Papers and Originals

Myocardial Infarction Following Surgical Operations

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Brit. med. J., 1968, 4, 725–728

Summary: One hundred and forty-one randomly selected surgical patients, aged 35 years or over, were studied preoperatively, followed through their operative procedures, and reassessed during the first postoperative week for evidence of myocardial ischaemia associated with surgical operations under general anaesthesia. Of these patients 38% were found to have preoperative clinical evidence of heart disease, hypertension, or diabetes; 45% had abnormal preoperative E.C.G. patterns.

Three patients experienced myocardial infarction during or within 36 hours of operation, all of the occult type; all were in the preoperative abnormal groups. Non-specific postoperative E.C.G. changes were equally common in the groups of patients with normal or abnormal preoperative electrocardiograms.

A relationship existed between a rise in serum lactic dehydrogenase (L.D.H.) concentration and the field of the operation, but the diagnosis of infarction was not confused provided serum L.D.H. isoenzyme patterns and a rise in serum aspartate aminotransferase (S.G.O.T.) levels were consistent with the diagnosis.

Introduction

For five decades studies have been appearing in the literature relating to preoperative and postoperative cardiac disease in patients submitted to surgical operation under general anaesthesia. Some early authors (Wilson, 1912 ; Randall and Orr, 1930) published case reports of postoperative coronary occlusion, while others (Sprague, 1929 ; Morrison, 1948) investigated patients with known cardiac disease who underwent operative procedures. Later, retrospective studies involving large numbers of surgical patients contributed towards knowledge of the incidence, predisposing factors, clinical presentation, and prognosis in this group of patients (Wróblewski and LaDue, 1952 ; Wasserman *et al.*, 1955 ; Feruglio *et al.*, 1958 ; Knapp *et al.*, 1962).

Recently some prospective series have been reported. Baer *et al.* (1965) found that of 150 randomly selected surgical patients, assessed historically and by electrocardiography, 24 showed evidence of postoperative myocardial infarction. In a more selective study on 100 geriatric patients 65 to 95 years of age Walker and Macdessi (1966) reported that no fewer than 26 suffered myocardial insult either during or after operation, with a significant mortality. Serum enzyme elevations based on serum lactic dehydrogenase (L.D.H.), serum aspartate aminotransferase (S.G.O.T.), and serum alanine aminotransferase (S.G.P.T.) were used as diagnostic aids in their series. Kelley *et al.* (1967) further emphasized the value of serum enzyme studies in the diagnosis of postoperative myocardial infarction in 84 patients undergoing abdominal surgery.

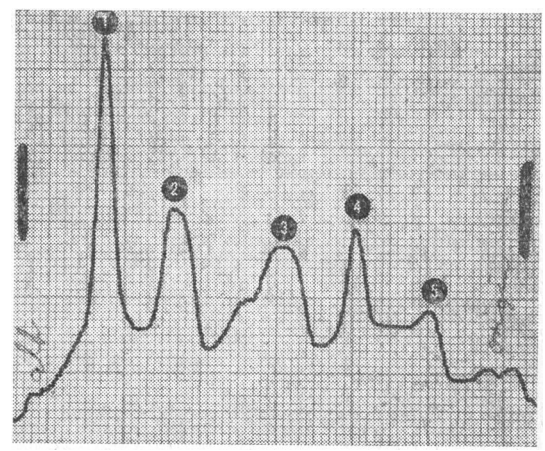
The aim of the present study was to determine, from a randomly selected group of surgical patients, the incidence of preoperative myocardial abnormalities and associated diseases, and to assess the patients' response to surgical and anaesthetic stress during the operative and early postoperative period. In this paper an attempt has also been made to correlate these findings and to determine factors which may indicate patients at special risk. An evaluation has also been made of methods used in this study to establish a diagnosis of myocardial infarction.

Materials and Methods

During 1966 and 1967 141 patients having operations under general anaesthesia were randomly selected from elective surgical operation lists. We excluded from the selection pool patients less than 35 years of age and those undergoing minor surgical procedures not requiring a full postoperative week in hospital.

Assessment of each patient was based on clinical findings and ancillary investigations: (*a*) within 24 hours before operation, (*b*) 36–48 hours after operation, and (*c*) on the sixth to eighth postoperative day. More frequent investigations were carried out if indicated.

