3.3.3

Abnormal ECG - Current of Injury

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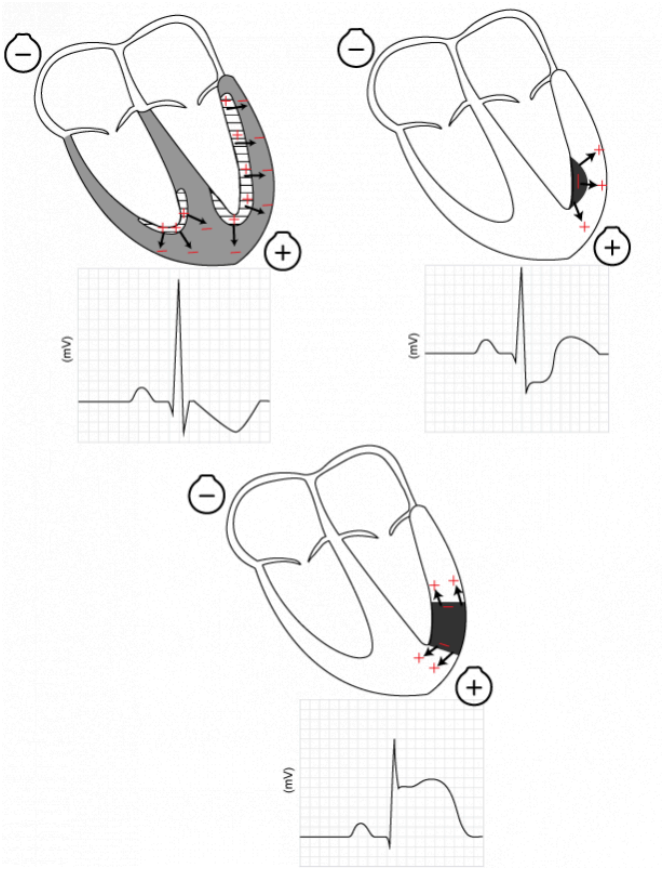

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Abnormal ECGs could result in another 20 pages or more, we will discuss a couple of important abnormal patterns derived from what we call a “current of injury”. When an area of the heart experiences a current of injury, due to damaged cells, this current of injury ends up causing the baseline “isoelectric” line to either raise or lower. This is because damaged cells have trouble maintaining resting membrane potentials and thus become depolarized. This abnormal depolarization creates an area in the heart that has negative charges on the outside of the cells in that region. The negative charge creates an abnormal dipole, meaning it creates a current when the heart should not be having a current. As a result, the ECG machine, which has been programmed to not see current at rest in the heart, automatically adjusts the baseline (isoelectric point) to filter out what it considers background noise, making a new baseline.

Typically this current of injury occurs in the ventricles and will not become evident until the end of the “S” wave. Why? This is because when the ventricles are fully depolarized (at the end of the “S” wave), all of the ventricular cells are depolarized and this “current of injury” is temporarily suspended (no more dipole because all the cells are now negative

on the outside) and the ECG machine will return to the original or “normal” isoelectric baseline. However, as the ventricles repolarize and switch the nondamaged cells back to a positive polarity on the outside surface again, the current of injury will return because the damaged cells will again appear more negative on the external surface, making the dipole at rest appear again and causing the ECG machine to make another adjustment. The resulting ECG will show different abnormal waves depending on the severity of the current of injury. Some of these abnormal waves will be addressed below.

