Critically ill patients with a primary diagnosis of coronary artery disease are routinely monitored to detect, evaluate, and treat myocardial ischemia to prevent potential myocardial infarction. In critically ill patients with noncardiac diagnoses, monitoring for ischemia is often not the focus or priority. Yet, clinicians are aware that critical illness is associated with increased metabolic demands due to the illness itself and that these demands may be compounded by preexisting or occult coronary artery disease and/or sustained physiological stress such as hypertension, hypotension, and anemia and treatment-related stress such as weaning from mechanical ventilation. Although previous studies suggest that myocardial ischemia or injury is common in critically ill patients, several investigations had small sample sizes, and few examined the extent of myocardial ischemia as measured by continuous 12-lead electrocardiographic (ECG) monitoring or the relationship of myocardial ischemia to elevated troponin levels.
Further, although demand-related ischemia, commonly indicated by ST-segment depression (rather than ST-segment elevation expected with “supply-side ischemia”), is more common in patients without cardiac disease, little is known about the frequency and outcomes of myocardial ischemia in critical care patients generally.

The purposes of this study were to determine the extent of myocardial ischemia and injury detected within the first 48 hours in the intensive care unit (ICU) in patients admitted for noncardiac conditions, and examine the relationship of myocardial ischemia, injury, risk of coronary artery disease, and acuity to the outcomes of cardiac events detected during the hospital stay.

Background

Perioperative cardiovascular risk factors include unstable coronary syndromes such as recent myocardial infarction, unstable angina, decompensated congestive heart failure, significant arrhythmias, and severe valvular disease. Critically ill medical-surgical patients admitted for noncardiac conditions are also at risk for cardiac events related to physiological stressors similar to the stressors induced by operative procedures. These stressors may include conditions such as hypotension or hypertension, anemia, cardiac arrhythmias, and the stress of weaning from mechanical ventilation. ECG changes associated with myocardial ischemia were compared with cardiac events in critically ill patients without cardiac disease in only a few studies. Most studies of detection of ischemia in such patients were conducted in patients undergoing weaning from mechanical ventilation and high-risk surgeries. In perioperative studies, investigators found higher complication rates in patients who had myocardial ischemia during the perioperative period. Mangano et al studied 474 men undergoing noncardiac surgery and found that postoperative ischemia correlated with postoperative adverse cardiac events in 83 patients (18%). In these 83 patients, ischemic events (death due to cardiac factors, nonfatal myocardial infarction, or unstable angina) occurred in 15, congestive heart failure in 30, and ventricular tachycardia in 38. Landesberg et al also used 3 leads of ambulatory ECG monitoring to detect development of ST-segment changes in patients undergoing vascular surgery. Postoperative myocardial ischemia was the strongest predictor of cardiac events, especially among patients with more than 2 hours of cumulative ischemia. ST-segment depression was the most common finding. Landesberg et al emphasized the factors associated with demand-related ischemia, hypothesizing that ST-segment depression most likely reflects subendocardial ischemia triggered by postoperative physiological and psychological stressors. More recently, Landesberg et al used 12-lead ECG monitoring and measurement of serum levels of troponin and creatine kinase in a study of 185 consecutive patients undergoing vascular surgery. Acute myocardial infarctions, all of which were non Q wave, developed in 12 patients (6.5%). All patients with diagnosed myocardial infarction had evidence of prolonged ST-segment depression before elevations of troponin and creatine kinase occurred.

Continuous 12-lead ECG monitoring is valuable for detecting myocardial ischemia and currently is the primary means of noninvasive continuous monitoring in patients at risk for this abnormality. However, most previous studies were limited in the number of leads used to detect ischemia or in the sample characteristics, such as all male populations or small sample sizes. Most investigators reported significant demand-related ischemia detected by monitoring for ST-segment depression and high percentages of silent ischemia. Because silent ischemia predominates, 12-lead monitoring may be crucial in the detection of ischemic events.

