Celebrating the 100th Birthday of the Electrocardiogram: Lessons Learned From Research in Cardiac Monitoring

By Barbara J. Drew, RN, PhD. From the Department of Physiological Nursing, University of California, San Francisco. Distinguished Research Lecture presented at the American Association of Critical-Care Nurses National Teaching Institute, May 6, 2002, Atlanta, Ga.

The electrocardiogram continues to be the gold standard for the diagnosis of cardiac arrhythmias and acute myocardial ischemia. The treatment of arrhythmias in critical care units has become less aggressive during the past decade because research indicates that antiarrhythmic agents can be proarrhythmic, causing malignant ventricular arrhythmias such as torsade de pointes. However, during the same period, the treatment of acute myocardial ischemia has become more aggressive, with the goal of preventing or interrupting myocardial infarction by using new antithrombotic and antiplatelet agents and percutaneous coronary interventions. For this reason, critical care nurses should learn how to use ST-segment monitoring to detect acute ischemia, which is often asymptomatic, in patients with acute coronary syndromes. Because the electrocardiographic lead must be facing the localized ischemic zone of the heart to depict the telltale signs of ST-segment deviation, the challenge is to find ways to monitor patients continuously for ischemia without using an excessive number of electrodes and lead wires. The current trend is to use reduced lead set configurations in which 5 or 6 electrodes, placed at convenient places on the chest, are used to construct a full 12-lead electrocardiogram. Nurse scientists at the University of California, San Francisco, School of Nursing are at the forefront in developing and assessing the diagnostic accuracy of these reduced lead set electrocardiograms. (American Journal of Critical Care. 2002;11:378-388)

I am truly honored to join the ranks of esteemed past recipients of the American Association of Critical-Care Nurses’ Distinguished Research Lecture. It was fitting to discuss my program of research in electrocardiographic monitoring at the 2002 National Teaching Institute because this year marks the 100th birthday of the electrocardiogram (ECG). In 1902, a Dutch physiologist, Willem Einthoven, published the first ECG recorded with his 270-kg (600 lb) machine, the string galvanometer, for which he was awarded a Nobel Prize. Einthoven never could have imagined the explosion of knowledge his invention would spark. In the ensuing 100 years, technological advances included pacemakers, defibrillation, antiarrhythmic drugs, invasive cardiac electrophysiology testing, implantable cardioverter defibrillators, radio-frequency ablation, transtelephonic transmission of the ECG, and much more.
My program of research at the University of California, San Francisco (UCSF), has advanced the field of electrocardiography by developing and testing better ways to detect cardiac arrhythmias and myocardial ischemia. I began the program after 18 years of clinical experience working in coronary care units. I was passionate about conducting research that would be relevant to clinical practice and that would improve the way my colleagues and I monitored patients. Although this passion has fueled my research endeavors, the successes I have achieved in the field of electrocardiography are largely due to 6 crucial factors:

1. Support from a research-intensive university department headed by a wonderful research mentor, Dr Christine Miaskowski.
2. Collaboration with clinical scientists in the division of cardiology at UCSF.
3. Contributions from stellar graduate students in the school of nursing at UCSF.
4. Funding from the National Institutes of Health.
5. Collaboration with clinical and engineer scientists through professional organizations, namely, the American Association of Critical-Care Nurses, the International Society of Computerized Electrocardiology, and the American Heart Association.
6. Collaboration with industry partners, who have incorporated findings from the research conducted by my colleagues and me to develop better cardiac monitors.

My focus here is on lessons learned from clinical trials at UCSF during the past 12 years, with a special emphasis on the findings that can be incorporated into current clinical practice to improve patients' care.

**Arrhythmia Monitoring Research**

My early studies focused on arrhythmia monitoring, specifically, on improving the diagnosis of wide-QRS-complex tachycardia. Some reports indicated that misdiagnosis of ventricular tachycardia (VT) as supraventricular tachycardia (SVT) with aberrant conduction resulted in inappropriate treatment and adverse outcomes for patients, including death. My arrhythmia studies were conducted in the cardiac electrophysiology laboratory at UCSF in collaboration with Dr Melvin Scheinman, a pioneer in electrocardiography, who introduced catheter ablation therapy for the treatment of tachycardias.

