Thallium-201 myocardial imaging in assessment of results of aortocoronary bypass surgery

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SUMMARY Thirty-six patients were assessed by thallium-201 myocardial imaging before and after aortocoronary bypass operations and the results were compared with evaluation based on symptomatic assessment, exercise testing, and electrocardiography.

After operation, the majority of patients were free from symptoms or symptomatically improved with increased exercise duration. Perioperative myocardial damage was shown in eight patients and myocardial ischaemia in 15 patients when assessed by thallium imaging during exercise. Thallium imaging proved more sensitive than electrocardiography in the demonstration of perioperative infarction and in the detection of postoperative ischaemia. Exercise electrocardiography may be misleading after aortocoronary bypass operations.

Thallium imaging offers a simple, objective evaluation of the results of revascularisation procedures, throws light on the mechanisms of relief of angina by operation, and helps in the assessment of the patient whose progress is unsatisfactory after operation.

Aortocoronary bypass surgery has become an established treatment for symptomatic obstructive coronary artery disease which is refractory to medical treatment. After operation the majority of patients are free from symptoms or substantially improved, with increased exercise capacity and, in general, this is related to graft patency though the relation is imprecise; some patients show improvement in both symptoms and exercise performance after perioperative myocardial infarction (Di Luzio *et al.*, 1974) or when all the grafts are occluded (Benchimol *et al.*, 1976). The suggested mechanisms for relief of angina comprise: a placebo effect of operation, denervation of the ischaemic myocardial segment, perioperative infarction of the previously ischaemic segment, improvement of left ventricular function, and improvement of myocardial blood flow by a patent bypass graft (Mnayer *et al.*, 1977). Objective assessment of the effects of bypass surgery on regional myocardial perfusion would contribute to the investigation of these possible mechanisms for relief of angina and aid management of the patient whose progress after operation is unsatisfactory. Thallium-201 myocardial imaging has proved a sensitive technique for the study of myocardial perfusion and we report here our experience using this technique to assess patients

before and after coronary artery bypass surgery and compare the results with those from evaluation based on symptomatic assessment, electrocardiography, and exercise testing.

Patients and methods

Thirty-six patients were studied before and after elective aortocoronary bypass surgery for stable angina pectoris. The study sequence comprised: clinical assessment, resting electrocardiography, resting thallium-201 myocardial imaging, exercise testing, exercise electrocardiography, and exercise thallium-201 myocardial imaging. Studies were performed preoperatively, at the time of cardiac catheterisation, and four to six months post-operatively.

CLINICAL ASSESSMENT

Angina was graded by New York Heart Association (NYHA) criteria. Previous myocardial infarction was established on the basis of a documented history of infarction or of diagnostic changes on the resting electrocardiogram.

EXERCISE TESTING

Patients were exercised on a bicycle ergometer (Elema Schonander EM 369). A standardised exercise procedure was employed with an initial

work load of 24.5 watts (150 kpm/min) for two minutes, increasing by 24.5 watts (150 kpm/min) every two minutes to the maximum tolerated work load. Beta-blocking drugs and other antianginal treatment were discontinued for 48 hours before testing and the patients were fasted for eight hours. During exercise nine electrocardiographic leads (I, II, III, aVR, aVL, aVF, V4, V5, and V6) were monitored continuously. The exercise electrocardiogram was considered to demonstrate ischaemia if, in a lead with an isoelectric ST segment and upright T wave at rest, there was ST segment depression of at least 100 μ V, persisting for 0.08 second after the termination of the QRS complex, with a horizontal or downsloping ST segment, and present for at least three consecutive beats during exercise or the first three minutes of recovery. The exercise test was discontinued with the development of angina, ST segment depression of 300 μ V or more, breathlessness, or exhaustion: a 'target' heart rate was not used. Exercise performance was documented in terms of total exercise duration using the standardised procedure and maximum heart rate achieved during exercise.

THALLIUM-201 MYOCARDIAL IMAGING

Myocardial imaging was performed at rest and after maximal exercise. On each occasion 1.5 mCi thallium-201, as thallous chloride (Philips Duphar DRN 8103) was given intravenously. The patient was fasted for eight hours before imaging. For the resting study imaging started 10 to 15 minutes after isotope injection; for the exercise study the isotope was administered during maximal exercise; exercise was continued at, or near, this level for a further one minute, and imaging started 10 minutes later. Imaging was completed within 30 minutes to reduce to a minimum the effects of redistribution of the isotope occurring after initial myocardial uptake. Three standard views of the myocardium were obtained, anterior, 45° left anterior oblique, and 90° left lateral, with additional views as indicated. The mercury x-ray emission (65 to 82 keV) from thallium-201 decay was imaged using a scintillation camera (General Electric Maxicamera), with a low-energy, high-resolution, converging collimator. Each image consisted of 300 000 counts and these were computer processed to produce a semiquantitative, 15-colour display.