Methods

Sample

Candidates for the study were consecutive patients admitted to the medical-surgical ICUs at 2 healthcare facilities: St. Mary’s Hospital, a midwestern community hospital in Decatur, Ill, from June to mid-July 2000, and Decatur Memorial Hospital, Decatur, Ill, from mid-July to November 2000. The institutional review boards of the participating institutions approved the study protocol. Patients were invited to participate in the study if they were adults 18 years or older, could speak and understand English, and were expected to remain in the ICU for at least 24 hours. Patients were ineligible if they were admitted to the ICU because of a lack of beds in the intermediate care unit, they were less than 18 years old, or they were in paced rhythm more than 50% of the time. Informed consent was obtained before enrollment in the study. Because of the critical condition of some patients, when required, an appropriate proxy, as
defined by Illinois law and hospital policy, gave signed informed consent.

**Study Variables**

Acuity was determined by using the Acute Physiology and Chronic Health Evaluation II (APACHE II). The following demographics and clinical data were collected:

- history of coronary artery disease or history of interventional procedures confirming coronary artery disease, such as coronary artery bypass graft surgery, angioplasty, and/or catheter-based interventional treatments; confirmed myocardial infarction, as indicated by history or ECG findings; risk factors for coronary artery disease, defined as history of angina pectoris requiring the use of nitrates; history of hypertension requiring antihypertensive treatment; history of hyperlipidemia requiring medical therapy; and diabetes mellitus;
- scores on APACHE II, completed 24 hours after ICU admission; and
- clinical cardiovascular events during hospitalization, defined as unstable angina requiring interventional treatment; acute myocardial infarction (diagnosed on the basis of acute progressive ECG changes and elevations of serial serum biomarkers), congestive heart failure (defined as presence of radiological evidence of infiltrates along with dyspnea and lung crackles) treated with diuretics, unstable cardiac arrhythmias requiring medical intervention to control signs and symptoms, hypotension (defined as mean arterial pressure less than 65 mm Hg) accompanied by signs and symptoms of poor peripheral or organ perfusion requiring hemodynamic support, and death due to cardiac factors (defined as death caused by dysrhythmia, heart failure, or other primary cardiac cause).

Patients were followed up for the duration of their hospitalization. Length of stay was calculated to the nearest 12 hours (or half day) for ICU stay and hospital stay.

Patients were monitored by using a 12-lead telemetry monitoring system (Datex-Ohmeda, Helsinki, Finland) with Mason-Likar placement of the electrodes (see Figure). For this study, a single-antenna system was installed near the central monitor, and cables were attached to patients by using a battery-operated transmitter with 10 lead wires.

ECG data were analyzed by using a solid-state digital reception station with software tested for accuracy and precision by using the European Society of Cardiology ST-T Database for ST-segment monitoring ($r = 0.975$). The sampling frequency of the Datex-Ohmeda system is 500 Hz, and the filter complies with the Association for the Advancement of Medical Instrumentation EC 11-1991 performance standards for diagnostic ECG devices. ST-segment amplitude was measured at 60 ms after the J point. Transient myocardial ischemia was defined as an elevation or a depression in the ST segment of 1 mm (0.1 mV) or more from baseline that persisted at least 1 minute. Episodes of transient ischemia were summed across leads in which the changes were detected, multiplied by the amount of deviation in increments of 0.5 mm greater than or equal to 1 mm. This multiplier was used to adjust for the magnitude of ST deviation and allowed calculation of myocardial ischemic burden (MIB) so that comparisons of MIB to other study variables were possible. MIB was calculated for each patient by multiplying the magnitude of ST-segment change in each lead by the duration in minutes and summing the products for the 12 leads.

When each patient was enrolled in the study, a baseline ECG tracing was obtained with the patient supine with no elevation of the head of the bed. The findings on this tracing were compared with measurements recorded with the patient in 3 other positions: right lateral, left lateral, and supine with the head of the bed elevated 45°. ST-segment changes associated with changes in body position were factored into the baseline data; shifts of 1.0 mm or greater from this baseline were considered potential ischemic events.
Troponin I Levels