Lessons learned from these arrhythmia studies included the following for making the important distinction between VT and SVT with aberrant conduction: (1) The 12-lead ECG is valuable. For example, we found that more than 90% of wide-QRS-complex tachycardias could be accurately diagnosed if the arrhythmia was documented with a 12-lead ECG. (2) A single lead II is poor. For example only 34% of the tachycardias in our study were correctly identified by using this lead. (3) Lead V1 is the best single lead. For example, we found that the recording from lead V1 most often contained the following: visible P waves to identify atrioventricular dissociation, which is indicative of VT; the widest QRS interval, which if greater than 0.16 seconds, is indicative of VT; and valuable QRS morphology criteria.

We also discovered that QRS morphology in lead MCL1 is not always identical to that in lead V1 during wide-QRS-complex tachycardia. For example, we found that QRS configurations in MCL1 differed from those in V1 in 40% of VTs and that relying on the findings in lead MCL1 led to a wrong diagnosis in 22% of VTs that were correctly identified when QRS morphology criteria in lead V1 were used. Thus, we reported that it was inappropriate to apply criteria intended for use with lead V1 when using lead MCL1 to monitor a patient.

In response to our reports about lead MCL1, manufacturers developed monitoring systems (including telemetry systems) with the capability of monitoring a "true" V1 lead. Because monitoring lead V1 requires 2 more electrodes than does monitoring lead MCL1 (ie, 5 electrodes rather than 3), the result was a slightly more cumbersome electrode configuration, especially in telemetry units where simple monitoring systems with 3 lead wires were popular.

We had also reported that 12-lead ECGs were valuable for accurate diagnosis of wide-QRS-complex tachycardias. However, it was often impossible to document a tachycardia by using a standard 12-lead ECG, especially if the tachycardia was nonsustained. In response to this finding, manufacturers developed cardiac monitors with full 12-lead capability, although the new monitors resulted initially in heavy monitoring cables and a cumbersome electrode configuration, which was especially challenging to maintain in patients who were restless or diaphoretic.

**Research on the Importance of Accurate Lead Placement**

The protocol for my studies in the cardiac electrophysiology laboratory involved my removing electrodes placed on patients by nurses in several monitored units at UCSF. I observed that electrodes were often not in the correct anatomic site; for example, the V1 electrode was often not precisely in the 4th intercostal space at the right sternal border. To determine whether imprecise electrode placement could cause misdiagnosis, I recorded from misplaced electrodes in several patients who had VT that did not cause an immediate loss of consciousness. Because the ECG monitoring leads used for my research were separate from the leads monitored during...
cardiac electrophysiology studies, I could misplace the research electrodes without interfering with the test. Some of these patients were left in VT for a few minutes to determine whether their blood pressure would remain stable. Much to my surprise, I discovered that I could change QRS morphology used as an indication of VT into morphology used as an indication of SVT by misplacing the electrode just a single intercostal space away from the correct anatomic location. This finding was a huge concern, given the inaccurate lead placement I had noticed from our clinical units.

In conjunction with the 2 cardiovascular clinical nurse specialists at UCSF, I decided to conduct a national random survey of critical care nurses to determine whether accurate lead placement was a widespread problem in clinical practice. Although the 302 critical care nurses who responded to the survey were an experienced group (mean age, 35 years; mean number of years of critical care experience, 8.5 years), only 37% properly marked lead placement on a diagram with clearly indicated ribs and intercostal spaces.

Another finding from the survey was that lead II was, by far, the most popular monitoring lead. For nurses who monitored a single ECG lead, lead II was selected by 74%; for nurses who monitored 2 ECG leads, lead II (plus lead V1 or lead MCL1) was selected by 87%. Of interest, 40% of nurses who monitored lead MCL1 had monitors capable of monitoring a true V1 lead. So, we published a recommendation stating, "If you have monitors capable of monitoring a true V1 lead (ie, the monitor provides a 'V' choice and the patient monitoring cable has five lead wires), then don't select MCL1."  

An interesting story about the monitoring research survey was that when I received the 302 questionnaires, I wanted to store them in a safe place until I had time to analyze them. Because a major earthquake had recently occurred in Northern California, I stored the questionnaires in an earthquake and fireproof file cabinet in my home in the Oakland-Berkeley hills. A few weeks after I stored the questionnaires, my house burned down along with about 3000 other homes in a major fire. When I returned to my home after the fire, the file cabinet was blackened and the metal handles were melted; however, the questionnaires were intact. I often say that "God really wanted to get out the message about accurate lead placement because it was the only thing we salvaged from our house fire!"