The normal left ventricular myocardial image shows relatively uniform isotope uptake throughout the myocardium. A defect is defined as a reduction of myocardial counts to below 75 per cent of the maximum myocardial counts on that image (Lenaers *et al.*, 1977). A defect on the resting images which is unchanged on subsequent exercise images represents infarction, while the appearance

of a new defect on exercise images or a substantial increase in the extent of a defect previously shown at rest represents ischaemia.

CARDIAC CATHETERISATION AND CARDIAC SURGERY

Selective coronary arteriography with multiple views of both right and left coronary arteries was performed using the Judkins technique. A coronary arteriographic lesion was considered significant if the luminal diameter was reduced by 50 per cent or more. At operation an attempt was made to revascularise all vascular territories with greater than 50 per cent stenosis of the supplying artery shown at coronary arteriography. Grafts were not established to vessels supplying obviously infarcted myocardium or to vessels with severe distal disease or inadequate 'run-off'. Cardiopulmonary bypass was conducted by bubble oxygenator with moderate haemodilution at 32°C. Aortocoronary bypass grafts were constructed using reversed segments of autologous saphenous vein. The distal anastomoses were made with the heart arrested either by electrical ventricular fibrillation or by hypothermic cardioplegia. In a number of cases sequential grafts were anastomosed to adjacent arterial branches in the same vascular territory. Endarterectomy was performed at the site of the distal anastomosis if necessary. The proximal anastomoses to the aorta were completed with the heart beating and often after discontinuation of cardiopulmonary bypass. All patients in this series had bypass grafts alone, and none had resection of a left ventricular aneurysm.

POSTOPERATIVE ASSESSMENT

The patients were reassessed four to six months after operation in the same way as before operation. Perioperative myocardial infarction was established by the appearance of new Q waves on the resting electrocardiogram at that time.

Results

The clinical features, coronary arteriographic findings, bypass grafts constructed, exercise data, electrocardiographic observations, and results of thallium-201 myocardial imaging are shown in Tables 1a and 1b. Thirty-six patients (34 men and two women, average age 52 years) with stable angina pectoris had aortocoronary bypass graft operations. Four patients had single vessel disease, eight had double vessel disease, and 24 had triple vessel disease. One hundred and two vessels were grafted using 78 single grafts and 12 sequential grafts. Endarterectomy was necessary before grafting in 19 vessels.

Table 1a Symptoms, exercise duration, coronary arteriography, and grafts

Case no.	Sex	Age (y)	Angina (NYHA)		Exercise duration (min)		Coronary stenosis $\geq 50\%$	Bypass grafts
			Preop	Postop	Preop	Postop		
1	M	42	2	1	16	15.5	LAD Dg Cx R	LAD Dg R
2	M	59	2	1	10.5	12	LM LAD OM R	LAD Dg R
3	M	60	3	2	6	9	LAD Dg Cx R	LAD/Dg OM R
4	M	65	2	1	8	8	LAD OM R	LAD Dg R
5	M	50	3	1	5.75	11	LAD Dg Cx OM R	Dg R
6	M	56	3	1	6	12	LAD OM R	LAD/Dg OM R
7	M	50	4	1	8	12	LAD Cx OM	LAD/LAD Dg OM/OM
8	M	57	4	1	4	9.5	LAD Cx R	LAD Dg R
9	M	57	2	1	6	10.75	LM LAD Cx OM R	LAD OM R
10	M	53	2	1	8.75	9.5	LAD OM R	LAD R
11	M	54	3	2	8	9	LAD Cx	LAD OM
12	M	52	3	3	8	8	LAD Cx R	LAD OM R
13	M	46	3	1	6	10.75	LAD Cx R	LAD OM R/R
14	M	56	3	1	5	13	LAD OM R	LAD OM R
15	M	63	3	1	5.5	8.5	LAD Cx OM R	LAD OM R
16	M	44	2	1	13.75	16	LAD OM R	LAD OM R
17	M	53	3	1	6	9.5	LAD Dg OM R	LAD/Dg OM R
18	M	44	2	1	11.5	13	LAD Dg R	LAD OM R
19	M	59	3	1	8	11.75	LAD OM R	LAD OM R
20	M	43	2	1	11.25	14	LAD Dg OM R	LAD/Dg OM R
21	M	48	3	1	4	7.25	Dg Cx OM R	Dg/Dg OM R/R
22	M	41	2	1	10	11	LAD Cx	LAD OM
23	M	49	2	1	11	9.5	LAD R	LAD R
24	M	42	2	1	16	17.5	LAD	LAD
25	M	49	2	1	7	12	OM	LAD OM
26	M	60	2	1	8	10	LAD R	LAD
27	M	49	3	2	5.75	7.5	LAD Dg Cx OM R	LAD OM R
28	F	40	2	1	7.75	8	LAD	LAD
29	M	57	3	3	8.75	9	LAD Cx OM R	LAD/Dg OM
30	M	50	2	1	9.5	13	Dg OM R	LAD/Dg OM R
31	M	44	2	1	10	13.5	LAD	LAD R
32	M	60	3	1	4.5	8	LAD Cx OM R	LAD OM R
33	M	66	3	3	5.5	6	LAD Dg OM R	LAD
34	M	50	2	1	10	11.5	LAD R	LAD R
35	F	63	3	3	4	4	LAD Cx OM	LAD OM/OM
36	M	49	2	2	9.5	9	LAD Cx OM R	LAD OM R

