Clinical experience with left main coronary artery stenosis

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We report the clinical features and the results of investigation and surgery in 20 patients with significant left main coronary artery stenosis. All had moderate to severe angina; 8 had pain at rest. Three had dyspnoea as a major symptom.

The electrocardiogram was abnormal in 17, with evidence of previous myocardial infarction in 10. Of the 11 patients exercised, 8 developed chest pain. Nine patients had a normal left ventriculogram.

At coronary angiography all patients had major disease elsewhere in addition to the left main coronary artery stenosis. There were no deaths or major complications associated with this investigation.

One patient was unsuitable for surgery because of diffuse left ventricular hypokinesia, one had a fatal myocardial infarction while awaiting operation, and there was one perioperative death. Sixteen of the 17 surgical survivors are free from angina. There has been a significant improvement in the maximum exercise capacity in the 10 patients who had pre- and postoperative exercise tests.

Stenosis of the main stem of the left coronary artery carries a poor prognosis, with less than half the medically treated patients surviving 5 years after diagnosis (Bruschke, Proudfit, and Sones, 1973; Webster, Moberg, and Rincon, 1974; Cohen *et al.*, 1972). The earlier reports on investigation and surgery in patients with this lesion suggest that both are associated with a high mortality (Cohen *et al.*, 1972; Lavine *et al.*, 1972).

In the four-year period, November 1970 to October 1974, we investigated angiographically 665 patients with suspected coronary artery disease. Twenty of these had stenosis of the left main coronary artery of more than 75 per cent. The clinical features and the results of investigations and surgery in this group are reported.

Methods

The investigation protocol followed has been reported previously (Balcon *et al.*, 1974). Angina and dyspnoea were graded from 1 to 4, using the same criteria as the New York Heart Association grading for dyspnoea. Routine chest radiographs and electrocardiograms were made. The electrocardiographic diagnosis and localization

of myocardial infarction were based on the criteria of McConahay *et al.* (1970). The patients had fasting serum cholesterol and triglyceride estimations and lipoprotein electrophoresis, and the lipoprotein abnormality was typed using the World Health Organization classification (1970). Patients performed a standardized exercise test in the upright position on a bicycle ergometer with electrocardiographic recording from a bipolar chest lead. Exercise started at 150 kpm/min (24.5 Watts) and increased by 150 kpm/min (24.5 Watts) every two minutes until the development of angina, ST segment depression of 2 mm or more, dyspnoea, or fatigue.

Left heart catheterization was performed from the right brachial artery after premedication with intramuscular diazepam. The resting left ventricular end-diastolic pressure was recorded and those without chest pain at rest were paced, usually from the right atrium, until the patient developed angina. Left ventriculograms were graded from 0 to 4, 0 being normal and 1 to 4 showing an increasing area of abnormal movement. Coronary angiography was performed by the Sones technique in all cases. The angiographic severity of coronary artery disease was represented by a numerical score. Each major vessel was scored on a scale of 0 to 4; 0 was normal, 4 total occlusion, and 1 to 3 stenosis of increasing severity (1 less than 50%, 2 50 to 75%, and 3 75 to 99%).

Operation was usually performed within four weeks of investigation but patients with recurring episodes of rest

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TABLE 1

Case no.	Age (yr)	Sex	Angina		Dyspnoea	Previous myocardial infarction	Electrocardiogram	Chest radiograph	Serum lipids			Beta-adrenergic blocking agents		
			Grade	Duration (mth)					Cholesterol (mg/dl)	Triglycerides (mg/dl)	Lipo-protein abnormality	Trinitrin	Agent	Dose/day (mg)
1	49	M	3	60	—	+	AMI and IMI	Normal				+	Propranolol	240
2	48	M	4	3	—	0	Normal	Normal	360	288	Type 2b	0	—	—
3	42	M	2	3	1	+	IMI	Normal	240	230	Type 4	0	—	—
4	63	M	2	6	3	0	IMI	Cor+PVC	245	278	Type 4	0	—	—
5	59	M	4	8	—	0	Transient ST depression	Normal	200	285	Type 4	+	Practolol	300
6	59	M	3	96	3	+	IMI	Enlarged heart, PVC	225	207	Type 4	+	—	—
7	45	M	3	72	—	0	LBBB	Normal				+	Propranolol	240
8	51	M	3	120	—	+	IMI	Normal	175	384	Type 4	0	Practolol	200
9	51	F	2	6	1	0	ASMI	Normal	356	133	Type 2a	0	Propranolol	60
10	60	M	4	36	—	0	Transient ST depression	Normal	260			+	Propranolol	120
11	48	M	2	12	2	0	Normal	Normal	286	220	Type 4	+	Practolol	300
12	49	M	2	60	—	+	ASMI	Normal				0	Propranolol	120
13	52	M	4	72	—	+	AMI	Normal	164			+	Oxprenolol	120
14	34	F	4	3	—	0	Transient ST depression	Normal	242	85	Normal	+	—	—
15	47	M	3	108	—	+	Inverted T in V3-6	Normal	260	24	Normal	+	Practolol	800
16	68	M	2	6	3	+	IMI	Enlarged heart, PVC	265	150	Normal	0	—	—
17	50	M	4	132	2	+	AMI and IMI	Enlarged heart				+	Oxprenolol	120
18	66	M	4	120	—	0	Transient ST depression	Normal	275			+	—	—
19	49	M	2	36	1	0	Normal	Normal	190	150	Normal	0	—	—
20	40	M	4	12	1	0	Inverted T in V3-6	Normal	235	180	Normal	+	Practolol	200

