to the improved clinical state observed during the midazolam infusion. However, it was only after adding midazolam that adequate sedation was obtained. In addition, effective sedation was achieved using a midazolam infusion without inhibiting adrenal steroidogenesis or producing cardiorespiratory instability. We conclude that a midazolam infusion may be a useful drug in the management of agitated patients in the ICU setting.

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Changes in T-wave Morphology Following Anesthesia and Surgery: A Common Recovery-room Phenomenon

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Preoperative and postoperative electrocardiograms (ECGs) are commonly obtained in patients at risk for perioperative ischemic events. In our institution, this practice identified a large number of patients with new postoperative T-wave abnormalities in whom there were no other signs or symptoms of myocardial ischemia. Concern that these acute changes represented myocardial ischemia often prompted intensive care unit admission, cardiology consultation and, occasionally, treatment with drugs. These patients, however, uniformly had an uneventful course without cardiovascular complications. This suggested to us that postoperative repolarization abnormalities may not be due to myocardial ischemia and that a less aggressive management approach might be warranted.

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Many laboratory tests (Thallium scanning, CPK isoenzymes) are available to diagnose myocardial ischemia or infarction. However, all have false negatives, and absolute exclusion of ischemia is not possible. We, therefore, employed an epidemiologic approach to determine the correlation between postoperative T-wave abnormalities and documented myocardial ischemia. This was accomplished by comparing preoperative and postoperative ECGs in a large population of general surgical patients, first to define the incidence of new postoperative T-wave abnormalities and then to attempt to correlate them with known markers of coronary artery disease. The records of all patients with new T-wave abnormalities were reviewed to determine if any corroborating evidence of myocardial ischemia had been detected. The basic hypothesis of this study is that if nonischemic repolarization abnormalities occasionally accompany anesthesia and surgery, then they should be seen with equal frequency in all patients, regardless of the presence or absence of coronary disease. In contrast, if postoperative T-wave abnormalities reflect myocardial ischemia, they should occur more frequently in patients with ischemic heart disease.

Methods

Postoperative ECGs (12-lead) were obtained within 1 h of admission to the recovery room on 394 consecutive surgical patients in whom preoperative ECGs were available. Two types of patients were excluded from the study: 1) patients having cardiac surgery were excluded because the heart is mechanically manipulated during these procedures; and 2) patients having neurosurgery were excluded because of the well documented occurrence of ST- and T-wave changes with CNS disorders.[1] In addition to the ECG, the following data were obtained for each patient: age, sex, American Society of Anesthesiologists (ASA) classification,[2] operative procedure, anesthetic technique, and the presence or absence of coronary artery disease. Criteria for diagnosis of preexisting coronary artery disease were: 1) a clinical history of angina pectoris or previous myocardial infarction; 2) clear-cut ECG evidence of prior myocardial infarction; or 3) a prior diagnostic evaluation consistent with myocardial ischemic disease.

Each author independently reviewed all preoperative and postoperative ECGs, and the diagnosis of new T-wave abnormalities required a unanimous review. Rate, rhythm, and QRS axis were recorded, and any changes in ST segments, T-wave morphology, and new conduction abnormalities were noted. T-wave flattening was defined as an isoelectric tracing in leads that previously had an upright T wave, and T-wave inversion was defined as inversion of the T wave in leads that previously had upright or isoelectric T waves. Changes in T-wave morphology that could be related to changes in the QRS axis or to changes in precordial lead placement were not counted as new T-wave changes.

As a first step, we assessed the association of new T-wave abnormalities with coronary artery disease without adjusting for confounding variables. A chi-square analysis was performed to determine if significant differences in the frequency of T-wave abnormalities existed between patients with and without coronary artery disease. Then we assessed whether the presence or absence of postoperative T-wave abnormalities is associated with a diagnosis of coronary artery disease while adjusting for a number of covariates including age, sex, ASA classification, operative site, anesthetic technique, and preoperative and postoperative heart rate. Multiple logistic regression was used for this analysis.[3] Here the probability of a new postoperative T-wave abnormality is expressed as a logistic function of the independent variables. The regression coefficient for a given covariate estimates the log-of-the-odds ratio of having an abnormality given the observed covariate value relative to the value zero. For example, the coefficient for coronary artery disease indicates the log-of-the-odds ratio of a new T-wave abnormality for patients with and without a history of coronary artery disease.

