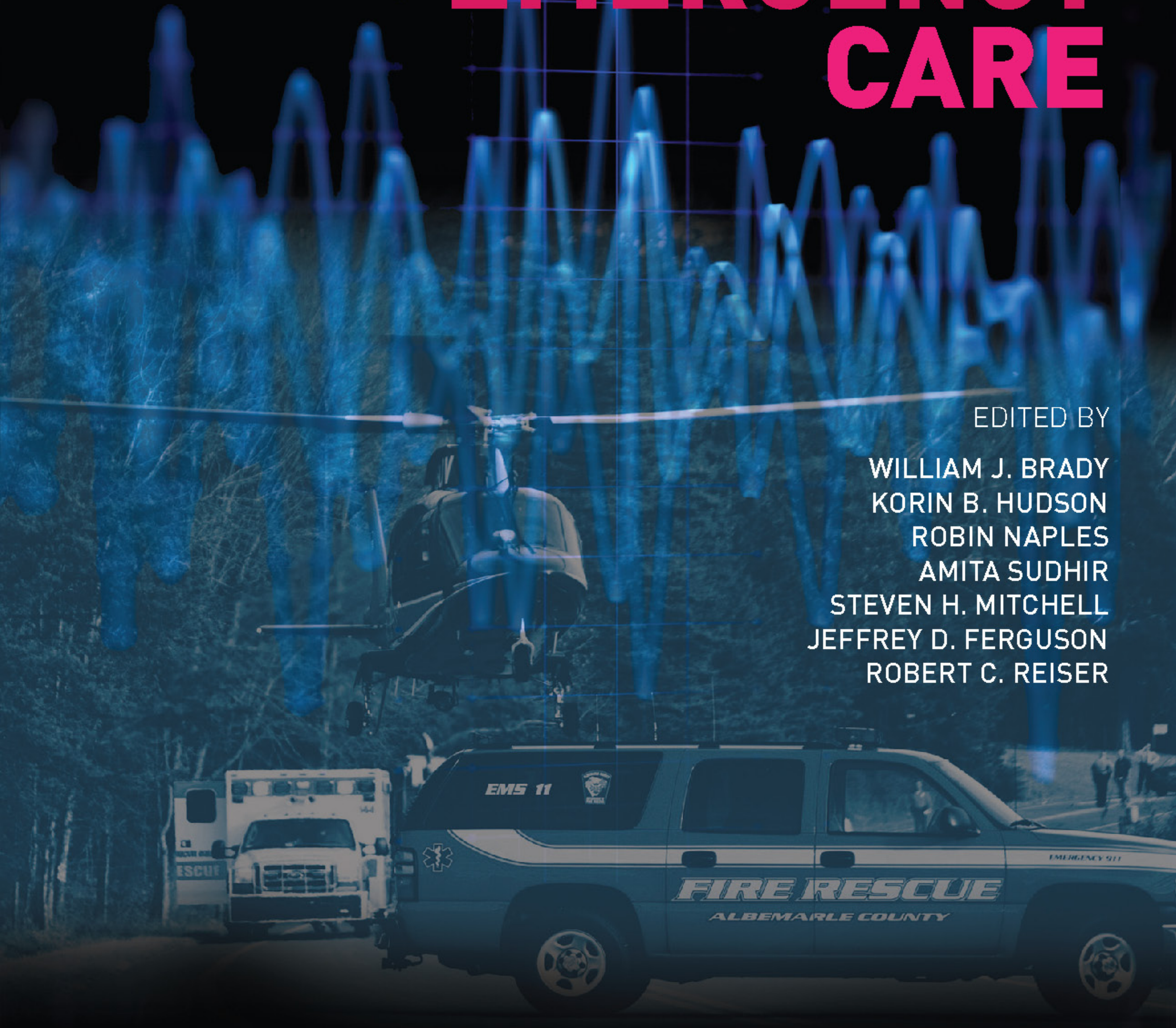
THE ECG IN PREHOSPITAL EMERGENCY CARE



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William Brady – To my wife, King Brady, my partner and a truly amazing person; to my children, Lauren, Anne, Chip, and Katherine, my inspiration; and to my mother, Joann Brady, for all that she has done (and continues to do) for me.

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Foreword

The Prehospital ECG: It's not just about STEMIs. . ...