Inverted T waves

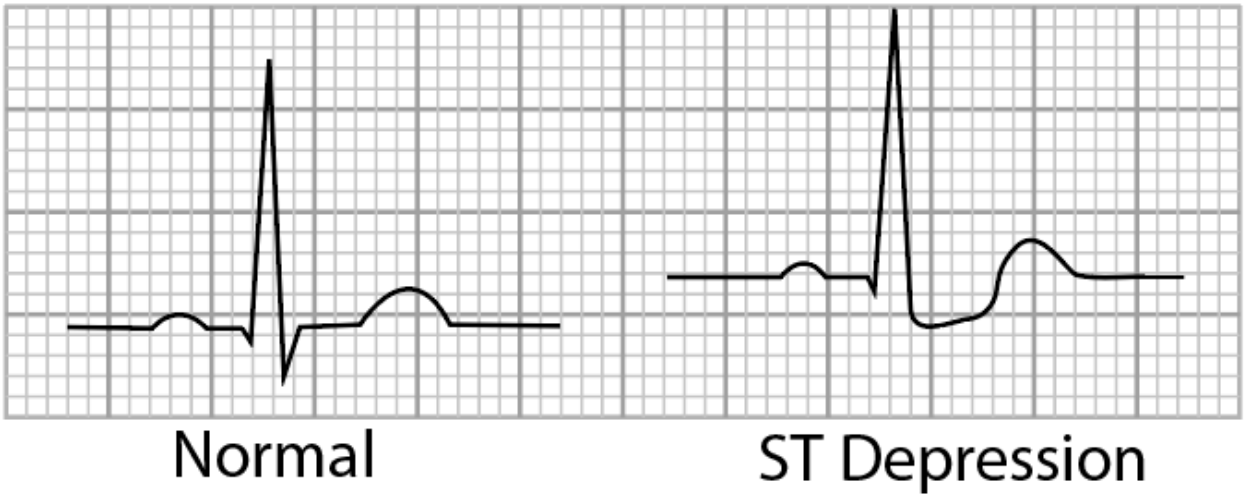
To understand an inverted T wave, lets first review normal T waves. Normal T waves are upright because the first cells to repolarize are epicardial cells and the last are the endocardial cells. This pattern of repolarization results in a vector opposite to that of depolarization because the electrical vector has a positive tail moving towards a negative sensor (if we set up the ECG sensor pads to simulate lead II). Thus, for the T wave to be inverted it must repolarized in the opposite direction, or stated another way the endocardium must repolarize before the epicardium.

Hypoxia in the endocardium can induce a state where the endocardium repolarizes before the epicardium. How? As the endocardium gets less oxygen than normal, the production of ATP decreases which in turn reduces the activity of the Na/K ATPase pump and activates the $I_{K\ (ATP)}$ channels. The reduction in pump activity induces a relative depolarization in the hypoxic cells and the activation of the $I_{K\ (ATP)}$ channels leads to a quicker repolarization. Therefore, rather than the endocardium depolarizing first and then repolarizing last, the endocardium will now depolarize first and repolarize first ("first"...meaning before the epicardium), switching the electrical vector. The switched electrical vector will now have a positive tail moving towards a positive sensor (inferior lateral part of the heart) and this causes the T wave to deflect down instead of up. Upside down T waves are shown in the image above (top left).

ST depression

A classic ST depression is caused by a negative vector at rest (due to hypoxic cells) that is oriented towards a positive sensor. The image above shows this in the top right corner as a blackened area on the inferior lateral wall of the left ventricle. Notice that the electrical vectors are oriented in a way that the “average” vector would extend in an inferior/lateral direction. If sensors were set up to simulate lead II, we would have a negative tail vector (-à) oriented towards a positive sensor and this would cause an ECG deflection in an upward direction.

Thus, because the background vector is causing an upward interference, the ECG machine will set the isoelectric point above its normal point. In the picture below, you can see that compared to the normal ECG, the current of injury has caused the ECG baseline to deflect upward. The other waves including P, Q, and R all occur relative to this new baseline (deflected upward because of the current of injury). At the “S” wave however, all the cells of the ventricles are depolarized and so all the cells are negative on the outside surface. We don’t have an area of negative setting up a dipole with an area that is still positive. So, at this point, the ECG will try to draw a line at the original base line (at the point of the S wave). However, as the heart repolarizes, the repolarization will move past the hypoxic cells and leave them still negative on the outside (after repolarization) but everywhere else repolarized to positive on the outside. The ECG will sense a background current of injury again and gradually deflect upward again to finish the T wave. This creates a shape recognized as an ST depression and suggests that there is an area of endocardium that is hypoxic.The abreviation for this is called **NSTEMI or nonSTEMI**, which stands for **Non ST E**levated **M**yocardial **I**nfarction.