Ischemia Monitoring Research

In the early 1990s, a major shift occurred in the treatment of cardiac arrhythmias in hospital units. This shift was largely due to findings from the Cardiac Arrhythmia Suppression Trial (CAST), which indicated that patients treated with antiarrhythmic agents had higher mortality than did patients treated with a placebo. The awareness that antiarrhythmic agents could cause more malignant ventricular arrhythmias than the patient had when these agents were not used led to a less aggressive approach to the treatment of arrhythmias. For example, instead of starting treatment with an antiarrhythmic agent when a patient had frequent ventricular ectopic beats, use of the agents was reserved for treatment of sustained and symptomatic arrhythmias.

Another shift occurred about the same time: a more aggressive approach to the treatment of acute myocardial ischemia, with the goal of preventing or limiting myocardial cell death. New antithrombotic and antiplatelet agents and percutaneous coronary interventions were used to treat patients with acute myocardial infarction and unstable angina. For this reason, I shifted the focus of my research from cardiac arrhythmia monitoring to ischemia monitoring. Although bedside cardiac monitors were developed as early as the mid-1980s with software for monitoring changes in the ST segment in order to detect acute ischemia, few clinicians understood or used this technology.

Although our research group had reported that monitoring lead V1 was valuable for detecting cardiac arrhythmias, we discovered in an early study on ST-segment monitoring that lead V1 was not efficacious for detecting acute myocardial ischemia. Because most cardiac monitors provided only a single V lead choice, this finding placed critical care nurses in the dilemma of having to choose whether a patient was more likely to have ischemia or wide-QRS-complex arrhythmias. And because myocardial ischemia can trigger malignant ventricular arrhythmias, both of these abnormalities—ischemia and life-threatening arrhythmias—may occur simultaneously in a patient.

The more I learned about acute myocardial ischemia in patients with acute coronary syndromes (unstable angina and acute myocardial infarction), the more I understood that ischemia is a localized phenomenon. For this reason, multiple ECG leads would be required to detect ischemia across the numerous myocardial zones related to the left, right, and circumflex coronary arteries and their branches. Studies on body-surface potential mapping, which used as many as 192 electrodes on the torso, indicated that ECG leads on the body surface must be placed directly over a localized ischemic myocardial zone in order to observe the telltale signs of ST-segment deviation. Therefore, the first problem tackled was, How can we detect ischemia in numerous myocardial zones without an excessive number of electrodes? A solution to this problem that my colleagues and I have
been investigating during the past decade is “reduced lead set” technology, which is a method of estimating a 12-lead ECG using a small number of electrodes.

We have evaluated 2 reduced lead set configurations: the EASI 12-lead (Philips Medical Systems, Andover, Mass) configuration and, more recently, the “interpolated” 12-lead (General Electric Medical Systems, Milwaukee, Wis) configuration (Figure 1). Our research team has conducted 2 major prospective clinical trials in which the EASI 12-lead configuration (Figure 1A) was used for ST-segment monitoring in patients with acute coronary syndromes. In the ST Analysis Trial (STAT study), we compared ST-segment monitoring with the EASI 12-lead ECG with routine cardiac monitoring for detecting ischemia in 490 patients admitted to the coronary care unit with acute coronary syndromes. In the ST Analysis and Monitoring of Patients and Evaluation of a Derived ECG (STAMPEDE) study, we compared ST-segment monitoring via the EASI 12-lead ECG with ST-segment monitoring via the standard 12-lead ECG in 621 patients who came to the emergency department because of chest pain. These patients also had ST-segment monitoring continued in the cardiac catheterization laboratory, coronary care unit, and step-down telemetry units.

One of the first lessons we learned in the STAT study is that leads used routinely in the coronary care unit to detect “arrhythmia” are insensitive for detecting acute myocardial ischemia. For example, of 463 ischemic events detected with EASI 12-lead ST-segment monitoring, 67% had no evidence of ischemia in leads II or V1, and 80% of these ischemic episodes were asymptomatic (“silent”). We found that the best ECG leads for detecting ischemia related to specific coronary arteries were as follows: right coronary artery, lead III; left anterior descending artery, lead V3; and left circumflex artery, also lead V3. Thus, if the goal of monitoring is primarily to detect ischemia, the dual-lead combination of III and V3 may be most efficacious for systems that do not provide full 12-lead ECG monitoring.

