Perioperative Holter Monitoring and Computer Analysis of Dysrhythmias in Cardiac Surgery

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In order to increase the accuracy and efficiency of studying perioperative dysrhythmias, 52 patients undergoing cardiac surgery were fitted preoperatively with a Holter monitor adapted for intraoperative recording, and the preoperative, intraoperative and early postoperative cardiac electrical activities were classified with a digital computer. Forty patients underwent coronary artery bypass grafting (CABG), eight had valve replacements, and four had combined procedures. The results showed the following: (1) high incidence of various dysrhythmias occurring during anesthesia induction and thoracotomy prior to aortic cross-clamp; (2) high incidence of continued atrial activity during cardioplegia; (3) lack of correlation between peak serum CPK-MB levels and dysrhythmias; and (4) a higher overall incidence of dysrhythmias in valve patients. Adapting the Holter monitor technique for cardiac surgery can solve the problem of observer vigilance inherent to such a study using a human "monitor watcher," and facilitate the accurate analysis of the vast amount of data obtained. This is important in quantitating the electrophysiologic effects of various perioperative interventions, such as the anesthetic agents, beta-blockers, calcium antagonists, and cardioplegic solutions.

Reliable and unbiased monitoring and analysis of cardiac dysrhythmias in perioperative cardiac surgery patients are important in evaluating the effects of various interventions, including anesthetic agents, beta-blockers, calcium antagonists, and different types of cardioplegic solutions. Although several investigators attempted to study the morbidity associated with such dysrhythmias, the quality of data often suffers from the inherent limitations of observer vigilance, and the logistic difficulty in evaluating and statistically analyzing the vast number of electrical complexes. Although the Holter monitor had been used to study dysrhythmias in the postoperative period, it has not been adapted for use in the intraoperative phase. In this study, we devised a Holter electrode system for continuous recording of ECG throughout the operative procedure, and a digital computer as a highly efficient classifier of electrical events. These electrical tracings were synchronized to the operative procedures by the recorder's clock channel which marked the perioperative stages, starting before the induction of anesthesia and lasting until the postoperative period. This allowed us both to precisely quantify the dysrhythmias and correlate them to the various critical phases of the cardiac surgery.

METHODS

Fifty-two patients including 40 coronary artery bypass grafts (CABG), eight valve replacements, and four combined revascularization and valvular operations were studied. All patients received premedication with morphine (0.1 mg/kg) and hyoscine 0.4 mg intramuscularly. Propranolol was continued by mouth if previously prescribed. During this light sedation, intravenous, arterial and Swan-Ganz lines were placed. Anesthesia was induced with an infusion of fentanyl (50 to 100 mg/kg), diazepam (15 to 30 mg), and pancuronium (10 mg). Lidocaine (Xylocaine) (1.5 mg/kg) was given intravenously prior to rapid intubation to minimize cardiovascular irritability during this procedure, and the patients were ventilated with a 50 percent mixture of N₂O and O₂.

The operation was performed using a midline sternotomy, cardio-pulmonary bypass with a Shiley bubble oxygenator, and systemic hypothermia (28 to 30°C) was instituted. The heart was arrested with an injection of 4°C crystalloid hyperkalemic (20 mEq KCl/L) cardioplegic solution. Further infusions of 4°C Iyonisol (7 mEq KCl/L) were made into each graft as soon as the distal anastomoses were performed.

An electrode system was developed which allows the simultaneous recording of two ECG channels from patients undergoing cardiac surgery. The Holter monitor is applied to the patient prior to premedication, invasive monitoring (Swan-Ganz catheter, arterial line, etc.), and anesthetic intervention, and is transported with the patient to and from the operating theater. There are four sensing electrodes which are attached to the patient with two in the left midaxillary line, one in the right midaxillary line, the last electrode in the right scapular region. The cardiac operations were carried out routinely with the patients in the supine position, and employed a sternal splitting incision. The sensing electrodes are therefore out of the operative field and yet the tracings obtained are of good quality. The Holter monitor recorded the two ECG signals and also recorded a clock channel so that events could be noted and the ECG rhythms correlated exactly with the various operative periods. For the purpose of this study, these three periods are: (1) one hour preoperatively (preop) and during "induction," intubation, and sternotomy, up to aortic cross-clamp (AXC). This is followed by a period of ventricular electromechanical arrest during cardioplegia; (2) "reperfusion" and rewarming period, and (3) from discontinuation of cardiopulmonary bypass (CPB), to the first 12 to 16 hours of
In the perioperative period, dysrhythmias are significant. The incidence of serious dysrhythmias is related to surgical procedures: (I) preaortic cross-clamp period, (II) myocardial reperfusion to end of cardiopulmonary bypass, and (III) early postoperative periods. CABG is coronary artery bypass graft, and valve, valve replacement.
postcardiopulmonary bypass periods.

