

# Ventricular repolarization

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## What is repolarization and what influences affect it?

The QRS complex of the electrocardiogram (ECG) reflects the occurrence of an electrical wave that propagates through the heart muscle, to trigger the mechanical contraction of each heartbeat. Following each QRS is a T wave that reflects the electrical recovery or repolarization of heart cells that were excited during the preceding depolarizing wave.

The T wave and the process of repolarization, in general, are complex and sensitive to many influences.

First, T wave morphology (shape), duration, and timing are sensitive to heart rate and to its changes. At fast heart rates, the “end” of the T wave comes closer to the QRS than it does at slow heart rates. In addition, the width of the T wave decreases with heart rate.

Second, the shape of T waves depends upon the activation sequence of the ventricles, i.e., the sequence with which the heart muscle is depolarized. Thus, T waves during normal sinus rhythm (in which the ventricles depolarize via the His-Purkinje specialized conduction system) are very different from those observed during activation from ectopic ventricular sites following PVCs, ventricularly paced beats, or ventricular tachycardia.

Third, T wave morphology and timing is affected by the heterogeneous distribution of action potential characteristics, which vary in normal hearts, and more so in abnormal hearts.

Fourth, the heart is innervated in a heterogeneous manner. Hence, stimuli from different nerve fibers can regionally alter action potential duration and morphology, thus altering T waves observed at the body surface.

Finally, since the process of repolarization is “directional”, there is a temporal-spatial sequence to repolarization. The ECG leads used to measure it will show different T wave morphology and timing at different body surface locations. This also contributes to the difficulty of detecting abnormal repolarization associated with disease or acute cardiac events, such as localized ischemia or acute myocardial infarction.



## How do cardiac disease and cardiac events affect the T wave?

Apart from the above influences on repolarization and T waves common to normal and abnormal hearts, disease introduces specific changes to T wave morphology and timing that reflect the electrophysiological abnormalities that are specific for each disease.

For example, the Long QT syndrome is a rare, genetically mediated disease in which syncope (fainting) episodes or sudden cardiac death are frequently the first evidence of disease. Typical to that syndrome, the interval between the beginning of the QRS and end of the T wave (QT interval) is abnormally long. We now know that the cause of this disease is abnormal structure and function of the thousands of ion channels in each cardiac cell, resulting to prolongation of the ionic repolarization currents in these cells.

Another, more common example is the onset of a heart attack in patients with ischemic heart disease (coronary artery disease). Characteristic is early repolarization, observed as elevation of the ST segment of the ECG, the portion of the signal that follows the QRS and precedes the T wave. Another phenomenon relating to ischemic heart disease is the frequent observation of beat-to-beat alternation of T wave pattern. That may be either macro- or microscopic in nature but is almost always associated with a potentially dangerous condition, and which often precedes bursts of arrhythmias.

Repolarization is exquisitely sensitive to many pharmacological agents, not just those prescribed for heart ailments, but many others. It has long been known that some antibiotics (erythromycin), antidepressants (tricyclic), anti-allergenic and other medicines can alter the T wave in patients with normal hearts. Of course the intended action of cardiac-specific drugs is the modification of cardiac cell electrophysiology to make the heart beat more strongly or to reduce the likelihood that the patient will have potentially lethal arrhythmias. These agents alter conduction and repolarization in a manner intended to reduce the risk of arrhythmias imposed by disease.

## How is repolarization useful?

By observing the ST-T waves in standard ECGs or by monitoring the changes in them over time, the physician is provided with a sensitive indicator of cardiac function and behavior that can be used to detect the presence of disease, or more importantly, to characterize the evolution of a potentially dangerous, life-threatening condition. Not only is the T wave crucial for diagnosing disease and detecting cardiac events, it is also important in monitoring the cardiac state following an event or verifying the effectiveness of therapy.

## Summary

In summary, repolarization is the electrophysiological phenomenon associated with the recovery (resetting) of cardiac cells, following their depolarization or excitation. The T wave of the ECG is the electrical manifestation of the repolarization process, and reflects the influence of heart rate, nerve tone, activation sequence, and electrical disturbances to normal electrophysiology associated with cardiac disease. Thus, T waves provide physicians with important and sensitive indicators of cardiac disease and abnormalities, as well as a means to assess therapy.

## Additional resources

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