Single lead or three lead cardiac monitoring was the sole means for EMS personnel to assess cardiac rhythm in the prehospital setting for many years. Resourceful EMS providers would use all three channels to verify rhythm, check for axis abnormalities and conduction disturbances, and even attempt to identify ST-T wave abnormalities in patients at risk for acute coronary syndrome. However, for most of EMS, the primary use of cardiac monitoring was to monitor the rhythm in the stable patient, or to determine which ACLS algorithm should be followed incases of cardiopulmonary arrest.

With the advent of fibrinolysis, EMS personnel and ED staff began to recognize the importance of early identification of STEMI patients as a means to reduce the ''door-to-drug'' time. When patients arrived by EMS with a diagnostic ECG having already been performed, patients received fibrinolysis much more quickly than if an ECG had not been done, or if the patient had arrived by private vehicle.

Fibrinolysis required preparation of the drug and patient screening for contraindications, but was otherwise less resource intense than PCI, which became widely used in the mid to latter 1990s. Like fibrinolysis, PCI is time critical, with ''door to balloon'' times serving as one of the crucial process metrics. Assembling a team for PCI consumed significant resources, including opening of a catheterization laboratory and the presence of the interventional cardiologist and other personnel who could perform the PCI. Mobilizing these resources during nights and weekends had the potential to engender significant time delays. STEMI systems began to mobilize the catheterization laboratory team based solely on the prehospital ECG interpretation. Many of these systems would rely on paramedic interpretation without a physician's interpretation of the ECG, due to the excellent interpretative skills developed by many EMS providers. The ability to perform 12-lead ECGs in the field has become a required skill in most EMS systems, and is now considered standard for STEMI systems to rely on EMS ECG interpretation to determine not only the destination hospital but also to activate the catheterization laboratory.

As paramedics have become skilled at recognition of STEMI, their interpretation skills in other clinical syndromes have developed. The prehospital ECG is not only administered to patients with suspected ACS, but is also used to better define rate, rhythm, or axis abnormalities first suspected on the single lead cardiac monitor. The 12-lead ECG is better able to define varying degrees of heart block as well as other conduction disturbances. Electrolyte abnormalities can be readily identified and dysrhythmias can be better recognized, thus allowing prehospital providers to tailor treatment to the underlying disorder.

The purpose of this text is to advance the interpretation skills of prehospital providers so that the ECG can be used as a diagnostic instrument for more than just the STEMI. In the same way that prehospital ECGs has reduced the ''door-to-drug'' and ''door-to-balloon'' times for STEMI, we are now in the era when the ECG can be used to speed the time to treatment of premalignant dysrhythmias or life-threatening electrolyte abnormalities. Readers of this book will benefit from the expertise of the authors, who have devoted a significant portion of their careers to teaching others the finer points of ECG interpretation. The diagnostic utility of the 12-lead ECG is vast, and after completing this book, readers will come to understand that the prehospital ECG is not only used to diagnose STEMI, but can be used to identify many other clinical condition, which if left untreated, would seriously compromise the health of the patient.

Robert E. O'Connor, MD, MPH

Dr. O'Connor is professor and chair of Emergency Medicine at the University of Virginia in Charlottesville. He is a past President of the National Association of EMS Physicians, a past Chair of the Emergency Cardiac Care Committee for the American Heart Association, and is a current board member of the American College of Emergency Physicians.

Preface

Electrocardiographic monitoring is one of the most widely applied diagnostic tests in clinical medicine today; its first application to the patient occurs in the prehospital setting and its use continues on into the hospital. The electrocardiogram, whether in monitor mode using single or multichannel rhythm monitoring or in diagnostic mode using the 12-lead ECG, is an amazing tool; it assists in establishing a diagnosis, ruling-out various ailments, guiding the diagnostic and management strategies in the evaluation, providing indication for certain therapies, offering risk assessment, and assessing end-organ impact of a syndrome. As noted in this impressive list of applications, it provides significant insight regarding the patient's condition in a range of presentations, whether it be the chest pain patient with ST segment elevation myocardial infarction (STEMI), the patient in cardiac arrest with ventricular tachycardia, the poisoned patient with bradycardia, or the renal failure patient with rhythm and morphologic findings consistent with hyperkalemia, among many, many others. . .. This extremely useful tool is noninvasive, portable, inexpensive, quickly obtained, and easily performed. Yet, its interpretation is not as easily performed and, in fact, requires considerable skill and experience as well as an awareness of its use in the appropriate clinical settings and limitations of patient data supplied.