Serum levels of cardiac troponin I were measured independently by the laboratories of the respective hospitals. The values for the first 33 patients were determined at St. Mary’s Hospital; those for the next 71 patients, at Decatur Memorial Hospital. Because the equipment differed at each hospital, the normal and abnormal ranges of values differed slightly according to the institution. At St. Mary’s Hospital, the Abbott AxSYM system\(^{17}\) was used. The normal lower limit was reported as less than 0.4 µg/L; values greater than 2.0 µg/L were considered diagnostic of acute myocardial tissue injury. At Decatur Memorial Hospital, the Automated Chemiluminescence System \(^{18}\) was used. For this system, the lower limit of normal was reported as less than 0.15 µg/L; levels of 1.5 µg/L or more were considered indicative of myocardial injury. Some patients had mild elevations that were higher than normal but less than values considered conclusive for injury. All levels reported as less than 0.4 µg/L (St. Mary’s Hospital) or less than 0.15 µg/L (Decatur Memorial Hospital) were entered as zero because exact measurements were not reported when detectable levels were less than these values. All levels greater than these cutoff points were entered into analysis as the actual reported values.

Testing for precision and accuracy of the troponin testing equipment was similar at each institution. Strict manufacturer’s guidelines for quality control were followed, including testing of control samples every 8 hours and daily 6-point calibration of reagent and equipment; during the calibration, duplicate specimens were run for precision and accuracy. During the study period, no violations or omissions of the quality control testing were observed in the respective laboratories.

Procedure

Patients were enrolled in the study as soon after admission to the ICU as possible. For each patient, 12-lead ECG ST-segment telemetry monitoring was conducted simultaneously with bedside ECG monitoring for arrhythmia. Strict skin preparation protocols were used, and an in-unit skin impedance check was done after application of electrodes to ensure proper skin preparation. Each patient had telemetric monitoring for 24 to 48 hours. A blood sample to determine the serum level of cardiac troponin I was obtained 8 to 12 hours after the telemetric monitoring period ended.

All continuous 12-lead ECG tracings were scanned daily, and ST-segment changes were compared with admission baseline tracings for evidence of transient myocardial ischemia. Full 12-lead tracings were printed for evaluation by the study cardiologist, who had no knowledge of data on the patients and was not involved in the care of patients enrolled in the study. The investigative team followed up patients daily for the duration of the patients’ hospitalization to record progress and the development of cardiac events.

Statistical Analysis

Demographic and categorical variables were analyzed by using descriptive statistics. A \(\chi^2\) analysis was used to compare findings between men and women among patients who did or did not experience transient myocardial ischemia or elevations in troponin I. Correlational analysis was used to determine relationships between acuity, age, MIB, troponin I levels, cardiac risk factors, cardiac events, and length of stay. Stepwise multiple regression was used for multivariate analysis. Significance was established at \(P < .05\). Residual analysis revealed acceptable linear trends. All analyses were conducted by using SPSS, version 10.\(^{19}\)

Results

Characteristics of the Sample

A total of 104 eligible patients were enrolled in the study. Of these, 76 had complete ECG data for the 24- to 48-hour monitoring period. The 28 patients who were not included in the analysis were eliminated
for the following reasons: 21 were transferred from the ICU before 24 hours elapsed, 4 died before the first 24-hour period of monitoring, and 3 had missing data for troponin levels.

More than 10% of patients had transient ischemic events, without symptoms, shown most often in lead V5 as ST-segment depression and accompanied by elevated levels of troponin I.

Slightly more than half (53.9%) of the 76 subjects were men. Most of the patients were white and were admitted for a surgical procedure (Table 1). The mean age was 65.5 years (SD = 15.7), and the mean APACHE II score was 14.8 (SD = 6.9). Differences between men and women who had ischemic events ($\chi^2 = 0.26; P = .61$) or elevated troponin levels ($\chi^2 = 0.09, P = .77$) were not significant.