A second lesson learned from the clinical trials was that monitoring a patient’s ST “fingerprint” lead is not always adequate for detecting recurrent ischemia after acute myocardial infarction or percutaneous coronary interventions. The ST fingerprint lead is defined as the lead with maximal ST-segment deviation in acute myocardial infarction or during inflation of the catheter balloon in percutaneous coronary interventions. Krucoff et al had reported that recording a 12-lead ECG during percutaneous coronary interventions provided an ECG template that was unique to the individual patient and dependent on the anatomic site of the patient’s intervention. This ECG template was valuable for detecting abrupt reocclusion after the intervention.

Although we found that the ST fingerprint lead was valuable for detecting the rare complication of abrupt reocclusion after percutaneous coronary interventions, this single lead could not be used to detect transient ischemic events.
ischemia due to other mechanisms. For example, we found that we would have missed 245 ischemic events that were detected by 12-lead ECG monitoring if we had monitored just the ST fingerprint lead (Table 1). Our conclusions agreed with those of Klootwijk et al., who reported that patients admitted to the hospital with acute coronary syndromes often have more than a single transient ischemic event manifested in different ECG leads. Therefore, multilead (ideally, 12-lead) ST-segment monitoring is recommended to portray ischemia in the multiple potential ischemic zones of the heart.

A third lesson we learned is that acute myocardial infarction and transient myocardial ischemia may not be detected when the standard “snapshot” 12-lead ECG is used. Figure 2A shows an example of a 76-year-old woman enrolled in the STAMPEDE study who came to the emergency department because of chest pain. Her initial ECG did not indicate marked ST-segment elevation. Minutes later, a monitor alarm alerted us to the development of striking ST-segment elevations in the “inferior” leads II, III, and aVF (Figure 2B). On the basis of these changes, early reperfusion therapy was initiated with a thrombolytic agent. When the continuous ST segment amplitude data in this patient were reviewed, a dynamic pattern of ST-segment elevation was observed, with periods of normal, isoelectric ST segments alternating with periods of extreme ST-segment elevation (Figure 3). The patient’s serum level of troponin I subsequently became elevated, and the ECG showed the Q waves associated with acute inferior wall myocardial infarction. Independent from our study protocol, the emergency department staff recorded a total of 5 standard 12-lead ECGs. None of these standard ECG recordings showed ST-segment elevation because all the recordings coincided with the periods of normal ST segments.

This pattern of dynamic ST-segment elevation has been termed “intermittent reperfusion” and is thought to represent cycles of thrombotic occlusion and spontaneous reperfusion during the early stage of infarction. A total of 7 articles have reported the frequency of intermittent reperfusion in acute myocardial infarction, and a meta-analysis of these studies indicates that the frequency is 34% to 40% (95% CI). It is not surprising that the 5 serial ECGs recorded in our patient did not detect ischemia, because dynamic ST-segment changes may not be detected with a single snapshot ECG, which depicts a brief 10 seconds of ECG information. Thus, unless continuous, multilead ST-segment monitoring is used in the emergency department, most likely some patients who would benefit from early reperfusion therapy for myocardial infarction associated with ST-segment elevation will go untreated.

Continuous monitoring of the 12-lead ECG in the emergency department in the STAMPEDE study also allowed us to detect patients with unstable angina who might have been missed because of the fleeting nature of their ischemia. One such patient was a 47-year-old woman who came to the emergency department because she had had intermittent chest pain during the previous several days. She had no history of coronary artery disease, but she had the coronary risk factors of hypertension and smoking. She was asymptomatic at the time her initial ECG was recorded (Figure 4A), which did not show any ST-segment abnormalities.

Because her chest pain was considered atypical of angina, and because of her normal ECG findings, plans were made to discharge her from the emergency department. Before she left, however, she asked to use the bathroom, which was down the hall. We put our ST-segment monitor on an intravenous pole so the patient could be monitored while walking down the hall. While walking, she complained of her “atypical” chest pain, and an alarm on the monitor alerted us to the ECG in Figure 4B, which shows ST-segment depression in numerous leads. Of interest, ST-segment elevation is present in lead aVR, with less elevation in lead V1, a finding that recently has been described as an indication of disease of the left main coronary artery. Although these deviations in the ST segment lasted only a couple of minutes, they confirmed that the patient’s chest pain was due to myocardial ischemia, and she was admitted to the hospital with a diagnosis of unstable angina. The next morning, a coronary angiogram revealed a 99% stenosis of her left main coronary artery, and she was transferred directly to the operating room for coronary artery bypass surgery. Clearly, if continuous ST-segment monitoring had not been used, this patient would have been sent home with an extremely high-risk coronary lesion.