This textbook has been prepared to assist the prehospital provider with the interpretation of the electrocardiogram and a solid understanding of its use across the range of presentations and applications. This textbook is arranged into five sections. Section one is a brief introduction and review of the ECG in the clinical setting. Section two focuses on the ECG and rhythm diagnosis, considering the electrocardiographic findings from an in-depth differential diagnostic perspective – in other words, rhythms with normal rates as well as bradycardia and tachycardia, allowing for the QRS complex width and regularity. Section three reviews the 12-lead ECG in patients suspected of acute coronary syndrome, including ST segment elevation myocardial infarction. Section four discusses the range of special presentations, patient populations, and uses of the electrocardiogram. Section five is a listing of various electrocardiographic findings, again from the differential diagnostic perspective; in this section, various rhythm and morphologic presentations are discussed, such as the narrow and wide complex tachycardias and ST segment elevation syndromes.

This textbook addresses the use of the ECG in its many forms by the prehospital provider, whether 911 ground EMS response, aeromedical transport, or interfacility critical care transfer. The novice electrocardiographer can use this text as his or her primary ECG reference; additionally, the experienced interpreter can use this textbook to expand his or her knowledge base. This work stresses the value of the ECG in the range of clinical situations encountered daily by prehospital providers – it illustrates the appropriate applications of the electrocardiogram in acute and critical care EMS settings.

Most importantly, this textbook is written by clinicians for clinicians, with an emphasis on the reality of the prehospital setting. I and my coeditors, advisory editors, and authors have enjoyed its creation – we hope that you the prehospital clinician will not only enjoy its content but also find it of value in the care of your patients. We thank you for what you do every day.

William J. Brady, MD
Charlottesville, USA
July 2012

Section 1 | The ECG in Prehospital Patient Care

Chapter 1 | Clinical applications of the electrocardiogram (ECG)

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The electrocardiogram (ECG) has become a mainstay of medical care since Einthoven first introduced the concept of electrical imaging of the heart in 1903. He named the five electrical deflections of an ''electrical heart beat'' with the now well-known descriptors – P, Q, R, S, and T (Figure 1.1). Accurate interpretation of the ECG has become a necessary skill for every clinician who cares for acutely ill patients. The ECG is a non-invasive, inexpensive, easily performed test that allows a clinician to view the electrical activity in the heart. The ECG provides information not only about a patient's heart rhythm, but also about both cardiac (e.g., acute coronary syndrome [ACS] or myopericarditis) and non-cardiac conditions (e.g., electrolyte disorders, toxic ingestions, and pulmonary embolism).

Electrocardiogram evaluation of rhythm disturbances

The rapid and accurate detection of ventricular fibrillation leading to sudden cardiac death has led to the development of prehospital emergency medical service (EMS) systems worldwide since the late 1960s. The use of ECG monitoring has grown from this early important step to become a mainstay of patient evaluation, not only for cardiac arrest but also for many other conditions. The ECG is the primary tool for evaluating the underlying rhythm of the heart. The ability to evaluate the heart rhythm is critical as cardiac dysrhythmias often are symptomatic and require immediate treatment. However, even if the dysrhythmia is not symptomatic, treatment may still be required to prevent future complications. Atrial fibrillation is a good example of a cardiac dysrhythmia easily identified on ECG, where symptoms may be completely absent or may be severe requiring immediate intervention. Depending on the rate (either fast or slow), the patient's symptoms may range from a benign fluttering in the chest to more serious symptoms of fatigue, chest pain, or syncope. Figure 1.2 is an example of atrial fibrillation with rapid ventricular response. A patient who experiences heart block may be symptom free or at risk for syncope or cardiac arrest with a high-degree atrioventricular (AV) block, as seen in Figure 1.3. Even when a patient is stable and without active symptoms, the ECG may provide clues that a patient is at risk for a potentially malignant rhythm. The patient depicted in Figure 1.4 is an example of long QT syndrome complicated by malignant ventricular dysrhythmia. The recognition of a prolonged QT interval is critical as patients with this electrocardiographic finding are at higher risk for dysrhythmia and sudden cardiac death (Figure 1.4).