RESULTS

Incidence

In general, when all dysrhythmias are considered together, the patients with valve replacements had the highest incidence of dysrhythmias (75 percent). Patients with combined procedures were consistently the most unstable (Fig 2).

Temporal Occurrence of Dysrhythmias

Anesthesia Induction Phase (I): SVT occurred in 50 percent of the valve patients during this phase. The PVCs were fairly common to all groups, whereas ventricular tachycardia (VT) and ventricular fibrillation (VF) occurred only in patients undergoing valve replacements (Fig 3A).

Reperfusion Phase (II): This period was remarkably stable except for the ventricular ectopy found in all groups. Ten of 54 patients required defibrillation (Fig 3B).

Postoperative Period (III): This period again demonstrates there was minimal atrial dysrhythmia in the CABG group, whereas SVT is quite common in the valve groups. The ventricular ectopy incidence is the same.

Dysrhythmia and Type of Operation

The CABG patients demonstrated a steady incidence of PVCs both during induction and postoperatively. The incidence of SVT, VT, and VF, while not as common, was relatively constant (Fig 3C).

The valve patients were remarkable for the high incidence of both ventricular and atrial dysrhythmia both preoperatively and postoperatively (Fig 3D). The combined CABG and valve patients showed minimal atrial dysrhythmia prior to AXC with marked ventricular ectopy and the reversal of this pattern postoperatively.

![THE COMPARATIVE INCIDENCE OF DYSRHYTHMIAS IN DIFFERENT PATIENT GROUPS DURING THE INDUCTION PERIOD (I)](image1)

![THE COMPARATIVE INCIDENCE OF DYSRHYTHMIAS IN DIFFERENT PATIENT GROUPS DURING THE REPERFUSION PERIOD (II)](image2)

![TYPE AND INCIDENCE OF DYSRHYTHMIAS IN CABG PATIENTS (I)](image3)

![TYPE AND INCIDENCE OF DYSRHYTHMIAS IN VALVE PATIENTS (II)](image4)

**Figure 3A. upper left: B, lower left: C, upper right: D, lower right. SVT: Supraventricular tachycardia; PVC L 3-5: Premature ventricular contractions, Lown grade 3-5; V Tach (VT): Ventricular tachycardia; V Fib (VF): Ventricular fibrillation; I-III: Peri-op periods as described above in Figure 2.**
Table 1—Atrial Activity during Cardioplegia

<table>
<thead>
<tr>
<th>Atrial Activity</th>
<th>Defib*</th>
<th>Time to Recovery (Min)</th>
<th>With SVT</th>
<th>Without SVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (n = 23)</td>
<td>6</td>
<td>10.9 ± 1.9†</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>No (n = 31)</td>
<td>4</td>
<td>12.9 ± 1.6†</td>
<td>5</td>
<td>26</td>
</tr>
</tbody>
</table>

*Defib is number of patients requiring electrical defibrillation after reperfusion; time to recovery, time (minutes) between the release of aortic cross-clamp to restoration of stable rhythms, and with and without SVT, number of patients with or without postoperative supraventricular tachycardia.

†p < 0.02

Atrial Activity during Cardioplegia

Atrial activity during cardioplectic arrest occurred in 42 percent of our patients. Its presence, however, was not associated with a higher incidence of postoperative SVT (chi-square test, p > 0.05). The elapsed time to stable rhythm after removal of aortic cross-clamp was 10.4 ± 7.6 minutes when atrial activity was present and 12.85 ± 8.5 minutes when the atria were electromechanically silent (p < 0.02) (Table 1).

Dysrhythmia and Myocardial Damage

Reperfusion Period (2): There was no statistical difference in peak serum CPK-MB observed, regardless of the presence or absence of dysrhythmia during the reperfusion period (Fig 4).

Postoperative Period (3): There was also no significant correlation between the peak serum CPK-MB and patients with or without dysrhythmia during the postoperative period.