Abbreviations: LM, left main coronary artery; LAD, left anterior descending coronary artery; Dg, major diagonal branches of LAD; Cx, left circumflex coronary artery; OM, obtuse marginal branches of Cx; R, right coronary artery; LAD/Dg, sequential graft.

SYMPTOMS

Before operation all patients had significant angina; 19 were NYHA grade 2, 16 were grade 3, and one was grade 4. After operation, 28 patients (78%) were free from symptoms, three (8%) were improved (grade 2), and five (14%) were unchanged, four with continuing severe angina (Table 1a).

EXERCISE TESTING

The results of pre- and postoperative exercise studies show that, for the group as a whole, mean exercise duration increased from 8.15 (± 3.07) minutes before operation to 10.54 (± 2.83) minutes after operation ($P < 0.001$). The maximum heart rate achieved increased from 136 (± 21)/min before operation to 156 (± 19)/min after operation ($P < 0.001$). Statistical analysis was by paired Student *t* test.

RESTING ELECTROCARDIOGRAPHY

Before operation 17 patients had electrocardiographic evidence of previous myocardial infarction. After operation two patients had new Q waves on

the resting electrocardiogram while 16 had persistent T wave inversion in anterior or anterolateral chest leads not present before operation (Table 1b).

EXERCISE ELECTROCARDIOGRAPHY

Before operation 29 patients had ischaemic ST segment depression occurring during exercise in at least one lead of the electrocardiogram, and 26 of these developed angina during the exercise test. One additional patient developed left bundle-branch block with the onset of angina. Six patients had no electrocardiographic changes during exercise. After operation 13 patients had ischaemic ST segment depression during exercise but only four of these developed angina during the exercise test. In 10 of the 13 patients ST segment depression developed at a greater work load after operation than before (Table 1b).

RESTING THALLIUM-201 IMAGING:

INFARCTION (Tables 1b and 2)

Before operation 14 patients had defects on resting thallium images which corresponded in location to

Table 1b Localisation of ischaemia and infarction by electrocardiography and myocardial imaging