Prevalence of Myocardial Ischemia

A total of 37 transient ischemic events developed in 8 (10.5%) of 76 patients. All but 1 patient experienced episodes of ST-segment depression, and 35 episodes (95%) were clinically silent. Of the 8 patients with ischemia, 6 also had elevated levels of troponin I. In the 37 transient ischemic events, multiple leads were involved in all but 1 patient. The following leads showed significant ST-segment deviation: V5 (n=17), II (n=12), V3 (n=11), V4 (n=9), aVF (n=8), V6 (n=8), and III (n=2). In this group of patients, leads I, aVL, aVR, V1, and V2 were the leads in which no changes in the ST segment were detected. Contiguous leads were involved in 20 transient ischemic events (54%). The most common contiguous lead combinations were leads II and aVF (7 events, 19%), leads V3 through V5 (5 events, 14%), and leads V4 through V6 (4 events, 11%). Table 2 gives the characteristics of patients who had MIB. Patients with measurable MIB had significantly more elevations in troponin I ($P < .001$) and cardiac events ($P < .001$) than did patients without MIB.

Development of Elevated Levels of Troponin I

Serum levels of cardiac troponin I also varied considerably, ranging from nondetectable to 43.3 µg/L, consistent with acute myocardial infarction (Table 3). All confirmed myocardial infarctions (n = 6) were non Q wave, and chest pain occurred in only 1 (17%) of the 6 cases. A total of 12 patients (15.8 %) had elevated serum levels of troponin I of 1.0 µg/L or greater. Of these, 10 had levels of 1.5 µg/L or greater; 7 of the 10

<table>
<thead>
<tr>
<th>Patient</th>
<th>Ischemic events</th>
<th>Cardiac troponin I, serum level, µg/L</th>
<th>ST-segment changes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Mean duration, min</td>
<td>Burden</td>
</tr>
<tr>
<td>Male 69</td>
<td>Open cholecystectomy, bilateral hernia repair, failure to wean</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>Female 86</td>
<td>Small-bowel resection</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Male 70</td>
<td>Hemicolecotomy</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Male 79</td>
<td>Respiratory failure</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Male 72</td>
<td>Pneumonia</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Male 78</td>
<td>Cerebrovascular accident</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Female 71</td>
<td>Respiratory failure</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Female 84</td>
<td>Colon resection</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

More than 10% of patients had transient ischemic events, without symptoms, shown most often in lead V5 as ST-segment depression and accompanied by elevated levels of troponin I.

Table 2 Myocardial ischemic burden in critically ill patients admitted for noncardiac conditions*
had levels greater than 3.0 µg/L. Among the 12 patients with elevations in troponin I, myocardial infarction was undiagnosed by clinicians in 6 before the study findings (all but 1 serum level was <3.5 µg/L).

The troponin I levels from this study were not used to make clinical diagnoses. However, elevations were reported to the appropriate attending physicians and resulted in further diagnostic follow-up and/or alterations in treatment in 3 patients. In 1 patient, non–Q-wave myocardial infarction was diagnosed on the basis of subsequent serum markers and echocardiography. In 2 patients, mild elevations in troponin I prompted the addition of β-blocker therapy to the treatment regimen. On the basis of traditional medical measures, non–Q-wave myocardial infarction was diagnosed in all but 1 of the 7 patients who had substantial elevations in troponin I.

Of the 7 patients with substantial elevations in troponin I, 6 (86%) had cardiac events during hospitalization, for a total of 12 events (mean = 1.7 per patient). Of the remaining 5 with elevations less than 3 µg/L, 2 patients had a total of 5 events, and the other 3 patients had no cardiac events during hospitalization.

**Correlational and Multivariate Analysis**

Significant positive correlations were detected among several variables measured in the study (Table 4). Most significant were the correlations between MIB and cardiac events ($r = 0.58$) and between elevations in cardiac troponin I and cardiac events ($r = 0.36$).

According to the Spearman rank correlation, risk factors were significantly correlated with age ($r = 0.26, P = .22$) and hospital length of stay ($r = 0.23, P = .04$).