A fourth lesson we have learned is that inconsistent lead placement can cause false alarms on the ST-segment
monitor and potentially lead to overtreatment. Electrodes located close to the heart (eg, the midprecordial leads) can record very different ST/T waves if the electrodes are moved a short distance from the original sites. Electrodes may be moved for a variety of valid reasons, such as skin irritation, placement of a defibrillator pad, or recording of an echocardiogram. It is important for clinicians to distinguish ST/T wave changes due to movement of an electrode from ST/T wave changes indicative of ischemia.

Another cause of false alarms are ST-segment changes due to changes in body position. Adams and I reported that changes in body position produce clinically significant ST-segment deviation (≥1 mm) in 15% of healthy subjects. A change in the ST segment due to a change in body position should be suspected when the QRS waveform changes along with the ST segment, a situation that is unlikely during an ischemic event (Figure 5).

We recently investigated a new reduced lead set system that we term the interpolated 12-lead ECG (General Electric Medical Systems; Figure 1B). This lead system uses 6 electrodes placed in standard lead locations (4 limb leads plus V1 and V5 leads) to construct the remaining precordial leads to obtain a full 12-lead ECG. The advantages of using standard lead locations are that clinicians do not need to be taught unfamiliar electrode placement and that the resultant 12-lead ECG contains 8 “true” standard leads (I, II, III, aVR, aVL, aVF, V1, and V5). We found that the interpolated 12-lead ECG is comparable to the standard 12-lead ECG for diagnosing multiple cardiac abnormalities, including wide-QRS-complex tachycardias and acute myocardial ischemia.

One of the things I am most proud of is an expert panel I convened to develop a practice guideline for ST-segment monitoring. This international group of 10 physicians, 10 nurses, and 1 biomedical engineer
Figure 3 One-hour ST-segment monitoring data recorded in the emergency department of the patient described in Figure 2. The y axis shows millimeters of ST-segment deviation, with 0 mm representing the normal isoelectric value, positive numbers indicating ST-segment elevation, and negative numbers indicating ST-segment depression. The x axis shows time. A dynamic pattern of ST-segment elevation is apparent (representative P-QRS-T complexes are shown at 3 time points above the trend). Standard 12-lead electrocardiograms were recorded serially for a total of 5 electrocardiograms (dashed arrows). None of these 5 snapshot electrocardiograms depict acute ischemia because they were recorded during periods of normal, isoelectric ST segments.

Figure 4 A, Initial 12-lead electrocardiogram recorded in a 47-year-old woman who came to the emergency department because of intermittent chest pain. Except for a prolonged QT interval, the findings on this baseline electrocardiogram are normal. B, While the patient was walking down the hall to the bathroom, the alarm on her ST-segment monitor sounded and she experienced chest pain. The 12-lead electrocardiogram shows ST-segment depression in multiple leads.
met at the 1998 annual scientific sessions of the American Heart Association in Dallas and reached consensus on the following questions:

- Who should have ST-segment monitoring?
- What are the goals and recommended time frames for ST-segment monitoring in patients with various diagnoses?
- Who should not have ST-segment monitoring?
- What ECG leads should be monitored?
- What equipment is required for accurate ST-segment monitoring?
- What strategies improve the accuracy and clinical usefulness of ST-segment monitoring?
- What knowledge and skills should clinicians have for safe and effective ST-segment monitoring of patients in a hospital unit?
- What are the priorities for future research and development?

Table 2 shows the experts’ recommended time frames for ST-segment monitoring of patients with acute coronary syndromes.

Our future directions include a new clinical trial, which is just under way. The trial was given the acronym IMMEDIATE AIM, which stands for Ischemia Monitoring and Mapping in the Emergency Department in Appropriate Triage and Evaluation of Acute Ischemic Myocardium. In this trial, we will determine whether estimated body-surface potential mapping is superior to 12-lead ST-segment monitoring for detecting acute ischemia. If we are successful in using a reduced number of electrodes to estimate the ECG findings at 192 sites around the entire body torso, we will be able to find a patient’s “hot spot” where ST-segment changes indicative of ischemia are most extreme. Future cardiac monitors could then provide software to indicate where a patient’s hot spot is located so that a nurse could select this site for monitoring.