Rest studies (infarction)					Exercise studies (ischaemia)			
Case no.	Preop ECG	Tl-201	Postop ECG	Tl-201	Preop ECG (max. ST depression) (mm)	Tl-201	Postop ECG (max. ST depression) (mm)	Tl-201
1	INF	INF	T↓	—	2	AS INF	1	AL
2	—	—	T↓	—	3	AS AL	—	—
3	—	—	—	—	2	AL	3	AL
4	AS INF	AS INF	—	—	1	AS INF	—	AS
5	AS INF	AS AL INF	T↓	—	5	PL INF	1	—
6	INF	INF	T↓	—	1	AS INF	—	—
7	—	—	T↓	—	3	AL	1	AL
8	—	—	—	—	LBBB	AS INF	LBBB	—
9	—	—	T↓	AS*	3	AS INF	—	—
10	AS	AS	—	—	—	AS INF	—	—
11	AS	AS	T↓	AL	3	AS AL INF	1	AL
12	INF	—	—	—	3	PL INF	—	INF
13	—	—	—	—	3	PL	—	—
14	AS	AS	—	—	2	AS INF	2	—
15	AL INF	PL INF	T↓	—	1	PL INF	—	INF
16	INF	INF	—	—	1	AL PL INF	2	PL
17	AL INF	PL INF	—	—	3	INF	1	—
18	—	AS INF°	T↓	—	1	AS INF	—	—
19	AS	AS	—	—	—	—	—	—
20	—	—	—	—	2	AL PL	1	—
21	INF	INF	T↓	—	2	PL	—	—
22	—	—	—	—	—	INF	—	—
23	—	—	AL INF	AL INF	2	AL INF	—	INF
24	—	—	T↓	—	1	AS AL	—	—
25	—	—	T↓	—	1	PL INF	1	PL INF
26	—	—	—	—	—	INF	—	—
27	—	—	INF	PL	1	PL INF	3	INF
28	—	—	—	—	1	AS	—	—
29	AS	—	AS†	AL	1	AS INF	—	AS
30	INF	INF	—	—	1	INF	—	—
31	AS	—	—	—	1	AS AL	—	—
32	AS	AS PL	T↓	AS*	4	—	—	—
33	—	—	T↓	—	1	AL PL	1	AS AL
34	—	PL	—	—	—	AL INF	—	—
35	—	—	T↓	AS	3	AS AL	2	AS AL
36	—	—	T↓	AS	—	AS INF	—	INF

AS, anteroseptal; AL, anterolateral; PL, posterolateral; INF, inferior/posterior; *, patchy necrosis; °, severe ischaemia; †, ST segment elevation after operation; T↓, T wave inversion in anterior or anterolateral leads after operation; LBBB, left bundle-branch block.

Table 2 Thallium-201 myocardial imaging—infarction

Electrocardiogram		Thallium-201 imaging		
		No. of patients	Defect (infarction)	Normal
Preoperative	Q waves	17	14	3
	Normal	19	1	18
Postoperative	New Q waves	2	2	0
	T wave inversion	16	5	11
	Unchanged	18	1	17

the electrocardiographic signs of previous infarction. In three patients with electrocardiographic evidence of infarction resting images were either normal or minimally abnormal. One patient had a posterolateral defect on thallium images without electrocardiographic evidence of infarction and another patient had anteroseptal and inferior defects on thallium images suggesting infarction but the resting images after operation were normal suggesting that

the preoperative abnormalities represented ischaemia rather than infarction.

After operation, thallium imaging suggested new myocardial infarction in eight patients. Two had new Q waves on resting electrocardiograms. One, with previous anteroseptal infarction, had conspicuous ST segment elevation in anteroseptal leads immediately after operation but there was no increase in the extent of Q waves on the resting electrocardiogram subsequently. Five had T wave inversion in anterior leads; the thallium images in two of these patients suggested patchy anteroseptal necrosis.

EXERCISE THALLIUM-201 IMAGING: ISCHAEMIA (Tables 1b and 3)

Before operation 34 patients had evidence of ischaemia on exercise thallium images: 28 of these developed ischaemic ST segment depression during exercise, one developed left bundle-branch block,

Table 3 Thallium-201 myocardial imaging—ischæmia

Electrocardiogram	No. of patients	Thallium-201 imaging Defect (ischæmia)	Normal
Preoperative	ST depression	29	28
	Non-specific	7	6
Postoperative	ST depression	13	9
	Non-specific	23	6
			17

and five had no changes on exercise electrocardiography. One patient with gross ST segment depression had extensive infarction rendering interpretation of the exercise thallium images difficult and one patient had no evidence of ischaemia on either test.

After operation 15 patients had evidence of continuing ischaemia on thallium imaging though in the majority the extent of the abnormality was reduced. All eight patients with persistent postoperative angina were in this group. Nine of these patients had ST segment depression on electrocardiography during exercise. Twenty-one patients had no evidence of ischaemia on thallium imaging after operation; all were free from symptoms and none had chest pain during exercise, but four developed ST segment depression at heavy work loads. Repeat coronary arteriography was undertaken on three patients (cases 33, 35, and 36) who had continuing and intractable angina after operation. In one patient (case 33) extensive anterior ischaemia on postoperative exercise thallium imaging correctly predicted occlusion of his single left anterior descending coronary artery graft. In the second patient (case 35) postoperative thallium imaging showed antero-septal ischaemia and a limited anterior infarct; left ventriculography after operation showed a new region of apical hypokinesia, the left anterior descending graft was occluded, and the sequential graft to the two circumflex branches was severely narrowed. In the third patient (case 36) postoperative thallium imaging showed infarction of the previously ischaemic antero-septal region with severe inferior ischaemia; left ventriculography showed a new region of anterior hypokinesia and all three grafts were occluded.

