Anesthesiology
51:393–397, 1979

Myocardial Ischemia during Non-cardiac Surgical Procedures in Patients with Coronary-artery Disease

W. Lawrence Roy, M.D., Gerald Edelist, M.D., F.R.C.P.(C),† Brian Gilbert, M.D., F.R.C.P.(C)‡*

The purpose of this study was to determine the incidence of ST-segment depression during anesthesia and operation. Graded exercise testing has demonstrated a high correlation between ST-segment depression and myocardial ischemia. Therefore, 11 patients without and 29 patients with known coronary-artery disease were monitored during surgical procedures with a commercially available exercise electrocardiographic monitor (Viagraph). Comparisons were made between this device, which monitored lead V_5, and the standard operating room monitor, which monitored lead 11. Eleven of 29 patients in the disease group demonstrated significant ST depression. Nine of the 11 ischemic episodes were not recognized on the standard operating room monitor. Retrospective review of anesthetic records of those 11 patients with ST-segment depression revealed rate–pressure product values greater than 11,000 for ten of them. Postoperatively, three of the 11 patients with significant ST-segment depression had changing electrocardiograms compatible with ischemia. None of the control group demonstrated significant ST-segment depression. The incidence of ischemia was 38 per cent during anesthesia and operation in the coronary-artery-disease group. Lead V_5 analysis is superior to lead 11 analysis in detecting ST-segment depression. The period in which intubation is performed is one of the highest-risk intervals during anesthesia and operation, particularly when it is associated with an increased rate–pressure product. (Key words: Heart: electrocardiography; ischemia. Monitoring: electrocardiography.)

PATIENTS who have ischemic cardiac disease often need surgical procedures for conditions unrelated to their coronary-artery disease. At present, there is controversy regarding the anesthetic management of these patients.[1] To determine whether therapeutic intervention influences the outcomes of patients with ischemic heart disease, it seemed useful to have some idea of the prevalence of ischemic episodes during non-coronary-artery operations. This has been difficult to document, as the best indicator of ischemia, chest pain, is absent during the anesthetic interval. The relatively large experience with exercise testing in patients with ischemic heart disease has indicated that there is a correlation between myocardial ischemia as evidenced by chest pain and ST-segment depression in the exercise electrocardiogram; however, this method is complicated occasionally by false-positive and false-negative results. Since anesthesia and operation create stressful situations similar in many ways to that resulting from exercise, we used the technology of exercise testing adapted to the operating room to document the incidence of myocardial ischemia in a group of patients with ischemic cardiac disease while they were undergoing non-cardiac operations.

Materials and Methods

Twenty-nine patients with the diagnosis of ischemic cardiac disease established on the basis of a clear history of effort-related angina pectoris, myocardial infarction, or electrocardiographic (ECG) evidence of ischemic cardiac disease were selected for study. Patients with left-bundle-branch block, other conduction defects that tend to obscure or produce difficulty in the interpretation of ST-segment depression, or left ventricular hypertrophy with strain pattern were excluded. There was no restriction in this group as to age, sex, or type of operation contemplated (table 1). There was no attempt to exclude patients receiving propranolol or those who had previously had aorto-coronary bypass procedures. We intended to make this group one that reflected the patient population with ischemic cardiac disease as we usually observe it in daily practice. Another group of 11 patients with no evidence of ischemic cardiac disease was chosen to determine the incidence of false-positive ST-segment depression. These patients were young and were free of symptoms, signs or ECG changes of ischemic heart disease. The choices of premedication and anesthetic technique were left entirely in the hands of the clinician managing each patient's anesthesia (table 1). The anesthesiologist, who was not one of the authors, was advised to conduct anesthesia in the usual fashion. When a significant ischemic period was detected by us, it was recorded and the clinician was informed of its occurrence. The anesthesiologist in charge was free to act on this information as he or she saw fit. He was asked to record carefully the blood pressure and pulse rate during this period, for future retrospective review of the patient's anesthetic record.

After premedication and before induction of anesthesia, ten electrodes were appropriately placed

* Resident.

† Professor of Anaesthesia.

