Myocardial infarction after aortocoronary saphenous vein bypass

Vectorcardiographic study¹

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Vectorcardiograms and scalar electrocardiograms were recorded in 30 patients before and after aortocoronary saphenous vein bypass surgery to determine whether vectorcardiograms are helpful in making the diagnosis of perioperative transmural infarction. The vectorcardiogram indicated inferior infarction in 2 cases and anterior infarction in 1 case when the diagnosis was not apparent on the electrocardiogram. In the solitary case of anterior infarction diagnosed by the electrocardiogram, anterior infarction was already present on the pre-operative vectorcardiogram.

The study indicates that the recording of vectorcardiograms before and after aortocoronary bypass surgery facilitates the diagnosis of perioperative anterior and inferior infarction and may reveal perioperative infarction about a previously infarcted area.

Since aortocoronary bypass by saphenous vein graft was first reported (Favaloro, 1968), the operation has gained widespread acceptance as a means of relieving angina pectoris in a large majority of patients. However, the procedure is frequently associated with electrocardiographic features of myocardial infarction. The limitations of the electrocardiogram in diagnosing infarction are well known and it has been frequently shown that the vectorcardiogram can diagnose infarction which is not apparent on the electrocardiogram (Hugenholtz *et al.*, 1961; Wolff *et al.*, 1961; Simonson *et al.*, 1966; Gunnar *et al.*, 1967). It was the aim of this investigation to determine whether use of the vectorcardiogram in addition to the electrocardiogram is helpful in making the diagnosis of infarction attributable to aortocoronary bypass surgery.

Subjects and methods

Thirty patients aged between 36 and 66 years who had been admitted to the Royal Victoria Hospital, Montreal, for aortocoronary saphenous vein bypass

were examined. Patients who underwent additional procedures were not included. Record was made of previous episodes of myocardial infarction. An electrocardiogram and vectorcardiogram were recorded on each patient during the 72 hours before operation, and from 7 to 10 days after operation; corresponding electrocardiograms and vectorcardiograms were recorded within one hour of one another. A direct-writing Sanborn electrocardiograph was used to record the standard 12-lead electrocardiogram. A Sanborn Model 185-100 vectorcardiograph was employed and the vectorcardiograms were recorded by a Polaroid camera set at f8 and 0.5 s, using black and white Polaroid film, type 107. The vectorcardiograms were recorded with the patient in the recumbent position; the Frank lead system was employed (Frank, 1956).

Conventional electrocardiographic criteria (Perloff, 1964; Schrank *et al.*, 1974) and vectorcardiographic criteria (Chou and Helm, 1967; Gunnar *et al.*, 1967; McConahay *et al.*, 1970; Starr *et al.*, 1974) of known value in the diagnosis of transmural myocardial infarction were employed. T loop changes were not considered diagnostic of infarction and were examined separately. Conduction disturbances were also sought.

In evaluating the incidence of perioperative

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transmural infarction within various subgroups, cases with electrocardiographic, vectorcardiographic, and postmortem evidence of infarction were considered together since necropsy of hearts with infarction not associated with operation has shown that the diagnostic accuracy of the vectorcardiogram and electrocardiogram together exceeds either method alone (Burch *et al.*, 1958).

The vectorcardiograms were analysed to detect any change in direction of the maximum projection of the T vector in the frontal, horizontal, and right sagittal planes. When the spatial vector is almost perpendicular to the projection being examined very small changes in the direction of the vector can cause great alterations in its projection. Therefore, changes in direction of the maximum T vector were considered evidence of a change in the T loop only when these were more than 20° in at least two planes.

Results

QRS CHANGES

Before bypass surgery 15 patients had electrocardiographic evidence of infarction (Table 1).

Table 1 Transmural infarction before and after aortocoronary bypass surgery

Case No.	History of previous infarction	Preoperative		Postoperative change	
		ECG	VCG	ECG	VCG
1	Yes	A	A, L	—	—
2	Yes	A, L, I	A, I	—	—
3	Yes	A, I	A, I	—	—
4	Yes	I	I	—	—
5	No	—	—	—	—
6	Yes	A	A	(Died)	(Died)
7	Yes	—	—	—	—
8	Yes	I	I	—	—
9	Yes	I	I	—	A
10	Yes	I	I, A	A	—
11	No	—	—	—	—
12	Yes	I	I, P	—	—
13	Yes	—	P	—	I
14	No	—	—	—	—
15	Yes	—	—	—	—
16	No	—	A	—	—
17	Yes	—	—	—	I
18	Yes	A	A, I	—	—
19	No	—	—	—	—
20	No	—	—	—	—
21	Yes	P	P	—	—
22	No	—	—	—	—
23	No	—	—	—	—
24	Yes	I	I	—	—
25	Yes	—	A	—	—
26	No	—	—	—	—
27	Yes	I	I	—	—
28	Yes	I	I	—	—
29	Yes	A	A, I	—	—
30	No	—	—	—	—

ECG, electrocardiogram; VCG, vectorcardiogram; A, anterior; L, lateral; P, posterior; I, inferior.

The vectorcardiogram also showed evidence of infarction in these cases, but in 6 cases the sites of infarction differed. In addition, the vectorcardiogram indicated anterior infarction in 2 cases, one of which was supported by clinical history, though there was no evidence of infarction on the scalar electrocardiogram, and suggested posterior infarction in another when there was a normal electrocardiogram and no apparent history of infarction. Twelve patients had neither electrocardiographic nor vectorcardiographic evidence of infarction before operation, though 2 gave histories of infarction.

Only one patient died during the period of the study (operative mortality 3%). This death occurred 36 hours after operation and necropsy showed extensive recent inferior myocardial infarction; there was clinical, electrocardiographic and vectorcardiographic evidence of previous anterior infarction.