Discussion

Earlier studies on the electrical stability of the myocardium during cardiac surgery, and the attempts to minimize dysrhythmias by altering myocardial protection or preoperative and postoperative medication, often suffer from a lack of accurate quantitation. The continuous nature of cardiac activity demands continual observation. Standard ECG monitors are limited by observer vigilance. The wide range of reported dysrhythmias associated with cardiac surgery is derived in part from differences in observation techniques.

The Holter monitor, which has been used in nonoperative as well as preoperative and postoperative cardiac patients, has not been used to study patients during the operative procedure. This study shows that by interfacing a Holter monitor with a computer, one can evaluate every beat. A large quantity of accurate information on cardiac electrical activity throughout the operative intervention is obtained. Although all the electrical complexes can be recalled for visual morphologic interpretation, with continuing improvement and sophistication of the computer software, it has been rendered progressively less labor-intensive.

The literature indicates a wide variation in the incidence and type of dysrhythmia associated with cardiac surgery. In valve replacement patients, the reported incidence of postoperative supraventricular tachycardia varies from 4 percent to 74 percent, while in CABG patients, it ranges from 10 percent to 64 percent. The higher incidence of SVT we observed postoperatively in patients with valve replacement and combined CABG-valve surgery than those reported by Ivey et al and others (ranging from 15 percent to 40 percent) is at least in part due to the higher level of observer vigilance made possible by the

CORRELATION OF CPK-MB AND THE INCIDENCE OF DYSRHYTHMIAS DURING THE REPERFUSION PERIOD (II)

![Graph showing correlation of CPK-MB and incidence of dysrhythmias during reperfusion period](null)

Figure 4. There is no correlation between the incidence of dysrhythmias in the reperfusion period (II) and the peak serum CPK-MB levels in the early postoperative period.
Holter monitor. Likewise, the incidence of PVCs preoperatively and postoperatively reported by deSoyza et al as 14 percent and 16 percent, respectively, is higher in our series.

One of the interesting findings of this study is the high degree of electrical instability during the preaortic cross-clamp period, while the patients were undergoing placement of Swan-Ganz and arterial lines, anesthesia induction, sternotomy, and cannulations. In CABG patients, the incidence of PVCs Lown grade 3 to 5 in the two-hour "induction phase" was 35 percent compared to only 20 percent in 16 hours of intensive care unit course. In the valve replacement patients, SVT was noted in 50 percent of patients during the induction phase and only 37 percent during the intensive care unit (ICU) period. Although part of these dysrhythmias may be caused by mechanical handling of the heart following sternotomy, the high incidence of serious dysrhythmia prior to the institution of cardiopulmonary bypass is potentially hazardous. Although many patients undergoing CABG received beta-blockers and calcium antagonists in the preoperative period, the anxiety of the patients and the high level of circulating catecholamines before and after anesthetic induction may be the important factors, and may require the careful attention by both the anesthetist and the surgeon.

As previously reported, there is a high incidence of continued atrial activity during aortic cross-clamp and cardioplegia. However, we failed to confirm in our series the earlier observation that persistent atrial activity was associated with a higher incidence of postoperative SVT. In fact, patients with persistent atrial activity during cardioplegia had an earlier return to stable rhythm following reperfusion.

The hypothesis that the incidence of dysrhythmia during reperfusion and the early postoperative period may be related to the degree of myocardial damage was also examined. The correlation between such dysrhythmias with the peak level of CPK-MB obtained in the early postoperative period was poor. This observation does not by itself exclude the possible role of myocardial damage on cardiac arrhythmias, but rather indicates that many other metabolic factors could affect the electrical stability of the myocardium in this clinical setting. The data presented in this report, relating the type and frequency of dysrhythmias to various operative procedures and periods, reflect the current practice in cardiac surgery as described above. They may be compared in the future with those obtained following the new modifications of cardioplegic, surgical, and anesthetic techniques, as well as the preoperative and postoperative medications.

In conclusion, it appears that with the increasing sophistication of computer technology, the advantages of using a monitoring system which counts and classifies every beat of the heart is obvious. It can be used in the perioperative period in cardiac surgery. This study shows that it can be adapted for intraoperative monitoring, without interfering, or being interfered with by the surgical procedures. Studies which purport to compare the effects of antidysrhythmic medications, anesthetic, or cardioplegic techniques aimed at decreasing perioperative arrhythmias should be able to employ this technology, quantitate the data, and make accurate comparisons possible.

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