‡ Director of Non-Invasive Cardiology Unit.

Received from the Department of Anaesthesia, Mt. Sinai Hospital, and University of Toronto, Toronto, Ontario M5G 1X5, Canada. Accepted for publication March 13, 1979. Presented at the Annual Meeting of the American Society of Anesthesiologists, New Orleans, Louisiana, October 1977.

Address reprint requests to Dr. Edelist.

0003-3022/79/1100/0393 $00.75

in order to monitor a 12-lead ECG. The limb leads were placed over the clavicles and lower ribs bilaterally, while the chest leads were positioned as usual. Blood pressure was monitored by sphygmomanometer unless direct arterial pressure monitoring was indicated. We employed a Viagraph® exercise testing system from Philips Electonics. Prior to induction and again upon recovery, we recorded a 12-lead electrocardiogram. During induction, we continuously recorded, on paper, leads V_4, V_5, and V_6. During the remainder of the procedure, the exercise leads II, AVF, V_3, V_4, V_5, V_6 were recorded every 3 min. In addition to the direct writer, a continuous oscilloscopic display of V_5 on our apparatus and lead II on a standard monitor were available. A digital read-out of heart rate and the magnitude of ST-segment depression, as well as an averaged picture of the last 16 QRST complexes in lead V_5, aided in analysis of the patient's condition. Since noise occurs at random and the ECG complex occurs at periodic intervals, noise reduction is accomplished through the averaging process in proportion to the square root of the number of complexes averaged, which in this case is four. During interference from electrosurgical units, the averager retains the current 16-beat running average but will refuse to accept data for processing. The written record is not affected by electrosurgical units. Thus, we were able to continue monitoring during periods when cautery was being used. At the completion of each 20-min ST-segment analysis, a histogram that averaged the amount of ST-segment displacement over 1-min intervals was available. This was compared with two other histograms, one that averaged heart rate, the other an averaged ST integral. The processor within the instrument computes ST-segment displacement and integral from the averaged

TABLE 1. Patients' Ages and Anesthetic Induction and Maintenance Drugs Used for Patients with Ischemic Heart Disease

	Age (Years)	Operative Procedure	Induction Drugs	Maintenance Drugs†
Patient 1	68	Direct laryngoscopy	Thiopental, succinylcholine	Fentanyl, *d*-tubocurarine
Patient 2	64	Lumbar discotomy	Thiopental, pancuronium	Morphine, halothane, pancuronium
Patient 3	67	Sigmoidoscopy	Thiopental, succinylcholine	Fentanyl, succinylcholine
Patient 4	63	Dental extraction	*d*-Tubocurarine, thiopental, succinylcholine	Enflurane
Patient 5	41	Inguinal hernia repair	*d*-Tubocurarine, thiopental, succinylcholine	Morphine, pancuronium
Patient 6	70	Esophagoscopy	*d*-Tubocurarine, thiopental, succinylcholine	Fentanyl, pancuronium
Patient 7	52	Hemorrhoidectomy	Epidural—2 per cent lidocaine	
Patient 8*	54	Bilateral inguinal hernia repair	Thiopental, halothane, pancuronium	Halothane, pancuronium
Patient 9*	55	Cholecystojejunostomy	Thiopental, pancuronium	Morphine, pancuronium
Patient 10	63	Vaginal biopsy	Nitrous oxide, enflurane	Enflurane
Patient 11*	64	Anterior-colonic resection	Thiopental, morphine, pancuronium	Morphine, pancuronium
Patient 12*	68	Inguinal hernia repair	Thiopental, pancuronium	Enflurane, pancuronium
Patient 13	45	Cholecystectomy	Gallamine, thiopental, succinylcholine	Fentanyl, pancuronium
Patient 14*	59	Anterior-colonic resection	Thiopental, morphine, pancuronium	Morphine, pancuronium
Patient 15*	53	Transurethral resection bladder tumor	Thiopental	Enflurane
Patient 16	57	Dental extraction	Thiopental, succinylcholine	Morphine, *d*-tubocurarine
Patient 17	59	Dental extraction	*d*-Tubocurarine, thiopental, succinylcholine	Halothane
Patient 18*	68	Scleral buckling	Morphine, thiopental, succinylcholine	Halothane, pancuronium
Patient 19	64	Inguinal hernia repair	Epidural—2 per cent mepivacaine	
Patient 20	66	Ventral hernia repair	Epidural—2 per cent lidocaine	
Patient 21	43	Cholecystectomy	Thiopental, *d*-tubocurarine, succinylcholine	Fentanyl, pancuronium
Patient 22	74	Transurethral resection bladder tumor	Spinal—tetracaine	
Patient 23	63	Aorto-femoral bypass graft	Thiopental, morphine, pancuronium	Morphine, pancuronium
Patient 24*	50	Aorto-femoral bypass graft	Thiopental, morphine, pancuronium	Halothane, morphine, pancuronium
Patient 25	60	Biopsy palate	Thiopental, succinylcholine	Halothane
Patient 26	44	Femoral-popliteal bypass graft	Thiopental, *d*-tubocurarine, succinylcholine	Halothane, *d*-tubocurarine
Patient 27	64	Excision ovarian tumor	Thiopental, *d*-tubocurarine, halothane, succinylcholine	Halothane, *d*-tubocurarine
Patient 28	74	Vaginal hysterectomy	Epidural—mepivacaine, 2 per cent	
Patient 29*	67	Bilateral femoral-popliteal grafts	Thiopental, morphine, pancuronium	Morphine, pancuronium