One of the most important parts of prehospital medicine is the recognition and treatment of life-threatening dysrhythmias. For prehospital rhythm interpretation, the use of the ECG in a single- or multilead analysis mode is the most

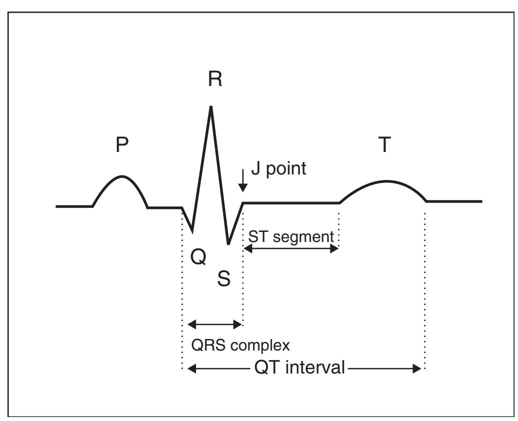

Figure 1.1 The PQRST complex – a single ''electrical heart beat.''

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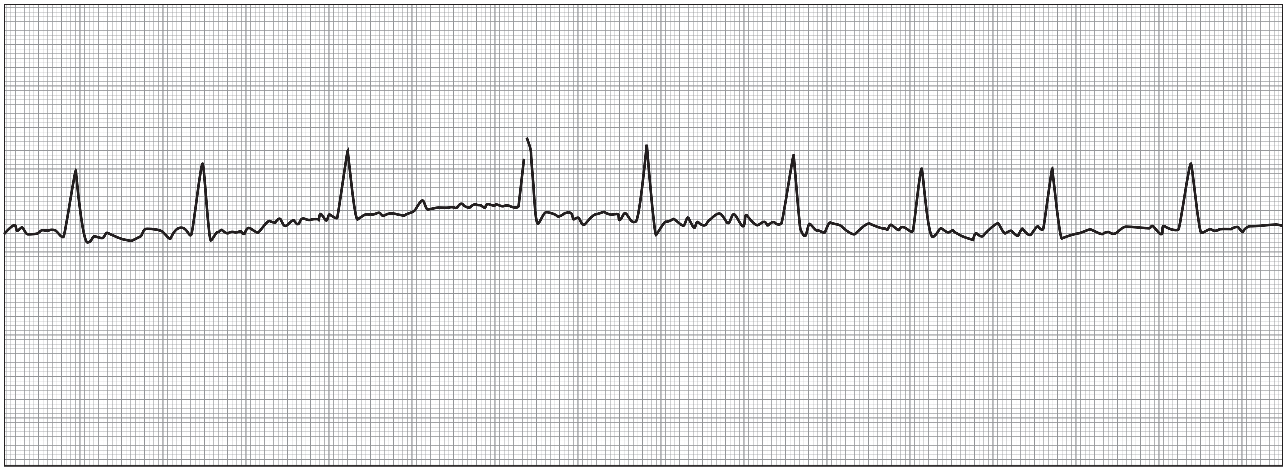


Figure 1.2 Atrial fibrillation with rapid ventricular response; note the ''irregularly irregular'' rhythm.

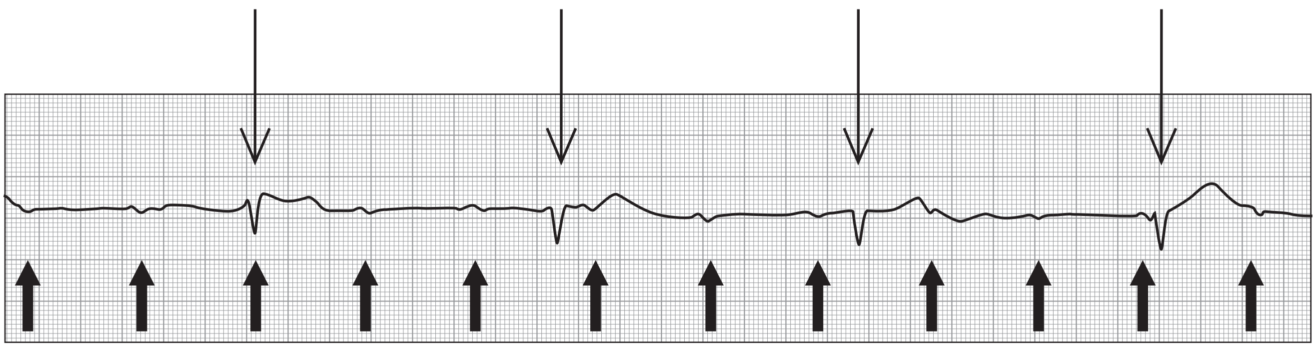


Figure 1.3 Third-degree AV block demonstrating no relationship between P wave (small arrow) and QRS complex (large arrow). This ECG nicely demonstrates the intrinsic ventricular rate of 20–40 beats per minute and sinus rate of 60–80 beats per minute.