Because APACHE II scores, MIB scores, elevations in troponin I, and age all correlated significantly with cardiac events when $P < .10$ was considered an indication of significance, these variables were entered into the multiple regression equation with

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Table 3  Findings in patients with elevated serum levels of cardiac troponin I*

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, years</th>
<th>Reason for admission</th>
<th>APACHE II Score</th>
<th>MIB</th>
<th>Cardiac troponin I, serum level, µg/L</th>
<th>Cardiac events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>79</td>
<td>Acute renal failure</td>
<td>15</td>
<td>None</td>
<td>1.2</td>
<td>None</td>
</tr>
<tr>
<td>Female</td>
<td>68</td>
<td>Colon resection</td>
<td>15</td>
<td>None</td>
<td>1.8</td>
<td>None</td>
</tr>
<tr>
<td>Female</td>
<td>86</td>
<td>Colon resection</td>
<td>15</td>
<td>366</td>
<td>1.3</td>
<td>2 Angina, congestive heart failure</td>
</tr>
<tr>
<td>Male</td>
<td>79</td>
<td>Respiratory failure</td>
<td>27</td>
<td>36</td>
<td>43.3</td>
<td>1 Non–Q-wave myocardial infarction</td>
</tr>
<tr>
<td>Male</td>
<td>72</td>
<td>Pneumonia</td>
<td>12</td>
<td>192</td>
<td>18.2</td>
<td>3 Non–Q-wave myocardial infarction, congestive heart failure, supraventricular tachycardia</td>
</tr>
<tr>
<td>Male</td>
<td>78</td>
<td>Cerebrovascular accident</td>
<td>15</td>
<td>23</td>
<td>8.9</td>
<td>3 Non–Q-wave myocardial infarction, congestive heart failure, death due to cardiac factors</td>
</tr>
<tr>
<td>Female</td>
<td>71</td>
<td>Respiratory depression</td>
<td>20</td>
<td>6</td>
<td>1.5</td>
<td>None</td>
</tr>
<tr>
<td>Male</td>
<td>65</td>
<td>Thoracotomy</td>
<td>10</td>
<td>None</td>
<td>8.1</td>
<td>2 Angina, non–Q-wave myocardial infarction</td>
</tr>
<tr>
<td>Male</td>
<td>84</td>
<td>Respiratory arrest</td>
<td>41</td>
<td>None</td>
<td>9.9</td>
<td>2 Non–Q-wave myocardial infarction, death</td>
</tr>
<tr>
<td>Female</td>
<td>95</td>
<td>Repair of perforated sigmoid colon</td>
<td>13</td>
<td>None</td>
<td>1.5</td>
<td>3 Supraventricular tachycardia, severe hypotension, congestive heart failure</td>
</tr>
<tr>
<td>Female</td>
<td>84</td>
<td>Colon resection</td>
<td>19</td>
<td>179</td>
<td>3.5</td>
<td>2 Non–Q-wave myocardial infarction, congestive heart failure</td>
</tr>
<tr>
<td>Male</td>
<td>72</td>
<td>Pneumonectomy</td>
<td>9</td>
<td>None</td>
<td>3.3</td>
<td>None</td>
</tr>
</tbody>
</table>

*APACHE II indicates Acute Physiology and Chronic Health Evaluation II; MIB, myocardial ischemic burden, calculated by multiplying the magnitude of ST-segment changes in each lead times the duration in minutes and summing the products for the 12 leads.
cardiac events as the dependent variable. MIB accounted for the largest variability (29%), and MIB, elevations in troponin I, and age together accounted for 39% of the variability of cardiac events ($R^2 = 0.387$, $F = 15.17$, $P < .001$). The APACHE II score was the only variable that did not significantly affect the equation. Although risk factors were correlated with age, the effect of risk did not significantly affect cardiac events in univariate or multivariate analysis.

### Discussion

One purpose of this study was to determine whether ischemia and injury developed in the first 24 to 48 hours in the ICU in critically ill patients admitted for noncardiac conditions. We found that transient myocardial ischemia occurred in the first 24 to 48 hours in more than 1 in 10 patients and that more than 15% had evidence of myocardial injury. Similar to the results of other studies, most transient ischemic events were silent and were associated with ST-segment depression, a common finding in demand-related myocardial ischemia.

Demand ischemia is difficult to study because unlike the classic patterns of ST-segment changes in contiguous leads, as found in supply-sided ischemia, demand ischemia patterns are unpredictable. In animal studies, controlled occlusions of selected coronary arteries resulted in continuous ST-segment changes consistent with myocardial injury, whereas demand-induced ischemia resulted in a global, subendocardial ischemia with typical ST-segment depression in non-contiguous leads.