Clinical Assessment.—(*a*) *History.* A general history was taken, with special reference to ischaemic heart disease, hyper-



Isoenzyme pattern showing peaked L.D.H.$_1$ typical of myocardial infarction. In this patient E.C.G. changes were non-specific and the diagnosis of myocardial infarction was made from the isoenzyme pattern.

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tension, and diabetes. Symptoms such as cardiac pain and exertional dyspnoea were especially recorded. (*b*) ***Physical Examination.*** A thorough physical examination was made, with special reference to cardiovascular disease.

Investigations

Routine.—Haemoglobin estimation and chest *x*-ray examinations were performed on all patients preoperatively.

Specific.—An electrocardiogram, with use of the 12 standard leads, was performed on each patient on the three separate occasions referred to above. The tracings were read and classified as normal or abnormal, and any changes occurring during the first postoperative week were recorded. The abnormal tracings were classified as having infarct patterns, non-specific S–T segment and T-wave changes, conduction defects, arrhythmias (atrial fibrillation, ectopics), left ventricular hypertrophy, and others. Serum enzymes were estimated with the use of L.D.H. (normal range 210–440 units) and S.G.O.T. (normal range 10–40 units), blood samples being taken at the time of electrocardiography. All sera with estimated L.D.H. levels above 500 units had isoenzyme patterns determined.

Of the 141 patients studied 70 were male and 71 female. The age distribution showed that 20 patients were 35–44 years of age (14%); 32 were 45–54 (23%); 45 were 55–64 (32%); 32 were 65–74 (23%); 10 were 75–84 (7%); and 2 were 85 years or older (<2%).

Preoperative Assessment

Single Abnormality

A total of 53 (38%) of the patients had either historical or physical evidence of heart disease, hypertension, or diabetes with electrocardiographic correlates (see Table I). Of these 53 patients 20 gave a past history of heart disease alone. Six of these claimed to have had a prior coronary occlusion, four showing typical infarct patterns on E.C.G. tracings. Twelve patients suffered from ischaemic cardiac pain; one of these had evidence of myocardial infarction and six had non-specific S–T segment and T-wave changes. Hypertension was found in 19 patients. This diagnosis was based on whether they were being treated for this condition or had a diastolic blood pressure of 110 mm. Hg or more, and/or a systolic of 180 mm. Hg or over preoperatively. There was E.C.G. evidence of infarction in one patient of this group. Four proved diabetics had no other symptoms.

TABLE I.—*Classification of E.C.G. Patterns in Patients Who Were Found Preoperatively to Have Historical or Clinical Evidence of Heart Disease, Hypertension, or Diabetes*

Symptoms and Signs (Preoperative)	No.	%	E.C.G.					
				Abnormal				
			Normal	Infarct	Non-specific	Conduction Defect	L.V.H.	Arrhythmia
Heart disease ..	20	14						
Myocardial infarction ..	6		1	4	1			
Ischaemic cardiac pain	12		2	1	6	2		1
R. heart disease	2				1		1	
Hypertension ..	19	13	7	1	5	1	3	2
Diabetes ..	4	3	2		1			1
Heart disease and hypertension ..	3	2		3				
Heart disease and diabetes ..	2	1			1	1		
Hypertension and diabetes ..	4	3	1		1		2	
Heart disease, hypertension, and diabetes ..	1				1			
Total ..	53	38	13	40				

Multiple Abnormalities

Ten patients had a combination of a history of coronary artery disease with hypertension and/or diabetes. All had E.C.G. abnormalities, including three with patterns of previous myocardial infarction.

Operative Procedures

The majority of patients underwent general surgical procedures and there were smaller numbers of orthopaedic, gynaecological, plastic, urological, intracranial, and thoracic cases. The analysis shows the following:

General Surgical: 89 (63%).—Upper Abdominal 27: includes cholecystectomy, gastroenterostomy, partial gastrectomy, adrenalectomy. Lower Abdominal 9: includes anterior resection, abdominoperineal resection, hemicolectomy. Miscellaneous 53: includes mastectomy, thyroidectomy, hernia repair, vein surgery.

Orthopaedic: 13 (9%).—Includes amputation and laminectomy.

Gynaecological: 13 (9%).—Includes hysterectomy and vaginal repair.