* Patients in whom ST-segment depression developed.

† All patients given general anesthesia received nitrous oxide, 50–70 per cent.

ECG complexes. These values are measured from a reference point in the isoelectric P-R interval, which is taken 60 msec preceding the maximum point on the R-wave. ST-segment displacement is measured 80 msec following the maximum R-wave. The ST integral is the area bounded by: 1) a horizontal line drawn through the isoelectric point in the P-R interval; 2) a vertical line drawn through a point that occurs 140 msec after the maximum R-wave; 3) a vertical line drawn through a point that occurs 60 msec after the maximum R-wave; 4) the ST segment between 60 and 140 msec following the maximum R-wave. When the digital display showed ST-segment depression greater than 1 mm, a direct write-out was procured for further analysis and documentation. An ischemic episode was said to occur when ST-segment depression greater than 1 mm that was horizontal or downsloping for 80 msec beyond the R-wave was present for more than three beats.[2] Also, when the ST integral was greater than 7.5 microvolts/sec, ischemia was considered to be present, although this did not occur in isolation during this study. All of the recorded material was reviewed by one of us (B.G.) who was well versed in exercise-testing techniques and interpretation of ST-segment depression. In the cases of patients in whom ischemia developed during operation, serial ECG and enzyme determinations were made each day for three days postoperatively. Also, because of a high incidence of increased blood pressure and heart rate at the time of the ischemic changes, the patients' charts were reviewed retrospectively to determine the rate–pressure product during those events.

The difference in incidences of ST-segment depression between the patients with and without cardiac disease was examined using chi-square analysis with the Yates correction. P values less than 0.05 were considered significant.

This protocol was approved by the Research Advisory Committee of Mount Sinai Hospital.

Results

None of the 11 patients in the non-coronary-artery-disease group showed ST-segment depression. In contrast, 11 of the 29 patients in the group with coronary-artery disease showed ST-segment depression in the exercise leads.§ These values are significantly different, $P < 0.001$. Two of the 11 ischemic episodes were found on standard lead 11 of the operating room monitor by the anesthesiologist responsible for that particular case.§ There appeared to be a relationship between increases in blood pressure and heart rate and episodes of ST-segment depression. Of six patients with rate–pressure product values of less than 11,000, only one showed ST-segment depression. Of the 23 patients with rate–pressure product values of more than 11,000, ten showed ST-segment depression.§ The difference, however, is not statistically significant, owing to the small population in the low-rate–pressure-product group. The increased rate–