In noncardiac surgical patients, lead V5 is primarily diagnostic of demand-related ischemia. Although lead V5 is excellent for detecting subendocardial ischemia, ST-segment depression in this lead must be interpreted cautiously because such depression can also represent reciprocal change associated with acute myocardial infarction in nearly every major coronary occlusion. In our study, ischemia was most frequently detected in lead V5, but if lead V5 had been the only lead used, only 46% of ischemic events would have been detected. Most patients had changes in multiple leads, a finding that supports current recommendations that patients at risk for myocardial ischemia be monitored by using the full 12-lead ECG ST-segment detection systems.

### Table 4  Correlation among measured variables in critically ill adults with noncardiac conditions (n = 76)*

<table>
<thead>
<tr>
<th>Pearson correlation</th>
<th>Age</th>
<th>APACHE II</th>
<th>Troponin I</th>
<th>MIB</th>
<th>Risk</th>
<th>Cardiac events</th>
<th>LOS, ICU</th>
<th>LOS, hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APACHE II</td>
<td>0.22</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Troponin I</td>
<td>0.17</td>
<td>0.25†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIB</td>
<td>0.22</td>
<td>0.02</td>
<td>0.22</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac events</td>
<td>0.35†</td>
<td>0.20</td>
<td>0.36†</td>
<td>0.58†</td>
<td>0.13</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOS, ICU</td>
<td>-0.20</td>
<td>0.26†</td>
<td>-0.03</td>
<td>-0.07</td>
<td>0.12</td>
<td>-0.08</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>LOS, hospital</td>
<td>0.06</td>
<td>-0.01</td>
<td>-0.16</td>
<td>-0.04</td>
<td>0.16</td>
<td>-0.11</td>
<td>0.51†</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*APACHE II indicates Acute Physiology and Chronic Health Evaluation II; ICU, intensive care unit; LOS, length of stay; MIB, myocardial ischemic burden, calculated by multiplying the magnitude of ST-segment changes in each lead times the duration in minutes and summing the products for the 12 leads.
†$P < .05$
‡$P < .01$

For patients at risk of transient myocardial ischemia, continuous 12-lead monitoring is ideal; if 12-lead monitoring is not available, the combination of lead V5 and an inferior lead is recommended.

In previous studies, such as those in patients undergoing weaning from mechanical ventilation, demand ischemia was also associated with adverse hospital outcomes. Abalos et al. investigated ischemia during weaning in 62 patients who were randomly assigned to 1 of 3 weaning methods. When 2 leads were used for ECG ST-segment monitoring, 19.3% of the patients experienced ischemia during weaning. Hurford et al. used thallium-201 scintigraphy in 15 ICU patients undergoing weaning and reported that 47% experienced ischemia. In a subsequent study, using continuous ECG monitoring, Hurford and Favorito found positive ST-segment changes indicative of ischemia in 6 (35%) of 17 patients receiving mechanical ventilation. Compared with the other 11
patients, the 6 patients with ischemia had more difficulty with weaning, and only 1 of the 6 survived to hospital discharge, a survival rate of 17%. Among the 11 patients who did not have ischemia, the survival rate was 73%.

In our study, 75% of patients with transient myocardial ischemia also had noteworthy elevations in the serum levels of cardiac troponin I. The presence of bundle branch blocks (n = 4) and the potential for intraoperative ischemia (n = 2) may have obscured ECG detection of ischemia in the remaining patients with elevations in troponin I (n = 6) in whom no ST-segment changes were detected. Because the 12-lead ECG monitoring system was brought into the ICU for this study, 12-lead ECG monitoring was not initiated until the patients were admitted to the ICU, and the patients could not be monitored if they left the unit for testing or surgery. Thus, surgical patients possibly sustained myocardial ischemia preoperatively or intraoperatively, a situation that might have caused the elevations in troponin I that were detected later. Cardiac troponin I is a sensitive cardiac marker that remains elevated for up to 5 days, a characteristic that may explain why some patients had elevated levels of troponin I but no myocardial ischemia during the monitoring period. Also, mild elevations of cardiac troponin I in patients admitted for noncardiac conditions may be caused by abnormalities other than acute coronary events, such as sepsis, as recently reported by Kahn et al25 and Spies et al.26 Also, Sharkey et al27 found remarkable reversible left ventricular contraction abnormalities in 22 patients with diagnoses as varied as central nervous system injuries, sepsis, and acute pulmonary abnormalities who had ECG abnormalities such as deep T-wave inversion and QT lengthening. Although our study was not designed to compare sepsis with elevations in cardiac troponin I, a recent study28 indicated a link between elevated serum levels of troponin I and increased mortality in patients with sepsis syndromes.