Urological: 10 (7%).—All were major open procedures (such as nephrectomy, nephrolithotomy, partial cystectomy, and prostatectomy) except one (transurethral resection).

Plastic: 10 (7%).—Includes local excision of lesion and graft: fasciectomy.

Thoracic and Intracranial.—These numbered 6 (4%).

Duration of Operations.—Of these, 49 (35%) took less than one hour, 57 (40%) between one and two hours, 25 (18%) between two and three hours, 7 (5%) between three and four hours, and 3 (2%) took four hours or more.

Anaesthesia.—In all, 132 cases (94%) were induced with thiopentone sodium and were maintained alone or in combination on nitrous oxide, oxygen, or halothane. Only 9 cases (6%) were maintained alone or in combination on cyclopropane, halothane, or ether. There were two cyclopropane inductions. Thirty-three patients (23%) suffered a hypotensive episode of 15 minutes or more during anaesthesia (systolic blood pressure less than 100 mm. Hg).

Electrocardiographic Analysis: (see Table II)

Normal Preoperative E.C.G.s

Of the total 141 patients studied 77 (55%) had normal preoperative E.C.G.s. Their average age was 55 years. Of these 77 patients 64 (that is, 83% of this preoperative normal group) underwent operation without any electrocardiographic change, the average duration of operation being one and a quarter hours. Those tracings which did change showed mainly non-specific patterns. There were no infarcts in this group.

Abnormal Preoperative E.C.G.s

Sixty-four patients (45%) had preoperative abnormal E.C.G.s. Their average age was 63 years (that is, 8 years older than the preoperative normal group). Of these patients 10 showed evidence of prior myocardial infarction. Of the 10 only four had a history of past coronary occlusion, five gave a history of angina, or angina and hypertension (see Table I), and one patient was completely asymptomatic, having apparently suffered a

TABLE II.—*Comparison of Preoperative and Postoperative Findings in the Two Groups of Patients Classified Preoperatively by Electrocardiography as Normal and Abnormal*

Preoperative				Postoperative			
E.C.G. Classification of E.C.G.	No. in Each Group	Average Age	Average Duration of Operation (Hours)	E.C.G. No Change	L.D.H. Rise	E.C.G. Change	L.D.H. Rise
NORMAL	77	55	1·25	64	20	13 (To non-specific, 10; V. ectopics, 3)	3
ABNORMAL	64	63	1·75	53	18	11	6
Infarcts	10						
Ant.	7			7			
Post.	3			2		1 + non-specific	
Non-specific	18			16		2 (to post-infarct 1; to normal 1)	
Conduction Defect	8						
(R) B.B.B.	4			4			
(L) B.B.B.	3			3			
2: 1 H.B.	1					1 + non-specific	
Arrhythmia	13						
Vent. ectopics	10			7		2 (to post-infarct 1 + non-specific 1)	
Atrial fib.	2			1		1 to normal	
Nodal rhythm	1			1		1 to normal	
(L) Vent. hypertrophy	10			7		3 (+ non-specific 2, + atrial fib. 1)	
(L) Vent. hypertrophy + non-specific	4			4			
Others	1			1			

silent infarct previously. All but one of these 10 patients had an unchanged postoperative E.C.G., and all survived operation unscathed. The average duration of operation in this group of 64 patients was one and three-quarter hours.

Postoperative E.C.G.s

The incidence of significant electrocardiographic change over the operative and early postoperative period in the normal and abnormal preoperative groups was not different (17% and 16% respectively) (see Table II). Three patients suffered myocardial infarction during or shortly after operation, and each had had a preoperative abnormal E.C.G. One came from the preoperative non-specific group, one from the arrhythmia group, and one from the left ventricular hypertrophy group (see Table I). Postoperatively two had proved posterior infarcts on E.C.G. evidence, and one (discussed later) with left ventricular hypertrophy revealed non-specific changes additionally in the postoperative period but had an enzyme pattern diagnostic of myocardial infarction.