Four other patients showed electrocardiographic features of perioperative infarction (13%) but there was no agreement between the vectorcardiogram and electrocardiogram in indicating infarction. In 3 patients infarction was only apparent on the vectorcardiogram: 2 had an inferior and 1 an anterior infarct. The electrocardiogram showed anterior infarction in 1 patient in whom the vectorcardiogram, but not the electrocardiogram, had already shown preoperative anterior infarction (Table 1).

Three patients without apparent infarction developed left posterior hemiblock after operation (10%) and another left anterior hemiblock (3%); no patient developed bundle-branch block.

When vectorcardiograms were examined before and after operation, alterations in the T loop were noted in 19 out of 29 cases (one of whom died) (Table 2). Those with a history of previous infarction were more susceptible to T loop changes ($P < 0.01$).

Discussion

Determination of the incidence of myocardial infarction caused by aortocoronary saphenous vein bypass surgery is important for two reasons: (1) because of the complications of myocardial infarction, and (2) because the relief of angina may be the result of perioperative infarction of ischaemic myocardium (Friedewald *et al.*, 1973; Schatz, 1973).

The cause of relief of angina pectoris in individual patients is difficult to assess; it has been shown that sham operations may relieve angina in 95 per cent of cases (Battezzati *et al.*, 1959) and relief of pain may be the result of interruption of afferent nerve

Table 2 Change in direction of maximum projection of T vector

Case No.	Change in direction of maximum projection of T vector (degrees)		
	Horizontal	Frontal	Right sagittal
1	0	80	40
2	0	100	5
3	95	80	120
4	25	5	40
5	15	10	5
6	—	—	—
7	35	40	95
8	0	30	10
9	25	55	50
10	0	25	70
11	25	5	0
12	30	10	85
13	175	50	140
14	75	25	30
15	90	30	40
16	10	20	0
17	60	25	20
18	25	10	25
19	35	30	40
20	0	20	25
21	100	5	100
22	25	5	10
23	55	15	20
24	35	0	75
25	20	20	15
26	5	30	30
27	75	55	33
28	75	45	10
29	5	0	0
30	155	90	150

fibres at operation (Brewer *et al.*, 1973). Fortunately, many patients show objective evidence of improvement in oxygen delivery to the myocardium after operation. This has been shown by exercise electrocardiography (Amsterdam *et al.*, 1970), treadmill exercise tolerance (Knoebel *et al.*, 1971), improvement in myocardial lactate utilisation during atrial pacing (Hammond, 1970; Kremkau *et al.*, 1971; Beer *et al.*, 1972), and increased myocardial oxygen tension (Gardner *et al.*, 1971).

The diagnosis of myocardial infarction after aortocoronary bypass surgery is also fraught with difficulties. Even non-thoracic surgery can be followed by the appearance of Q waves on the scalar electrocardiogram in patients with ischaemic heart disease (Chamberlain and Edmonds-Seal, 1964). Inflammation of the pericardium caused by cardiac surgery may cause T wave changes simulating subendocardial infarction (Brewer *et al.*, 1973). Schrank and his colleagues (1974) have suggested that operation may shift the position of the heart and consequently distort the electrocardiogram and vectorcardiogram. Electrocardiographic changes could also result from alterations in thoracic impedance (Schmitt, 1964). Though Kline and co-workers (1972) have observed transient Q waves

during open heart surgery and have suggested that these may be the result of localised hyperkalaemia, this additional source of error is probably irrelevant since postoperative cardiograms were recorded 7 to 10 days after operation.

Only necropsy evidence can provide conclusive proof of perioperative infarction. However, in this study, the vectorcardiogram indicated perioperative transmural infarction which was not apparent on the electrocardiogram. Though the vectorcardiogram diagnosed more cases of infarction than the electrocardiogram, the sensitivity of both methods combined was greater than either alone. It is not surprising that the vectorcardiogram is superior since it provides a more detailed record of the electrical activity of the heart. Schrank and his colleagues (1974) have also noted that after aorto-coronary bypass surgery the vectorcardiogram can diagnose anterior infarction which is not apparent on the electrocardiogram, but they found that the vectorcardiogram was not helpful in detecting inferior infarction. In this study, inferior as well as anterior infarction could be detectable only by the vectorcardiogram.

Since the diagnostic sensitivity of the electrocardiogram is related to the size of an infarcted region (Myers *et al.*, 1948, 1949), more extensive infarction about a previously infarcted area may have accounted for the solitary electrocardiographic diagnosis of perioperative anterior infarction when vectorcardiographic evidence of anterior infarction was already present before operation. This result suggests that the recording of preoperative as well as postoperative vectorcardiograms may be necessary if infarction about a previously infarcted area is to be recognised.

The T loop of the vectorcardiogram is less clearly inscribed than the QRS loop. Therefore, in this study, changes in direction of the maximum projections of the T loop were not considered if they were less than 20°. The maximum projections of the T vector do not necessarily represent the same spatial vector and hence quantitative assessment of changes in direction of the maximum spatial vector are not possible. However, large changes in its direction will always be recognised by the method of describing the T loop used in this study.

Alterations in the T loop occurred in 66 per cent of cases. The significance of these changes is difficult to evaluate, but the fact that transmural infarction is a complication of aortocoronary bypass operation suggests that subendocardial infarction can be incriminated in some cases. However, pericarditis resulting from surgery causes identical changes, and changes in repolarisation which follow

sudden reperfusion of ischaemic myocardium may be the result of relief of ischaemia rather than of infarction (Smith *et al.*, 1974). It is possible that this may have contributed to the increased incidence of T loop changes in patients showing previous infarction.

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