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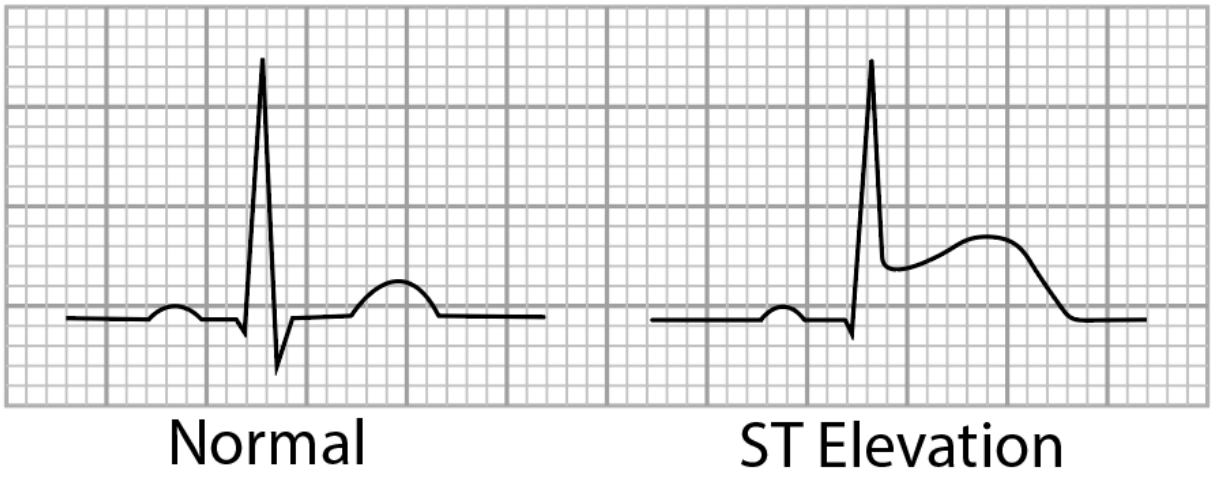
ST elevation

A classic ST elevation is caused by an area of hypoxic cells that involves the entire thickness of an area of the ventricular wall (usually toward the inferior pole of the ventricle). The image above shows this in the bottom center as a blackened area that crosses the entire wall thickness. This is often called a “transmural” infarct. Notice that the electrical vectors are oriented in a way that the “average” vector would extend in more of a superior direction. If sensors were set up to simulate lead II, we would have a negative tail vector oriented towards a negative sensor and this would cause an ECG deflection in an downward direction.

This downward deflection is again called a “current of injury” but is a downward deflection this time. In the picture below, you can see that compared to the normal ECG, the current of injury has caused the ECG baseline to deflect downward. The other waves including P, Q, and R all occur relative to this new baseline (deflected downward because of the current of injury). At the “S” wave however, all the cells of the ventricles are depolarized and so all the cells are negative on the outside surface. We don’t have an area of negative setting up a dipole with an area that is still positive. So, at this point, the ECG will try to draw a line at the original base line (at the point of the S wave). However, as the heart repolarizes, the repolarization will move past the transmural injury and leave them still negative on the outside (after repolarization) but everywhere else repolarized to positive on the outside. The ECG will sense a background current of injury again and gradually deflect downward again to finish the T wave. This creates a shape recognized as an ST elevation and suggests that there is an area where hypoxia exists across an entire area of ventricular thickness. Transmural infarcts reflect that there is even greater loss of blood flow than the inverted T waves or the ST depression. Sometimes a patient can reveal an ST depression that converts to an ST elevation which would suggest that heart damage is progressing and could suggest that emergency intervention is necessary. The abreviation for this is called **STEMI**, which stands for **ST E**levated **M**yocardial **I**nfarction.



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