Serum Enzyme Changes

Lactic Dehydrogenase

Serum L.D.H. rose from preoperatively normal levels to postoperatively elevated levels in 47 patients, 23 of these 47 being found in the normal preoperative E.C.G. group (see Table II); 24 of the 47 were in the preoperatively abnormal E.C.G. group. The actual number of elevations was twice as many in the abnormal E.C.G. group which underwent operative E.C.G. change (6) as in the normal group which underwent E.C.G. change (3), but the numbers are so small as to be of doubtful significance. Overall there appeared to be little correlation between normal and abnormal preoperative or postoperative E.C.G.s and postoperative enzyme elevation. Of the three myocardial infarctions diagnosed postoperatively serum enzyme elevation was helpful in diagnosis in only one case. The two posterior infarctions had slight elevations only (in one patient serum L.D.H. rose but still remained within normal limits). The third infarct patient had a typical postinfarction rise to 1,082 units. A more interesting and significant finding was the correlation between raised postoperative serum L.D.H. levels and the type of surgical procedure performed. Of the total 54 cases of intra-abdominal and pelvic procedures (excluding hernia repairs) 28 had raised serum L.D.H. values postoperatively (see Table III). In seven of the nine open urological cases there was a raised L.D.H., and in the gynaecological cases each of the four patients with raised L.D.H. had abdominal hysterectomy.

TABLE III.—*Numbers of Patients with Postoperative Elevation of L.D.H. in Relation to the Type of Surgical Procedure Performed*

Surgical Procedure	Total Cases	No. with L.D.H. Rise	Percentage with L.D.H. Rise
General surgical:			
Upper abdomen	27	15	56%
Lower abdomen	9	2	22%
Miscellaneous	53	13	24%
Orthopaedic	13	2	15%
Gynaecological	13	4	11%
Urological	10	7	70%
Plastic	10	1	10%
Thoracic and intracranial	6	3	50%

Isoenzyme Patterns.—All sera returning a postoperative L.D.H. level of 500 units or more had isoenzyme patterns determined. There were 27 in this group. Most patterns showed a preponderance of the fractions $L.D.H._1$, $L.D.H._2$, or $L.D.H._3$, in varying combinations, or there was a generalized non-specific rise in all fractions ($L.D.H._1$ to $L.D.H._5$). In only one case was a distinctive and diagnostic pattern of myocardial infarction revealed. This patient's serum L.D.H. rose to 1,082 units (accompanied by S.G.O.T. elevation) at the first postoperative check, and was still moderately high six days later. The peak fraction was $L.D.H._1$. The liver function, $L.D.H._5$, was not found to be specifically raised in any sera.

Serum Aspartate Aminotransferase

Six patients had normal preoperative and raised postoperative S.G.O.T., and with one exception there was an accompanying L.D.H. rise. The exception was a patient who suffered from obstructive jaundice due to pancreatic malignancy. Of the five patients with a rise of both S.G.O.T. and L.D.H. this was considerable in one, which indicated infarction (as previously mentioned). Another underwent a prolonged procedure (six hours), and although there was evidence of previous infarction there was no significant E.C.G. change postoperatively. The third patient died from advanced malignant disease on the third postoperative day; the fourth patient had metastatic carcinoma of the breast with hepatic involvement; and the remaining one had an unexplained rise following a right pyelolithotomy.

Comment on Cases

Operative and Postoperative Infarcts

Three patients were diagnosed as having an acute myocardial infarction during or within 36 hours of operation. All were in their sixth decade; two were males and one a female.

The males were 54 and 57 years of age respectively; both had suffered from ischaemic heart disease for some years, and one also had untreated hypertension. Both underwent cholecystectomy lasting one to two hours, and no operative hypotension or episodes of acute blood loss occurred. Neither patient complained of chest pain postoperatively, though one had an episode of hypotension for some hours on the first postoperative day and the other complained of orthopnoea also on the first postoperative day. Preoperative E.C.G.s revealed nonspecific S–T segment and T-wave changes in one patient and ventricular ectopics in the other. Both postoperative E.C.G.s showed typical Q waves in leads II, III, and aVF with T-wave inversion. Enzyme studies did not contribute to the diagnoses —L.D.H. and S.G.O.T. levels in both cases showing insignificant rises. Except for hypotension and orthopnoea, these two patients remained asymptomatic, and otherwise their convalescence was uneventful.