In our study, all acute myocardial infarctions that occurred during hospitalization were non Q wave, a common finding in studies of noncardiac surgical patients.5,8,15,28 As in other studies of noncardiac surgical patients, myocardial ischemia was also associated with other ischemic events common in postoperative noncardiac surgical patients, including unstable angina, death due to cardiac factors, and complications such as hypotension and ventricular tachycardia. In our study, these findings extended to critically ill patients other than patients admitted for surgical procedures or being weaned from mechanical ventilation.

Increased acuity, as indicated by APACHE II scores, was not predictive of cardiac events. However, post hoc power analysis based on the variability of APACHE II scores in this sample revealed insufficient power to rule out the influence of high acuity on these outcomes. Therefore, further studies are recommended to examine the relationship of acuity to the development of cardiac events.

In critically ill patients, 12-lead ECG monitoring should be available for older patients and for patients with increased coronary risk factors or histories of coronary artery disease. Although continuous 12-lead monitoring is not available in many institutions, bedside monitoring systems currently used include at least 2 leads for ST-segment monitoring. When information at the time of admission does not include which leads show the ST fingerprint indicative of ischemia,22 patients at risk for demand ischemia should be monitored by using multiple leads, preferably the full 12 leads. Our results indicate that if a 12-lead ST-segment monitoring system is unavailable, especially when only a single precordial lead is available for monitoring, lead V5 and an inferior lead should be used for monitoring, even though some ischemic events will not be detected.

Although lead V5 has been used in many postoperative noncardiac patients to monitor changes in the ST segment, the meaning of changes such as ST-segment depression in V5 may be problematic. In a study by Badner et al29 ST depression in lead V5 was associated with subendocardial ischemia and with reciprocal changes in conjunction with occlusions in the left anterior descending artery, the right coronary artery, and even the circumflex coronary artery. However, although changes in the ST segment in leads V5 and III are not diagnostic for subendocardial ischemia, the presence of the changes may indicate a need for a full 12-lead ECG and consultation with the physician directing the patient’s care. Further research in which ECG monitoring is used from admission to discharge is needed to determine the relationship between ischemia and cardiac outcomes. Determination of which leads to use should be guided by patients’ needs and risk for ischemia and/or arrhythmias.

Finally, critically ill patients in our study, who did not have primary cardiac diagnoses, were subject to ischemic events, increasing their risk for morbidity and mortality. Because continuous ECG monitoring of patients is now possible, further studies should be directed toward improved detection of myocardial ischemic events in critically ill patients without primary cardiac diagnoses who, because of their critical illness, experience sustained physiological stress associated with treatment, cardiovascular risk, and advanced age.

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REFERENCES
JOURNAL CLUB ARTICLE DISCUSSION POINTS

In a journal club, research articles are reviewed and critiqued. General and specific questions help to aid journal club participants in probing the quality of the research study, the appropriateness of the study design and methods, the validity of the conclusions, and the implications for practice.

When critically appraising this issue’s AJCC journal club article, Frequency and Outcomes of Transient Myocardial Ischemia in Critically Ill Adults Admitted for Noncardiac Conditions, consider the questions and discussion points listed below.