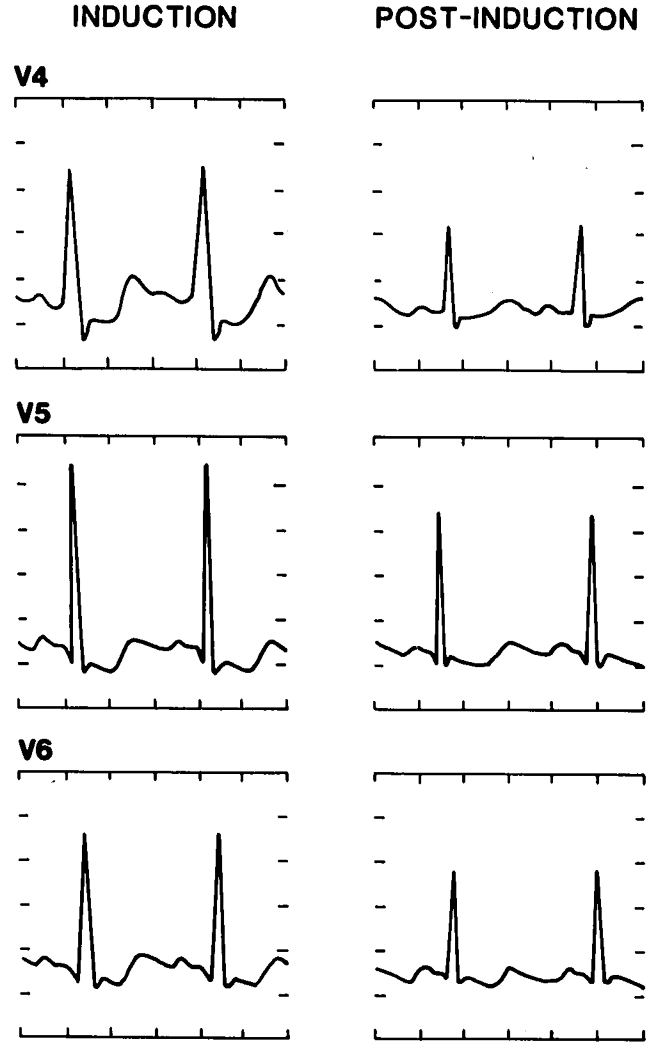

FIG. 1. Graphic representation of leads V_4, V_5, V_6 of Patient 29 during induction, showing significant ST-segment depression in leads V_4 and V_5. This tracing was obtained shortly after endotracheal intubation and was associated with a rate–pressure product of 18,000. The post-induction graph shows that the ST segment returned towards normal once the patient was well anesthetized. Horizontal axis scale: 5 mm between lines; vertical axis scale: 5 mm between lines.

§ See NAPS Document No. 03515 for 7 pages of supplementary material. Order from ASIS/NAPS, c/o Microfiche Publications, P.O. Box 3513, Grand Central Station, New York, NY 10017. Remit in advance for each NAPS accession number. Institutions and organizations may use purchase orders when ordering, however, there is a billing charge for this service. Make checks payable to Microfiche Publications. Photocopies are $5.00. Microfiche are $3.00 each. Outside the United States and Canada, postage is $3.00 for a photocopy or $1.00 for a fiche.

pressure product occurred most often about the time of intubation. Eight of the 11 ischemic episodes occurred during this time; seven of these were associated with rate-pressure products greater than 11,000. Three of the 11 patients were documented to have had ongoing ischemia postoperatively. One of them had documented myocardial infarction, associated with increased creatine phosphokinase (CPK). Two were discharged on the first postoperative day and were lost to follow-up. Six patients had received propanolol preoperatively; of these, two showed ST-segment depression. Three patients had previously had aorto-coronary bypass surgery. One had ST-segment depression. There was no difference between incidences of ST segment depression in the latter two groups of patients and the group of patients as a whole.

