Interesting Electrocardiogram

ELECTROLYTES AND THE ELECTROCARDIOGRAM

M. IRENE FERRER, MD
Consultant in Cardiology
Metropolitan Life Insurance Company
Professor Emeritus of Clinical Medicine,
College of Physicians and Surgeons, Columbia University
Consultant Electrocardiographer,
Presbyterian Hospital, Columbia Presbyterian Medical Center, New York, NY

This tracing was taken on a 51-year-old female admitted to the hospital for weakness and weight loss. She had ascites and was given diuretics. Metastatic liver disease was found. The electrocardiogram shows sinus rhythm at 95/min. with normal PR and QRS intervals. The striking finding is the presence of large U waves (best seen in leads V4-V6 where U is larger than the flat T wave). The U wave also is larger than T in leads II, III and AVF. Clearly this pattern is typical of moderate to marked hypokalemia and indeed the serum K was found to be 2.5.

The electrocardiogram in electrolyte imbalance is often, but not always, helpful. It is important to remember that the electrocardiogram is not capable of detecting mild to moderate degrees of any electrolyte disturbance. The only ions which have any important effect upon the electrocardiogram are potassium and calcium ions and a shift in hydrogen ion concentration. It is interesting that sodium disturbances per se do not produce any electrocardiographic alterations, but if shifts in sodium occur in association with derangements of Ca, K, and H+ the electrocardiographic effects of the latter electrolytes are enhanced.

Electrocardiographic disturbances in hyperkalemia (K intoxication). Early or minor degrees of hyperkalemia are probably not detected by the electrocardiogram and it is not until a level of approximately 7 mEq/L is reached in the serum that these disturbances appear with any consistency. One refers to early disturbances of hyperkalemia and to later manifestations because it is not clear whether it is the actual serum or the cellular levels of the electrolyte which are important, or both of these in association with the duration of the electrolyte imbalance. Early in hyperkalemia one will find an increase in size of the T waves but no change in their direction.

This increased voltage of T is particularly well seen in the left precordial leads, notably V5. Later, in hyperkalemia the PR interval will be prolonged, the QRS complex will widen and as a consequence of the widened QRS there may be some prolongation in the QT interval. This prolongation in QT is not a primary disturbance, however (i.e., it does not appear without widening of QRS).

There will also be certain arrhythmias as a consequence of hyperkalemia, particularly atrial fibrillation, and as the concentration worsens ventricular tachycardia and finally ventricular fibrillation will follow.

The electrocardiogram in hypokalemia (K depletion). Again early stages of hypokalemia will probably not affect the electrocardiogram. However, once a level of 3.0 - 3.5 mEq./L is reached the T waves will diminish in amplitude, and pari passu, the U wave will grow larger. These changes are seen in any electrocardiographic lead but once again are easiest to detect in the left precordial leads. At this time there may also be a depression of the ST segments in most of the electrocardiographic leads. A prolongation of the PR interval is seen at a later stage, as are the arrhythmias found with the hypokalemic state. These arrhythmias include atrial tachycardia and nodal tachycardia. These two rhythms also appear with digitalis intoxication and may be relieved by potassium, suggesting some association between the hypokalemic state and the expression of excess digitalis. This hypokalemic state is generally produced by excess diuretic therapy.

The electrocardiogram in calcium disturbances. In low calcium states there is a prolongation of the QT interval and when the calcium is increased to above normal the QT interval is shortened. The prolongation of the QT in hypocalcemia represents such a characteristic finding that it is almost diagnostic. The prolongation occurs at the expense of the interval between the end of the QRS and the beginning of the T wave, and the duration of the T wave remains perfectly normal. One has the impression that the T wave is simply pulled to the right of the QRS complex. In most other conditions in which a prolongation of QT occurs this is achieved by a widening of the T wave.

Alterations in pH. In acidosis the T wave is increased in amplitude, and in alkalosis there is a diminished amplitude of the T wave with, occasionally, actual inversion to negative T wave. It is not yet certain at which levels of pH these alterations appear. However, once again there may be a time factor involved, since with the acute onset of acidosis or alkalosis these T changes may be somewhat more pronounced than when the abnormal metabolic state is of long duration. It is also uncertain whether extreme degrees of pH must be reached or whether only slight shifts will produce these changes. In any case, clinically the most likely circumstances in which such changes may occur is the hyperventilation syndrome, and these T alterations should not be interpreted as evidence of heart disease in this setting.