Study Synopsis: The purpose of this study was to detect myocardial ischemia and injury in critically ill adults admitted for noncardiac conditions and to examine the relationship of myocardial ischemia, injury, and acuity to cardiac events. In a convenience sample of 76 consecutively admitted patients in 2 medical-surgical ICUs, continuous 12-lead ECG ST-segment telemetry monitoring was conducted simultaneously with bedside ECG monitoring for 24 to 48 hours. Serum cardiac troponin I levels were measured 8 to 12 hours after telemetric monitoring, and clinical cardiovascular events during hospitalization were analyzed. Transient myocardial ischemia was defined as a 1-mm (0.1-mV) change in ST level from baseline to event in 1 or more leads lasting 1 or more minutes. A total of 37 transient ischemic events developed in 8 (10.5%) of the patients. Six cases of MI were confirmed, of which only 1 was associated with chest pain. A total of 12 (15.8%) patients had elevated serum troponin levels, 6 of whom had undiagnosed MI before the results were known. The study demonstrated that critically ill adult patients admitted for noncardiac conditions are at risk for developing acute myocardial ischemia.

A. Description of the Study
   • What were the purposes of the study?
   • Why is the detection of myocardial ischemia significant to nursing?

B. Literature Evaluation
   • What are limitations of previous studies examining myocardial ischemia or injury?
   • Evaluate the research cited in the literature review and the argument developed to support the need for this study.

C. Sample
   • What were the inclusion and exclusion criteria?
   • How representative is the sample?

D. Methods and Design
   • Describe the study methods.
   • How were clinical cardiovascular events during hospitalization defined?

E. Results
   • What were the findings of the study?
   • What was the prevalence of myocardial ischemia?
   • What risk factors for myocardial ischemia were found to be significant?

F. Clinical Significance
   • What are implications of the study for clinical nursing?
   • Which patients would most benefit from 12-lead ECG monitoring in the ICU?

Information From the Authors: Lead author Kathy Booker, RN PhD, CCRN, explained that the idea for this study arose from her years of practice as a critical care clinical nurse specialist. “I saw many patients enter the ICU with noncardiac conditions and then develop an MI,” she explained. Booker conducted this study for her doctoral dissertation research. The research team helped with the study. Booker explains, “There was a team member on call 24 hours a day for the duration of the study. We had a standard protocol for skin prep based on AACN data, and all team members had special education and testing for correct precordial lead placement.”

Booker explained that most patients did not mind the additional electrodes, nor did they interfere with sleep. “There were a few patients who felt encumbered by the additional monitoring. Part of the problem from the nursing standpoint arose because we still had to have the 5 leads of the bedside monitor in place as well as our study leads. This made it difficult to give a good bath!” For some patients, Booker believes that their ischemia and injury may not have been detected were it not for their being monitored for the study. According to Booker, “With the exception of those with extensive ischemia and gross elevations of troponin, most ischemia was transient, with episodes lasting only 5 to 15 minutes. Of course, the ECG is not a perfect tool either and some patients had troponin elevations without ST changes.”

Implications for Practice: According to the study’s results, continuous ST-segment monitoring is beneficial for critically ill patients in detecting transient myocardial ischemia that may indicate risk for cardiac events. Booker believes that the study’s results have direct implications for critical care nurses: “I think the study underscores the need for careful ECG monitoring in multiple leads. ST segment analysis remains important.” Booker stressed that increased education for critical care nurses is important to improve their understanding of the potential significance of ECG changes that reflect ischemia. She added, “This is complex, however, because ST changes can occur for many reasons unrelated to ischemia. However, most ischemia in critically ill patients is silent, and nurses need to monitor for parameters other than chest pain that may signal myocardial compromise.” When asked about how AJCC’s readership could best use the information from the study, Booker commented: “I hope readers renew their commitment to ECG monitoring technologies and the application of the data to patients under their own care. For patients with potential demand ischemia, when only 2 leads of ST monitoring are available at the bedside, the use of lead III and V₅ seem warranted. For patients with supply-sided ischemia, leads should reflect the at-risk myocardium (based on admission ECG, interventional ECG, etc.).” Booker emphasized that clinical nursing research has a distinct role in improving nursing care; “I hope readers support bedside research efforts of others. We need to know so much more!”

Journal Club feature commentary is provided by Ruth Kleinpell.
Frequency and Outcomes of Transient Myocardial Ischemia in Critically Ill Adults
Admitted for Noncardiac Conditions
Kathy J. Booker, Karyn Holm, Barbara J. Drew, Dorothy M. Lanuza, Frank D. Hicks, Tim Carrigan, Michelle Wright and John Moran

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