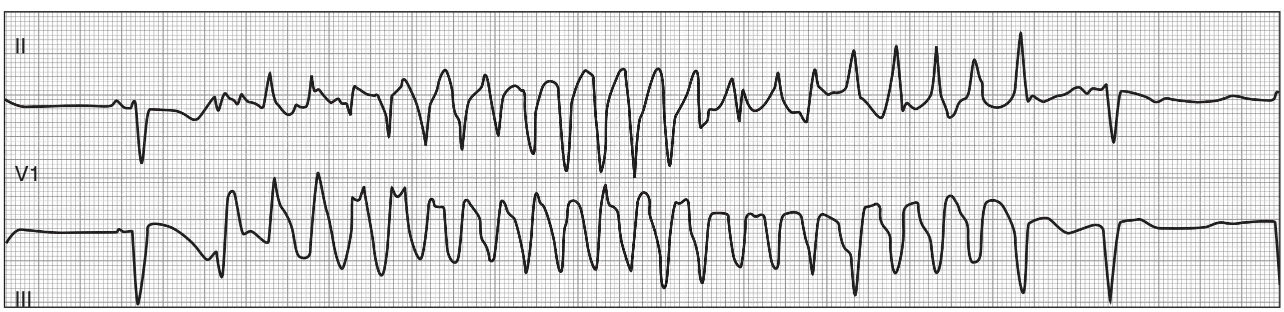


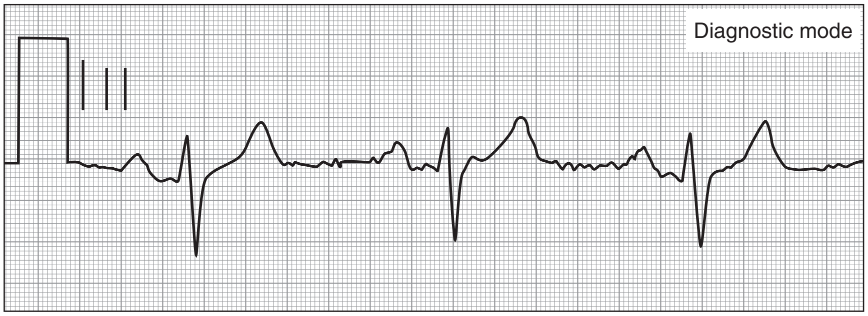
Figure 1.4 Brief episode of torsades de pointes in a patient with a QTc interval of 579 ms.

appropriate. For strict rhythm only analysis, the 12-lead ECG offers little additional information.

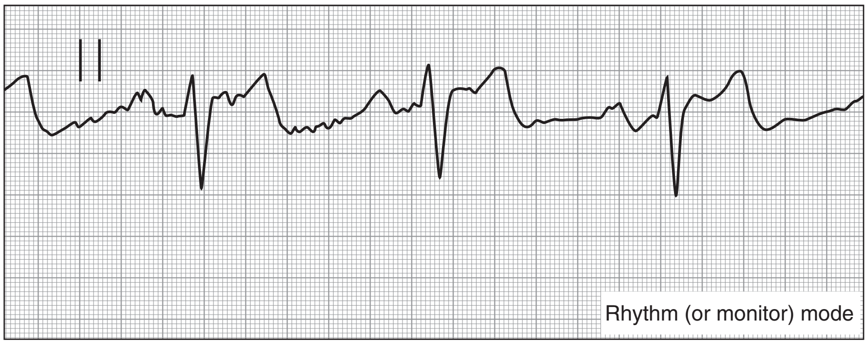
Electrocardiograhic evaluation in the setting of acute coronary syndrome

The ECG is also an important tool in evaluating the patient with a suspected ACS. The 12-lead ECG can not only provide important information regarding the ACS diagnosis but also guides therapy and predicts risk, and can suggest alternative diagnoses. The use of the 12-lead ECG in ''diagnostic mode'' is the most appropriate electrocardiographic tool; the use of single-lead rhythm monitoring is not of value with regard to ACS detection – yet single-lead monitoring is of extreme importance in the detection of cardiac rhythms, which can complicate ACS events (Figure 1.5).