Discussion

The symptomatic improvement which follows aortocoronary bypass graft operations is well established, with 70 to 80 per cent of survivors free from symptoms and approximately 90 per cent

improved one to two years after operation (Dunkman *et al.*, 1974; Mundth and Austen, 1975). Evaluation of the functional result by maximal exercise testing and exercise electrocardiography gives results which are broadly in agreement with those from symptomatic assessment (Lapin *et al.*, 1973). Reported graft patency rates from several cardiac centres are similar, with 80 to 90 per cent of grafts patent six to 24 months after operation (Dunkman *et al.*, 1974). Good symptomatic results, improved exercise tolerance, and abolition of exercise-induced ST segment depression generally correlate with complete revascularisation and graft patency (Lapin *et al.*, 1973; Sheldon *et al.*, 1973), but this correlation is imprecise and similar results may be seen after perioperative myocardial infarction (Di Luzio *et al.*, 1974) or when all grafts are occluded (Block *et al.*, 1976; Benchimol *et al.*, 1976). Some patients who are free from symptoms after operation show 'ischaemic' ST segment depression without chest pain during exercise testing (Bartel *et al.*, 1973). This dissociation is only rarely seen before operation or on medical treatment and has led to the suggestion that some of the benefit of operation might be the result of a placebo effect or denervation of the ischaemic myocardial segment, as well as perioperative infarction of the previously ischaemic segment, improvement of left ventricular function, or improvement of myocardial blood flow by a patent bypass graft (Mnayer *et al.*, 1977).

Studies of left ventricular function at rest have given variable results, with improvement or worsening of overall or segmental function, often unrelated to graft patency (Chatterjee *et al.*, 1973; Hammermeister *et al.*, 1974; Shepherd *et al.*, 1974). Improved left ventricular function during exercise may be seen in patients with good preoperative left ventricular function and patent grafts (Barry *et al.*, 1976). Studies of left ventricular function and graft patency carry a potential risk, and it is probably no longer justifiable to undertake these routinely on patients who are free from symptoms after operation (Bristow *et al.*, 1977); in addition graft patency *per se* does not establish the extent of myocardial revascularisation. An objective assessment of myocardial perfusion is needed to investigate the results of operation.

Radioisotope techniques have been widely applied to the study of overall and regional coronary blood flow but studies on the results of coronary artery bypass operations have been limited. Xenon infusion provides a quantitative measure of regional myocardial perfusion and after successful grafting substantial increases of flow have been shown distal to the patent graft (Kreulen *et al.*, 1974; Korbuly

et al., 1975). A limited number of non-invasive studies, using the monovalent cations to provide a qualitative measure of regional myocardial perfusion, have shown improved perfusion associated with patent bypass grafts and persistent perfusion abnormalities related to ungrafted vessels, perioperative myocardial infarction, or occluded grafts. These studies have used potassium-43 (Zaret *et al.*, 1974), rubidium-84 (Knoebel *et al.*, 1974), rubidium-81 (Lurie *et al.*, 1976), and thallium-201 (Ritchie *et al.*, 1977a). Thallium-201 has become the radioisotope of choice for the non-invasive evaluation of myocardial perfusion. This has provided a highly sensitive technique for the detection of coronary artery disease, and comparison of rest and exercise myocardial images distinguishes ischaemia from infarction (Bailey *et al.*, 1977; Ritchie *et al.*, 1977b; Botvinick *et al.*, 1978). Myocardial uptake of thallium-201 correlates closely with regional myocardial perfusion determined independently using microspheres (Strauss *et al.*, 1975) and the technique has proved reproducible (McLaughlin *et al.*, 1977).