The third infarction occurred in a 59-year-old woman who underwent bilateral adrenalectomy for Cushing's disease. She had suffered from untreated hypertension and diabetes for some years before admission. Her preoperative E.C.G. showed left ventricular hypertrophy. Clinically her postoperative course was asymptomatic and her E.C.G. showed only the addition of increased non-specific S–T segment and T-wave changes. Her enzymes, however, rose from normal preoperative levels to a S.G.O.T. of 220 units and serum L.D.H. of 1,082 units 24 hours postoperatively and fell to 26 and 948 units respectively on the sixth postoperative day. The isoenzyme pattern was unequivocal—it showed a peaked $L.D.H._1$, and on this evidence myocardial infarction was diagnosed (see Fig.).

Postoperative Mortality.—There were two postoperative deaths. Both patients had advanced malignant disease and died on the third and fifth postoperative day respectively. Though serum enzymes rose in both there was no evidence of acute myocardial infarction in either patient at necropsy.

Discussion

The incidence of acute myocardial infarction during and after operations under general anaesthesia in this prospective study was three cases in 141 patients, or about 2%. This is higher than that found in large retrospective studies previously reported (Wróblewski and LaDue, 1952; Wasserman *et al.*, 1955; Feruglio *et al.*, 1958; Knapp *et al.*, 1962), but distinctly less than the incidence recorded by Baer *et al.* (1965), who found 24 cases in 150 randomly selected surgical patients.

The high incidence of both symptomatic and asymptomatic cardiovascular disease has been demonstrated by the fact that 38% of patients in this randomly selected series had symptoms or signs of ischaemic heart disease and hypertension or diabetes alone or in combination, and that 45% had abnormal preoperative E.C.G.s. The average age of the abnormal preoperative E.C.G. group was higher (63 years) than that of the preoperatively normal group (55 years). The average duration of surgery was longer in the former group, probably reflecting the higher incidence of major surgical disease in these older patients. It was found that even though the patients in the preoperatively abnormal E.C.G. group were older and underwent more prolonged procedures the actual incidence of electrocardiographic change during operation was no greater than in the younger preoperatively normal group.

The three patients found to have myocardial infarction in this series suffered from symptomatic cardiovascular system disease prior to surgery. This is consistent with the findings of others (Wróblewski and LaDue, 1952; Wasserman *et al.*, 1955) that these people are predisposed to serious myocardial insult during or soon after operative procedures. Furthermore, it was found similarly that all three patients were in their sixth decade, all infarcted during or within 36 hours of operation and none complained postoperatively of chest pain. The survival and absence of morbidity in the 10 patients with known past myocardial infarction and the low incidence of operative change of their E.C.G. tracings must reflect cardiovascular stability and compensation of a considerable degree, though Knapp *et al.* (1962) found that 6% of patients with previous coronary occlusion suffered postoperative recurrence.

Because of the uniformity of method of anaesthesia there was no evidence that the anaesthetic agents themselves contributed towards a change in cardiovascular system state or in enzyme levels, nor was there any correlation with incidence or duration of operative hypotension.

Serum enzyme estimations showed that a moderate rise of serum L.D.H. was common when the field of operation was in the abdomen or pelvis. The accompanying isoenzyme patterns were either nonspecific or showed a preponderance of the fast fractions $L.D.H._1$ and $L.D.H._2$, and to a lesser degree $L.D.H._3$, usually combined. Kelley *et al.* (1967) found, by using S.G.O.T., serum L.D.H., and S.G.P.T., that minor liver trauma due to retraction or manipulation contributes towards enzyme elevations, and that these may interfere with the assessment of myocardial necrosis. When both S.G.O.T. and serum L.D.H. concentrations undergo significant rise determination of L.D.H. isoenzyme patterns is valuable. With these tests a confident diagnosis of postoperative myocardial infarction can often be made, even in the presence of equivocal electrocardiographic changes.

It is interesting to reflect that in the three patients found to have suffered painless postoperative infarction the myocardial insult would not have been detected but for the routine assessment carried out in this survey.

We believe that the low incidence of myocardial damage in this series in comparison with other prospective series is at least partly a reflection of the high standard of anaesthesia administered, and we express our thanks to all members of the anaesthetic staff of Sydney Hospital. We also wish to thank Dr. Frank Neale for his invaluable help in biochemical studies, and members of the surgical staff of Sydney Hospital who so readily co-operated in this study.

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