In patients with ST segment elevation myocardial infarction (STEMI), the ECG not only provides the specific



(a)



(b)

Figure 1.5 In rhythm mode, ECG monitoring devices attempt to reduce artifact, enabling a more accurate rhythm evaluation. This artifact dampening effect can lead to distortion of the ST segment, producing ST segment changes which are, in fact, not present in diagnostic (or 12-lead ECG) mode. Shown here is a lead II tracing in a patient in diagnostic mode (a) and non-diagnostic rhythm mode (b). Note the appearance of ST segment elevation in rhythm mode, which is not present in the diagnostic mode.

diagnosis but is also the primary means for determining a patient's need for emergent reperfusion of the obstructed coronary artery; refer to Figure 1.6, which demonstrates an ECG of a patient with an inferior wall STEMI. It has been shown in numerous studies that the prehospital 12-lead ECG markedly reduces the time to hospital-based reperfusion (fibrinolysis and percutaneous coronary intervention) in patients with STEMI. In non-ST segment elevation myocardial infarction (NSTEMI) the ECG is also valuable. The ECG can display evidence of ongoing cardiac injury with T wave inversion or ST segment depression. The ECG can also help localize the obstructed coronary artery; for example, Wellens' Syndrome has a characteristic ECG pattern with changes to the T wave in the precordial leads, predominantly leads V2–V4, which can indicate a high-degree obstruction of the proximal left anterior descending coronary artery.

Electrocardiograhic evaluation in the setting of non–acute coronary syndrome pathology

The ECG is also a useful tool in the evaluation of non-coronary artery pathology that manifests with changes to the ECG. Refer to Table 1.1 for a list of selected diseases not related to coronary obstruction that may have significant

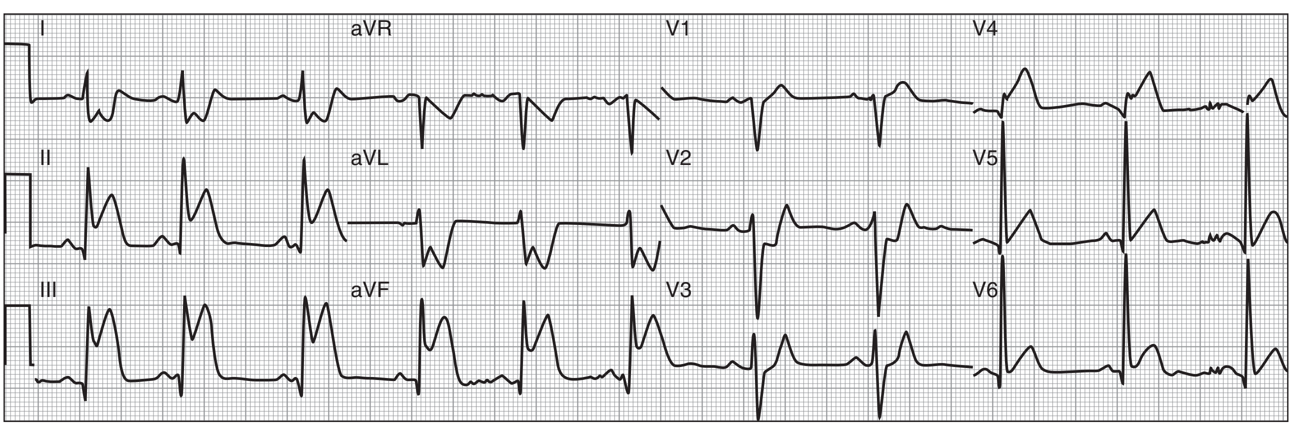


Figure 1.6 Acute inferior and lateral wall ST segment elevation myocardial infarction (STEMI).