The charts of all patients with new postoperative ECG changes were reviewed for evidence of myocardial ischemic events in the postoperative period. Criteria used to diagnose postoperative ischemia were: 1) anginal type chest pain; 2) enzyme or ECG changes diagnostic for myocardial infarction; 3) sudden death; 4) congestive heart failure; or 5) new malignant ventricular arrhythmias. Except in instances where the primary physician requested an ECG, postoperative ECGs were not reviewed until the study was completed.

Results

The overall incidence of new ECG abnormalities was 19% (73 of 394 patients). One patient had new ST segment changes, one patient had a new bundle branch block, and the remaining 71 patients had new T-wave abnormalities. Of these 71 patients, 46 had new T-wave flattening, and 25 had new T-wave inversion. T-wave abnormalities were present in the inferior leads in 35, in the anterior leads in 26, and in the lateral leads in 30 patients (includes 18 patients with changes in multiple locations). A representative example is shown in figure 1.

Forty of 394 patients had preexisting coronary artery disease, and the incidence of new T-wave abnormalities in these patients was nine of 40, or 23%. This incidence was no different from that of patients without preexisting coronary artery disease, which was 63 of 354 or 18% ($P < 0.5$). Power analysis indicates that the sample was of sufficient size to detect a relative risk for new T-wave abnormalities in patients with coronary artery disease of

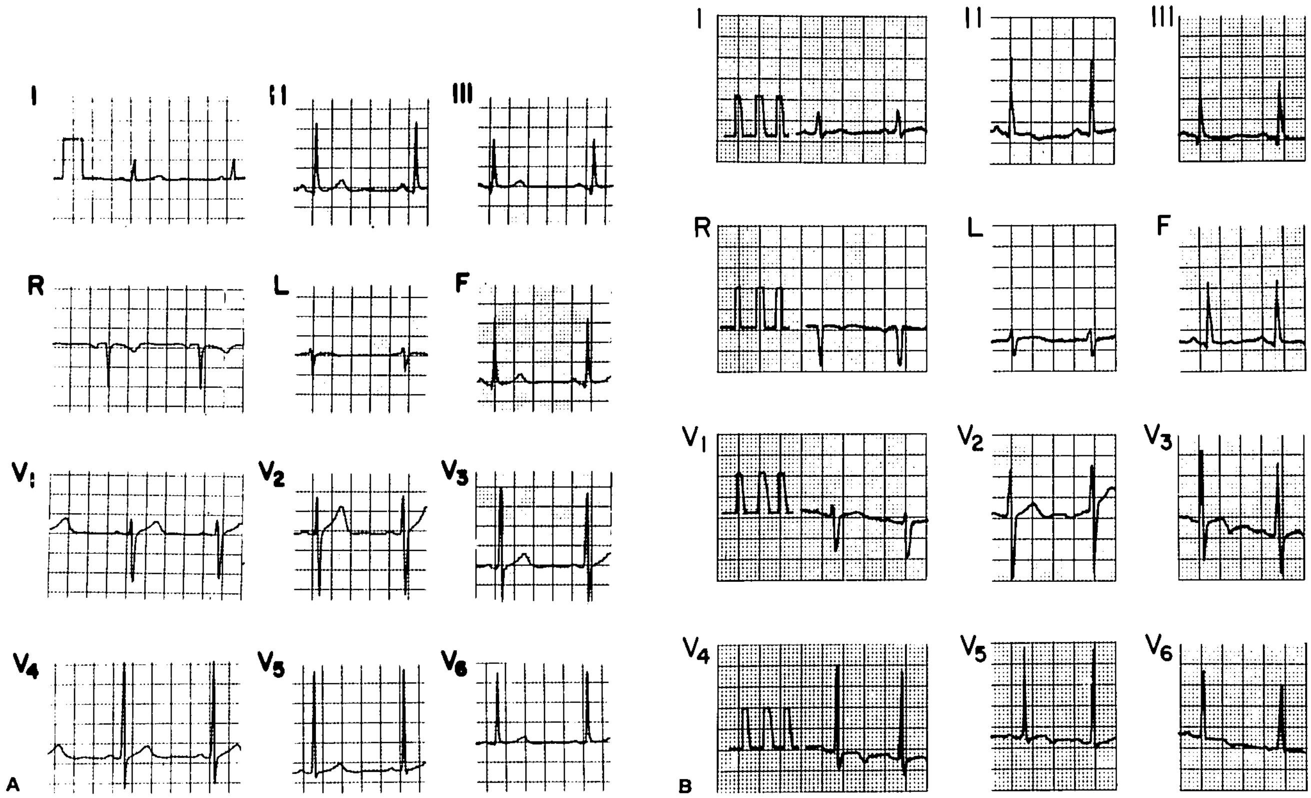

FIG. 1. Preoperative (*A, left*) and postoperative (*B, right*) ECGs of a 31-yr-old man, ASA 1, who underwent parotid gland resection under morphine–N_2O–ethrane anesthesia. Note flattened T waves in the inferior leads and inverted or biphasic T waves in the antero-lateral leads on the postoperative ECG.