Discussion

Our study revealed a 38 per cent incidence of ST-segment depression intraoperatively among patients with known coronary-artery disease. This seemed high, but is consistent with the findings of others. Recording the ECG before and after operation, Driscoll *et al.*[13] found that 23 per cent of 145 patients with documented arteriosclerosis showed fresh ischemic changes postoperatively. Chamberlain *et al.*[4] were able to demonstrate a 22 per cent incidence of ECG deterioration postoperatively in a similar group of patients. They also attempted to identify hazardous factors. These included abdominal surgical procedures, procedues lasting longer than two hours, and pronounced episodes of hypotension. Our figures, though alarming, are consistent with prior reports.

Tarhan *et al.*[5] and later, Steen *et al.*,[6] from the same institution, studied the myocardial infarction rate postoperatively in patients who had previously had myocardial infarction. They documented a high rate of myocardial infarction (27 per cent) within the first three months after a previous infarct, which stabilized at 5 per cent six months after a previous infarct. Mahar[7] recently studied the incidence of perioperative myocardial infarction in non-coronary-artery surgery and found a high risk of myocardial infarction (20 per cent) in the presence of three-vessel coronary-artery disease in patients who had not undergone bypass procedures previously. They showed the risk to be significantly less in patients who had undergone coronary-artery bypass operations. Nevertheless, the figures demonstrate the potential seriousness of myocardial ischemia intraoperatively.

One might question whether ST-segment depression as detected by us truly reflects myocardial ischemia. Recently, Rifkin and colleagues have shown that in patients with known ischemic cardiac disease, the ST-segment displacement correlates extremely well with ischemia.[8] McHenry[9] attempted to define situations where one might encounter false-positive results. These patient ages of less than 50 years, the female sex, hyperventilation or peformance of a Valsalva maneuver, and prior ST-segment abnormalities. Our own non-coronary-artery-disease group, chosen to reflect these possibilities, gave us no false-positive result; therefore, it is extremely unlikely that frequent episodes of ST-segment depression due to factors other than myocardial ischemia could have occurred in the coronary-artery-disease group.

The inclusion of patients receiving cardiac glycosides in the study might be criticized, since it is known that the interpretation of ST-segment abnormalities is more difficult in this group of patients. However, only one patient with ST-segment depression was taking digoxin, and he subsequently experienced postoperative myocardial infarction, evidence that the intraoperative event was real and significant. No other patient in the study had been taking cardiac glycosides. We conclude that a man more than 50 years of age with a past clinical history of coronary-artery disease in whom significant ST-segment depression develops intraoperatively is in all likelihood experiencing myocardial ischemia. Indeed, one patient in our ischemic group went on to have myocardial infarction postoperatively, while in two others, changing EKG tracings persisted for two to three days postoperatively, which suggested ongoing ischemia.

Lead 11 changes frequently correspond to events in the distribution of the right coronary artery, whereas V_5 changes generally reflect events in the distribution of the left anterior descending or the circumflex arteries. Blackburn[10] has found that 98 per cent of ischemic episodes tend to occur in the region supplied by these two vessels. Thus, V_5 would be the most useful lead to monitor if indeed a single lead were to be used. Obviously, six leads would be preferable, but perhaps less practical. Leads 11, AVF, V_3, V_4, V_5, and V_6 (exercise leads) should detect essentially all ischemic events. Some ischemic episodes were missed on the standard monitor because V_5 was not monitored. When there was significant ST-segment depression on the recorded lead 11, the changes wer often too subtle to be detected by observing the ECG tracing on the standard oscilloscope. Our experience is similar to that of Kaplan *et al.*,[11] who also suggested that monitoring V_5 during anesthesia is most appropriate for identifying myocardial ischemia.

The ischemic episodes seemed to be related most often to increases in heart rate and blood pressure following intubation. In normal exercising man, myocardial oxygen consumption correlates best with the product of heart rate and blood pressure. Those correlates are superior to those of the time–tension index and peak aortic pressure.[12] It now appears that measures to decrease myocardial oxygen consumption may be the appropriate mode of therapy, particularly during intervals of increased rate–pressure product. Control of rate–pressure product with propranolol, nitroglycerin, or halothane may be desirable in patients with coronary-artery disease. Investigations following changes in ST-segment and rate–pressure product values in response to these agents would seem to be worth consideration.

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