Table 1.1 Selected examples of non-coronary pathology evaluated by ECG

Pericarditis
- Diffuse non-anatomical ST segment elevation without reciprocal changes
- Diffuse PR segment depression
- Isolated ST segment depression and PR elevation in aVR

Pericardial tamponade
- Electrical alternans
- Low QRS complex voltage
- Diffuse PR segment depression

Hypothermia
- Osborn ''J'' waves
- Bradycardias and AV blocks
- Prolongation/widening of PR interval, QRS complex, and QT interval
- Atrial fibrillation with slow ventricular response

Hyperkalemia
- Diffuse non-anatomical peaked T waves
- Widening of PR interval and QRS complex widths

CNS events
- Diffuse, deep T wave inversions
- Minor ST segment elevations in leads with T wave inversions

Overdose and intoxication
- Rhythm disturbances
- Widened QRS complex
- Prolonged QT interval

abnormalities evident on the ECG. Pericarditis (inflammation of the pericardial sac) leads to a diffuse pattern of PR segment depression and ST segment elevation that can be differentiated from STEMI as the elevation is present in a pattern not anatomically related to a coronary artery distribution. At the same time, the diagnosis of pericarditis can be difficult, and the patient may present with chest pain and ST segment elevation, potentially leading to the incorrect diagnosis of STEMI. Pericardial effusion with ultimate cardiac tamponade is caused by fluid in the pericardium that can accumulate owing to a variety of causes including recent viral infection or cancer. On the ECG, this condition leads to sinus tachycardia and low QRS complex voltage. Electrical alternans is also seen in this setting and is characterized by beat-to-beat alterations in the QRS complex size, reflecting the swinging motion of the heart in the pericardial fluid.

There are also a host of conditions that are not primarily related to the heart where the ECG may provide a clue to diagnosis. Pulmonary embolism can present with the classic ''S1Q3T3'' on the ECG (Figure 1.7). Osborn waves are positive deflections occurring at the junction between the QRS complex and the ST segment that are typically observed in patients suffering from hypothermia with a temperature of less than 32°F. Several electrolyte disturbances exhibit characteristic changes to the ECG. Hyperkalemia first results in peaked T waves most apparent in the precordial leads. If the condition is untreated, however, the ECG may progress to widening of the QRS complex and the eventual fusing of the QRS complex and the T wave, resulting in a sine wave configuration and ultimately cardiac arrest. Central nervous system (CNS) events such as intraparenchymal hemorrhage, ischemic stroke, and mass lesion may also present with changes in the ECG, largely involving the T wave with inversion and prolongation of the QT interval.

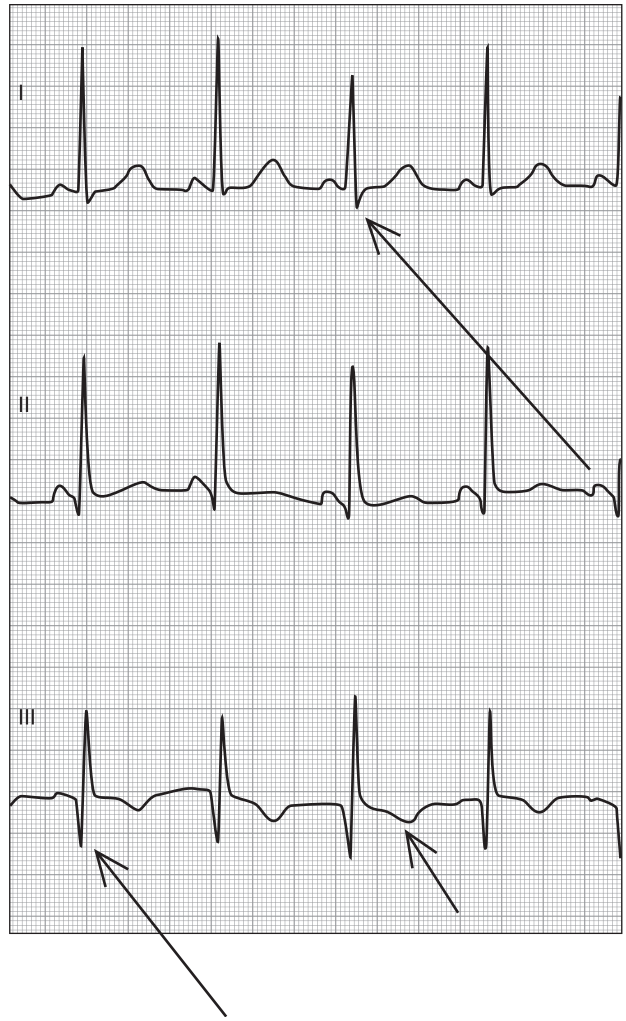


Figure 1.7 S1Q3T3 pattern in a young patient with bilateral pulmonary embolism. The S wave in lead I is indicated by the long arrow, the Q wave in lead III (medium arrow), and the inverted T wave in lead III (small arrow).