AMI, anterior myocardial infarction; IMI, inferior myocardial infarction; LBBB, left bundle-branch block; ASMI, antero-septal myocardial infarction; PVC, pulmonary venous congestion. Conversion from Traditional to SI units: Cholesterol: 1 mg/dl $\approx$ 0.02586 mmol/l; triglyceride: 1 mg/dl $\approx$ 0.0113 mmol/l.

pain had operation within 24 hours of coronary angiography. These latter patients had continuous electrocardiographic monitoring and regular sublingual trinitrin to relieve chest pain in the interval between angiography and surgery, but in no case was it considered necessary to use balloon counterpulsation.

Great care was taken to avoid any fall in blood pressure during induction of anaesthesia, and where necessary pressor agents were used. In all cases the heart was prepared for bypass as quickly as possible. Once on bypass the major division of the left coronary artery was prepared and an anastomosis, using either the left internal mammary artery or a long saphenous vein, was carried out. Occasionally an endarterectomy was performed first. If a vein was used it was immediately anastomosed to the aorta to establish coronary flow as quickly as possible. The other diseased arteries were grafted as necessary. Normothermic bypass was used throughout, together with elective fibrillation and aortic cross-clamping for periods up to 15 minutes as required.

The patients were seen at three months, six months, and then yearly after operation. Exercise tests were performed at each visit.

Results

The clinical data are shown in Table 1. There were 18 men and two women with ages ranging from 34 to 68 years (average of 52 years). Angina was the main symptom in 17, but was also present in the 3 other patients whose main complaint was dyspnoea. The mean grade of angina was 3.1 out of 4 (range 2 to 4). Eight patients had episodes of pain at rest. The mean duration of angina was 48 months, but was less than 6 months in 6 patients. Nine patients had a history of previous myocardial infarction. Four had diabetes (Cases 3, 4, 8, and 11). The mean serum cholesterol concentration was 249 mg/dl (6.4 mmol/l) with a range from 164 to 360 mg/dl (4.2 to 9.3 mmol/l). Six patients had a type 4 lipoprotein abnormality, one a type 2a and one a type 2b. The resting electrocardiogram was abnormal in 17, with 10 patients showing changes consistent with previous myocardial infarction.

Four had transient ST segment depression during

FIG. 1 Transient ST depression occurring at rest during angina.

TABLE 2

Case no.	Duration of follow-up (mth)	Angina grade		Maximum exercise load and end-point (kpm/min)	
		Preoperative	Postoperative	Preoperative	Postoperative
1	21	3	0	600, angina	1050, fatigue
2	14	4	0	600, ST depression and angina	750, fatigue and dyspnoea
3	12	2	1	600, dyspnoea	750, fatigue and dyspnoea
4	9	2	0	Not done	450, fatigue
5†	—	4	—	600, ST depression and fatigue	Died awaiting operation
6	6	3	0	150, dyspnoea and fatigue	300, fatigue
7	7	3	0	Not done	600, fatigue
8	9	3	0	450, dyspnoea	750, dyspnoea
9	10	2	0	450, angina	600, fatigue and dyspnoea
10	35	4	0	Rest pain	600, dyspnoea and ST depression
11	24	2	0	600, angina	750, fatigue
12	18	2	0	450, angina	600, fatigue
13	19	4	0	Not done	600, fatigue
14†	—	4	—	Rest pain	Died at operation
15	18	3	0	300, ST depression and angina	600, dyspnoea, fatigue and ST depression
16	4	2	Non-surgical		
17	4	4	0	600, angina	600, fatigue
18	3	4	0	Rest pain	Not done
19	3	2	0	Not done	1050, fatigue
20	3	4	0	Rest pain	900, fatigue

†Hospital death. 1 kpm/min=0.1635 Watt

episodes of rest pain. Fig. 1 shows intermittent ST depression at rest in Case 18. Four patients had cardiomegaly on chest x-ray. Twelve had been treated with sublingual trinitrin and 12 with beta-adrenergic blocking agents.

