram of persons without cardiovascular disease and without any evidence of exercise induced ischemia.

**Material and Methods**

It was a retrospective study. It was not possible to motivate asymptomatic patients with normal electrocardiogram and no cardiovascular risk factors for treadmill stress test. Patients were therefore, selected out of three hundred patients who consecutively underwent treadmill stress test at our centre. Treadmill stress test was performed using standard Bruce protocol. 12 leads electrocardiogram was recorded throughout exercise and upto eight minutes of recovery.
Inclusion criteria

- No cardiorespiratory symptoms and normal clinical examination.
- Normal resting electrocardiogram with presence of clear U wave in one or more leads
- Normal fasting and 2hr. Post prandrial blood sugar.
- Normal fasting lipid profile
- Normal echocardiograph including two dimensional, Doppler and coloured Doppler evaluation
- No clinical or electrocardiographic evidence of myocardial ischemia during maximal treadmill stress test.

Exclusion criteria

- Past history of treatment for heart trouble, coronary angioplasty or bypass surgery (109 cases).
- Patients being treated for hypertension and or diabetes with abnormal resting ECG (95 patients).
- Patients who had high pre-test probability of having coronary artery disease (i) Persons with strong family history of premature coronary artery disease or sudden death (3 Patients). (ii) Presence of three or more cardiovascular risk factor including systemic hypertension, diabetes mellitus, smoking, obesity and dyslipidemia (27 patients). It was done to exclude any possibility of sub-clinical cardiovascular disease.
- Persons who could not perform satisfactory stress test (15 patients)
- Development of bundle branch block, atrial or ventricular ectopics or tachyarrhythmia, ST segment and T wave changes during exercise or eight minutes of recovery (20 patients).
- Development of breathlessness or any discomfort suggestive of myocardial ischemia which was relieved during recovery. These cases were excluded even if they did not show classical electrocardiographic changes in conventional twelve leads. It was done to exclude any probability of posterior ischemia not manifesting in conventional twelve leads (3 cases).
- Inability to interpret clear U wave due to vibration or baseline shift (3 cases).

Final analysis included 25 cases.

Results

Age ranged from 36 years to 71 years. Sixteen were males and 9 were females. Resting pulse rate ranged from 49 beats / minute to 95 beats per minute. Resting systolic blood pressure ranged from 110mmHg to 150mm Hg. Diastolic blood pressure ranged from 70mm Hg to 90mm Hg. Peak heart rate ranged from 117/minute to 168/minute. Peak systolic blood pressure ranged from 160mm Hg to 180mm Hg. Peak diastolic blood pressure ranged from 60mm Hg to 102 mm Hg. None of the patients developed any symptoms, abnormal clinical findings or abnormal electrocardiographic finding. Three patients could not attain target heart rate. However, increase over resting heart rate was adequate (68 beats)/minute in one patient,
Representative electrocardiographic tracings are shown in (Figures 2-10). Only those leads are included which showed clear changes in U wave. This was done to prevent congestion in figure and highlight the issue under evaluation. All cases showed that during exercise stress test amplitude of U wave was more when the heart rate was faster than resting heart rate during early exercise and early recovery. During exercise, amplitude of U wave increased with increasing heart rate (Figure 10, stage 1 and 2). Further increase in heart rate resulted in further shortening of diastolic interval. P wave moved towards T wave and finally fused with T wave (Figure 10). P wave became taller and no U wave was visible (Figure 10, Peak exercise). During recovery, the heart rate declined and diastolic period increased. P wave separated from T wave. A clear and prominent U wave could be seen again (recovery 1 minute). With progressive decrease in heart rate, amplitude of U wave again decreased (Figure 10, recovery 5 minutes).

**Figure 2:** Electrocardiographic tracing recorded during treadmill stress test of patient no. 1. It shows increase in amplitude of U waves during stage 1 of exercise and during 3rd minute of recovery.

![Figure 2](image)

**Figure 3:** Electrocardiographic tracing recorded during treadmill stress test of patient no.3. It shows prominent U wave during stage 1 of exercise and first minute of recovery.

![Figure 3](image)
**Figure 4:** Electrocardiographic tracing recorded during treadmill stress test of patient no. 7. It shows increase in amplitude of U wave during first minute of recovery.

**Figure 5:** Electrocardiographic tracing recorded during treadmill stress test of patient no. 8. It shows increase in amplitude of U wave during third minute of recovery.

**Figure 6:** Electrocardiographic tracing recorded during treadmill stress test of patient no. 12. U Wave amplitude increased during stage 1 of exercise and during 1st minute of recovery.
Figure 7: Electrocardiographic tracing recorded during treadmill stress test of patient no. 18. It shows increase in amplitude of U wave during stage 1 of exercise and during fourth minute of recovery.

Figure 8: Electrocardiographic tracing recorded during treadmill stress test of patient no. 20. It shows increase in amplitude of U wave during third minute of recovery.
**Discussion**

Traditionally it is said that U wave is better seen at slow heart rate [1-4]. Our observations suggest that U wave is better visible at moderate increase in heart rate. Amplitude of U wave...
decreases as the heart rate falls. As the heart rate increases, amplitude of U wave also increases. However, it may not be clearly visible at fast heart rate as it is overlapped by the following P wave. Mechanism of increase in amplitude of ‘U’ wave with increase in heart rate during exercise in normal persons is not clear. Amplitude of U wave varies directly with the amplitude of T wave [1]. If we look at figure 10, it is clear that amplitude of T wave increases with increasing heart rate. Both the T wave and the U wave are part of repolarization; same factors could be increasing the amplitude of T wave as well as U wave with increasing heart rate. Exercise induced increase in sympathetic drive and blood pressure could be contributory. Significance of this observation is not clear. Exercise induced inversion of ‘U’ wave is a marker of critical stenosis of left anterior descending coronary artery [5-10]. Ischemia induced uncoupling of myocardial M cells from adjacent cell layers could be responsible for U wave inversion. Further invasive studies are needed to find exact significance of our observation.

**Limitations of our Study**

(a) Sample size is small due to strict inclusion and exclusion criteria.

(b) We cannot comment if age and sex have any influence on exercise induced increase in U wave amplitude in normal persons. Further studies including large sample size in different age and sex groups are needed to answer this issue.

(c) Coronary angiography was not performed in these cases as it was not ethical to advise an invasive procedure in totally asymptomatic patients without any cardiovascular risk factors and absence of any evidence of ischemia on maximal stress test.

(d) We cannot give any definite opinion about cause and significance of our observation. It will require electrophysiological studies at cellular level.

(e) Insist of these limitations, our observations clearly document that amplitude of U wave increases with exercise induced increased in heart rate in normal persons.

**Conclusion**

In patients without cardiovascular disease, U wave amplitude increases with increasing heart rate during exercise and again decreases with decrease in heart rate during recovery. It could be related to exercise induced changes in T wave amplitude. To the best of our knowledge, this effect of dynamic exercise on amplitude of U wave has not been reported in past.

**References**