2:1 with a probability ≥ 0.8. When multiple logistic regression was used to correct for possible interaction effects of the other variables, coronary artery disease was not identified as a risk factor for the development of new T-wave abnormalities (table 1). Similarly, the risk of developing new T-wave abnormalities did not correlate with either increasing age, sex, ASA classification, anesthetic technique or preoperative and postoperative heart rate (table 1). Patients undergoing intraabdominal procedures, however, developed postoperative T-wave changes more frequently than did any other population group tested (table 2), and logistic regression analysis correlated intraabdominal procedures with postoperative repolarizations abnormalities ($P = 0.06$; table 1). The actual incidence of new T-wave abnormalities in all population groups is shown in table 2.

TABLE 1. Multiple Logistic Regression Analysis—Correlation of Population Variables with Risk of T-wave Abnormalities

Variables	Log-Odds Ratio	Standard Error	*P*
Intercept	−0.5871	0.8836	0.51
Age	0.0005	0.0087	0.95
Sex	−0.1705	0.2721	0.53
CAD	0.5455	0.4702	0.25
ASA	−0.2550	0.2414	0.29
ANES 1	0.5169	0.5498	0.35
ANES 2	−0.4784	0.4738	0.31
SITE 1	−0.8320	0.8009	0.30
SITE 2	0.5721	0.3079	0.06
PREHR	−0.0109	0.0106	0.30
POSTHR	0.0045	0.0089	0.61

CAD = coronry artery disease; ASA = American Society Anesthesiologist Classification; ANES 1 = general *versus* regional; ANES 2 = inhalation *versus* balanced; SITE 1 = abdominal *versus* thoracic; SITE 2 = peripheral *versus* abdominal; PREHR and POSTHR = preoperative and postoperative heart rate.

Follow-up of the 71 patients with new T-wave abnormalities showed that one male patient (age 42 yr) developed transient pulmonary edema following resection of a pheochromocytoma. This patient probably received excessive iv fluids intraoperatively (5500 ml of crystalloid, and 1000 ml of colloid), had a central venous pressure of 21 mmHg, and rapidly improved after a furosemide-induced diuresis (3000 ml of urine output). The remaining 70 patients with postoperative repolarization abnormalities had no episodes of suspected myocardial ischemia during the postoperative period.

DISCUSSION

Postoperative ECGs are routinely obtained in high-risk patients to diagnose ischemia in a setting where residual anesthesia, narcotic analgesics, and surgical pain can mask the usual symptoms of myocardial ischemia.[4] Management of suspected perioperative myocardial ischemic events varies from institution to institution, but continuous ECG monitoring in a critical care facility is required. In addition, cardiology consultation frequently follows, and treatment with iv nitroglycerine or other vasoactive drugs may be indicated. In view of the high morbidity and mortality associated with perioperative ischemic events,[5] such interventions are justified in patients with myocardial ischemia. The limited availability and high cost of critical care facilities as well as the potential morbidity associated with the use of vasoactive drugs, however, require that the specificity of the postoperative ECG as a diagnostic test for postoperative ischemic events be critically examined. Our epidemiologic data suggest that new postoperative T-wave abnormalities are not specific for myocardial ischemia and that the use of limited and expensive resources or initiation of potentially dangerous therapy, without other supporting evidence of ischemia, may not be indicated.

The epidemiologic approach employed in our study provides indirect evidence that new postoperative T-wave changes are not due to myocardial ischemia. The incidence of coronary artery disease in the general population is higher in both older patients and in patients symptomatic with angina pectoris or previous myocardial infarction. Because new T-wave abnormalities occurred with equal frequency in our patients regardless of age or the presence or absence of coronary artery disease, it is unlikely that myocardial ischemia is responsible for these repolarization abnormalities. The fact that patients with new T-wave abnormalities did not develop signs and symptoms usually associated with myocardial ischemia provides further support for this conclusion. Without a means to absolutely establish the presence or absence of myocardial ischemia, we have no choice but to use indirect evidence in an attempt to gain insight into this common recovery-room phenomenon.