In this series the symptomatic results of operation were good with 78 per cent of patients free from symptoms and 86 per cent improved. Maximum heart rate achieved and duration of exercise were increased in the majority of patients. Evidence of perioperative myocardial infarction was found on thallium imaging in eight patients. In two of these the appearances suggested patchy anteroseptal necrosis with otherwise greatly improved perfusion. Myocardial necrosis may result from sudden reperfusion of a previously severely ischaemic region in patients in whom graft patency is later proven (Bulkley and Hutchins, 1977), and this is a possible mechanism in these cases. In the other six patients the thallium images suggested transmural infarction: two had new Q waves, one had transient ST segment elevation after operation, with no increase in the extent of Q waves subsequently, and three had T wave inversion in anterior leads. The limitations of standard electrocardiographic criteria for

the detection of perioperative myocardial necrosis compared with measurement of isoenzyme release and pyrophosphate imaging have been previously recognised (Platt *et al.*, 1976; Klausner *et al.*, 1977). Thallium imaging provides a simple technique for the demonstration of significant perioperative necrosis. The overall incidence of necrosis in this study was 8/36 (22.2%). Persistent T wave inversion in anterior or anterolateral leads is commonly observed after operation; in the 16 patients in whom these changes were observed in this series, they had no consistent significance in terms of regional myocardial perfusion as judged by thallium imaging. It is possible that minor myocardial damage below the resolution of the thallium imaging technique may be responsible for these electrocardiographic changes; however, the otherwise excellent results seen in the majority of these patients and the common occurrence of these changes after other heart operations not involving coronary artery bypass grafting suggest that these changes probably do not represent significant myocardial damage.

On the results of thallium imaging after operation the patients may be divided into three groups (Table 4). Group 1 comprises 21 patients, all free from symptoms, with no evidence of ischaemia on thallium imaging after operation; 18 had improvement in exercise duration after operation, and in 11 out of 15 ST segment depression was no longer seen during exercise. These results suggest patent grafts and complete revascularisation. The two patients with patchy anteroseptal necrosis are included in this group. Group 2 comprises nine patients with evidence of ischaemia on thallium imaging after operation; six were free from symptoms, five had improved exercise duration, and in three out of nine ST segment depression was no longer seen after exercise, the remaining six continuing to show ST segment depression. These results suggest inadequate revascularisation or occluded grafts. Restudy has been undertaken on one patient in this group in whom ischaemia on

Table 4 Thallium-201 myocardial imaging after operation

Group	Thallium-201 imaging	Number of patients	Angina (NYHA)			Exercise duration (min)			Resting ECG		Exercise ECG
			1	2	3	+	=	-	New Q waves	T inversion	
1	No ischaemia Complete revascularisation	21	21	0	0	18	3	0	0	8	4
2	Continuing ischaemia Partial revascularisation	9	6	1	2	5	4	0	0	5	6
3	Perioperative infarction and continuing ischaemia	6	1	3	2	2	3	1	2	3	3

Exercise duration: +, increased by 1 minute or more; =, unchanged; -, decreased by 1 minute or more (compared with preoperative).

thallium imaging after operation correctly predicted graft occlusion. Group 3 comprises six patients with perioperative myocardial infarction. In all, there was also evidence of ischaemia after operation; five of these patients still had angina, with little change in exercise tolerance, and three out of five continued to develop ST segment depression on exercise electrocardiography. Two patients in this group have been restudied: in each case left ventriculography showed a new region of hypokinesia corresponding to the infarcted myocardial segment, and the unchanged pattern of ischaemia in other myocardial segments was associated with graft occlusion.

Before operation, ST segment depression and the development of angina during exercise were closely related; however, after operation, 13 patients developed ST segment depression but only four of these developed angina during the exercise test. Nine of the 13 patients had definite evidence of ischaemia on thallium imaging though this was usually considerably reduced in extent compared with before operation. Four patients had continuing ST segment depression during exercise without evidence of ischaemia on thallium imaging, but in three of these there was evidence of previous infarction which may alter repolarisation during exercise.

This series does not represent a cross-section of our experience of coronary artery surgery during this period and is weighted by those patients whose progress after operation was complicated by persistence or recurrence of angina. It is not our policy to undertake reinvestigation by cardiac catheterisation in the absence of symptoms or if the preoperative or intraoperative assessment of left ventricular function and coronary anatomy suggest that a further operation would not be justified if graft occlusion were shown.

Thallium-201 myocardial imaging provides a simple, non-invasive, and objective assessment of regional myocardial perfusion after aortocoronary bypass operations and gives more information than symptoms, exercise testing, or electrocardiography. The technique elucidates the mechanisms of relief of angina by operation, helps in the management of the patient showing unsatisfactory progress after operation, and should prove useful in longer-term follow-up studies.

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