We are also mounting a multicenter randomized clinical trial called the ST SMART study (Synthesized Twelve-Lead ST Monitoring and Real-Time Tele-Electrocardiography). In this study, we will determine the effect of countywide prehospital transtelephonic ST-segment monitoring on time to reperfusion treatment and patients’ outcomes.

**Conclusions**

Research in ECG monitoring during the past decade has taught us many lessons. A growing trend is to monitor patients with 12 ECG leads, either by using a reduced lead system or the standard configuration. It is challenging, especially in light of the current nursing shortage, to incorporate the findings from cardiac monitoring research into clinical practice. I think that interpretation of 12-lead ECGs is an important skill for today’s critical care nurses. Nurses play a pivotal role in placing electrodes accurately, ensuring consistent lead placement over time, and assessing and responding appropriately to alarms that indicate

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**Figure 5** Precordial leads recorded with a patient supine (A) and after the patient rolled onto his left side (B). The positional changes in the ST segment, which are most evident in lead V5, were great enough to trigger a false alarm on the ST-segment monitor. An important clue indicating that this event was a positional, rather than an ischemic, event is the change in the QRS complex in the 2 electrocardiograms. If the ST-segment depression was due to transient myocardial ischemia, QRS voltage would not be expected to increase during the event.
arrhythmia and ischemia. I think it is imperative to teach nurses in UCSF’s master’s programs the skill of 12-lead ECG interpretation, because I think clinical nurse specialists and nurse practitioners have a responsibility to improve cardiac monitoring practices. An important goal for future studies is to determine whether more accurate monitoring will result in more timely diagnosis and treatment and better outcomes for patients.

ACKNOWLEDGMENTS

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REFERENCES

CE Test Instructions

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CE Test Form

Celebrating the 100th Birthday of the Electrocardiogram: Lessons Learned From Research in Cardiac Monitoring

Objectives

Upon completion of this article, the reader will be able to:
1. Identify 3 major findings from Dr Drew’s program of research
2. Describe 3 nursing interventions arising from Dr Drew’s program of research
3. Identify 2 areas of future research regarding cardiac monitoring

Mark your answers clearly in the appropriate box. There is only one correct answer. You may photocopy this form.

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CE Test Questions

Celebrating the 100th Birthday of the Electrocardiogram: Lessons Learned From Research in Cardiac Monitoring

1. Which physiologist published the first ECG?
   a. Einstein
   b. Einthoven
   c. Dubin
   d. Marriott

2. Dr Barbara Drew’s program of research involves developing and testing better ways to detect which of the following?
   a. Cardiac arrhythmias and myocardial ischemia
   b. Chest pain and cardiac arrhythmias
   c. Myocardial ischemia and oxygen consumption
   d. Oxygen consumption and chest pain

3. What percentage of wide-QRS-complex tachycardias can be accurately diagnosed with a 12-lead ECG?
   a. 60%
   b. 70%
   c. 80%
   d. 90%

4. In Dr Drew’s early studies, what percentage of tachycardias was correctly identified by using a single lead II?
   a. 22%
   b. 34%
   c. 40%
   d. 58%

5. Which one of the following was found to be the best single lead?
   a. V1
   b. V2
   c. V3
   d. V4

6. In Dr Drew’s study of experienced critical care nurses, how many nurses were able to properly mark lead placement on a diagram with clearly indicated ribs and intercostal spaces?
   a. 37%
   b. 44%
   c. 74%
   d. 87%

7. Which change in practice resulted from the Cardiac Arrhythmia Suppression Trial (CAST)?
   a. More aggressive treatment of arrhythmias
   b. Less aggressive treatment of arrhythmias
   c. More aggressive treatment of heart failure
   d. Less aggressive treatment of heart failure

8. How many of the ischemic episodes in the ST Analysis Trial (STAT) were found to be asymptomatic?
   a. 60%
   b. 70%
   c. 80%
   d. 90%

9. A single snapshot ECG depicts how many seconds of ECG information?
   a. 5 seconds
   b. 10 seconds
   c. 15 seconds
   d. 20 seconds

10. According to Adams and Drew’s study, changes in body position can result in clinically significant ST deviation in what percentage of healthy subjects?
    a. 5%
    b. 10%
    c. 15%
    d. 20%

11. What is the recommended duration of ST-segment monitoring for a patient with an acute coronary syndrome who comes to the emergency department with chest pain?
    a. 6 to 12 hours
    b. 8 to 12 hours
    c. 12 to 24 hours
    d. 24 to 48 hours