Nonischemic changes in T-wave morphology have been described with stress,[6] carbohydrate ingestion,[7] hyperventilation,[8] catecholamine infusion,[9] atropine administration,‡ and in the presence of gallbladder[10] and pancreatic disease.[11] Autonomic nervous system imbalance has been proposed as the underlying mechanism for these repolarization abnormalities,[12] and similar changes have been observed after vagotomy[13] and stellate ganglion blockade.[14] Nonischemic changes in T-wave morphology have not been previously described in the postoperative patient. Anesthesia and surgery are, however, stressful

‡ Hiss RG, Smith GB, Lamb LE: Pitfalls in interpreting electrocardiographic changes occurring while monitoring stress procedures. Aerospace Medicine 31:9–18, 1960.

TABLE 2. Population Analysis of New Postoperative T-wave Abnormalities

Population Variables		Number in Group	Per Cent Frequency of T-wave abnormalities
Age	≤35	95	19
	36–45	59	20
	46–55	59	14
	56–65	84	19
	>65	97	18
ASA Classification	I	90	21
	II	223	16
	III	73	19
	IV	8	13
Sex	M	229	17
	F	165	20
Operative site	Abdominal	93	25
	Thoracic	17	18
	Peripheral	284	16
Anesthetic technique	Regional	77	17
	General	317	19
	Inhalation	269	20
	Balanced	48	13

events, and disturbances similar to those listed previously are common in the postoperative period. Pain and tissue injury result in elevated levels of catecholamines,[15] cortisol,[16] and antidiuretic hormone,[17] and produce alterations in respiratory rate and minute ventilation.[18] Changes in serum electrolyte composition and body temperature and anticholinergic drug administration are common perioperative events that may also contribute to postoperative repolarization abnormalities. It is interesting to speculate whether the known association of T-wave abnormalities with intraabdominal pathology[10,11] may explain the higher incidence of postoperative T-wave changes in patients undergoing intraabdominal procedures.

Our data indicate that new T-wave abnormalities occur frequently in postoperative patients. These changes occur with equal frequency in all age groups and do not demonstrate any specific statistical correlation with preexisting coronary artery disease. Furthermore, follow-up of patients with new T-wave abnormalities did not reveal corroborating evidence of ischemic events or myocardial injury. T-wave abnormalities normalized in some patients within 4–6 h and persisted for 24–48 h postoperatively in other patients in whom serial ECGs were available. While the etiology of these repolarization changes remains speculative, we feel that myocardial ischemia may not be the cause of many postoperative T-wave abnormalities and that aggressive intervention may not be warranted in otherwise asymptomatic patients. The authors emphasize, however, that patients at risk for perioperative ischemic events require appropriate monitoring and control of heart rate and arterial blood pressure, regardless of the presence or absence of new T-wave abnormalities. Furthermore, the presence of: 1) new ST segment changes with or without symptoms; or 2) new T-wave abnormalities in association with chest pain, impaired ventricular function, or ventricular arrhythmias should be presumed secondary to ischemia unless alternative etiologies can be established.

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Anesthesia for Infants during Radiotherapy: An Insufflation Technique

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Radiation therapy is the primary treatment for retinoblastoma, a congenital malignancy usually diagnosed and treated during the first 3 yr of life.[1] The therapy is administered over a 4- to 6-week period and divided into 16 to 24 doses determined by the age of the patient and size of the tumor. Since these patients are so young, repeated doses of heavy sedation or general anesthesia are required to ensure absolute immobility during irradiation. Providing anesthesia that is effective, yet allows infants and children to grow and develop normally over such a prolonged period of therapy, can be challenging.

In 1963, Harrison and Bennet[2] introduced an insufflation technique using a Waters' oropharyngeal airway with a sidearm to administer halothane, nitrous oxide, and oxygen to infants undergoing radiotherapy. They reported no complications and rapid recovery for six infants over a course of 100 radiotherapy sessions. Infants regained consciousness within 5 min and resumed feeding within 1 h. In 1969, Browne *et al.* introduced a slightly different insufflation technique, a T-piece circuit attached to an orotracheal airway.[3] They reported no complications over a course of 50 treatments.

Recently, im ketamine has been used to sedate infants

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