Eleven patients performed the exercise test before operation (Table 2). The mean maximum exercise level achieved was 490 kpm/min (80.1 Watts) with a range of 150 (24.5 Watts) to 600 kpm/min (98.1 Watts). The end-point in eight of these was angina and in three it was dyspnoea. Three of the patients who were limited by angina developed ST depression of 2 mm or more at end-point.

Cardiac catheterization data are shown in Table 3. Eleven patients underwent the pacing stress test during catheterization. Angina was induced in these at heart rates ranging from 100 to 170 beats per minute. Five other patients had angina at rest during catheterization. The resting left ventricular end-diastolic pressures ranged from 5 to 48 mmHg (0.7 to 6.4 kPa), with a mean of 16 mmHg (2.1 kPa).

The left ventriculogram was normal in 9 patients. Five had a grade 1, 3 a grade 2, and 2 a grade 3 abnormality on their ventriculogram. Only 1 patient had diffuse left ventricular dysfunction (grade 4).

TABLE 3

Case no.	Left ventricular end diastolic pressure (mmHg)	Maximum pacing rate (beats/min) at angina	Coronary arteries: grading of disease †			Left ventricular angiographic grade
			Left anterior descending	Left circumflex	Right	
1	17	150	2 ^m	3*	1	1
2	5	170	2*	4*	0	0
3	17	150	3*	3*	3*	1
4	12	Rest pain	2*	3	4*	2
5	16	100	3	0	1	0
6	25	Not done	3*	1	4*	3
7	25	Not done	2*	2*	3* E	1
8	7	150	4* E	2	4* E	0
9	15	150	3*	3*	3*	1
10	48	Rest pain	0*	0*	3	2
11	7	110	3*	3*	2	0
12	10	170	4*	0*	2	2
13	10	130	3*	3	3	0
14	18	Rest pain	1*	3*	2	0
15	10	150	3 ^m	3*	4*	1
16	18	Not done	3	4	4	4
17	26	150	D* 4*	3	4*	3
18	8	Rest pain	2	2*	3*	0
19	12	Not done	3*	3*	0	0
20	20	Rest pain	D* 3*	3*	2*	0

Conversion from traditional to SI units: 1 mm Hg $\approx$ 0.133 kPa

†All patients had grade 3 stenosis of left main coronary artery

m, vessel bypassed with left internal mammary artery

*, vessel bypassed with saphenous vein

E, endarterectomy

D, diagonal branch left anterior descending grafted

All had at least one other major lesion (grade 3 or 4) in the coronary tree besides the left main coronary artery stenosis. Six patients had lesions of 2 other vessels and a further 6 had lesions of 3 vessels. The right coronary artery was affected in 12. There was radiographic calcification in the region of the left main stem in only 3 patients (Cases 1, 16, and 19). There were no major complications associated with the investigation.

One patient (Case 5) had a fatal myocardial infarction in hospital while awaiting operation. Another patient (Case 16) who presented with dyspnoea was considered unsuitable for surgery, because of diffuse left ventricular hypokinesia.

Eighteen patients had surgical treatment. The vessels bypassed and the types of graft used are indicated in Table 3. One patient had a single graft, 11 had double, 5 had triple, and 1 quadruple grafts. A prior endarterectomy was performed on 3 vessels and the left internal mammary artery was used twice. The graft flow was measured in 24 vessels and ranged from 30 to 140 ml/min, with a mean of 78 ml/min.

One patient (Case 14) became hypotensive during induction of anaesthesia and developed resistant ventricular fibrillation. At thoracotomy a large

portion of the left ventricle in the region supplied by the left coronary artery was non-contractile. A double coronary artery graft was performed but the patient did not survive operation.

The follow-up data are shown in Table 2. The mean duration of follow-up is 12.2 months. There have been no late deaths or myocardial infarctions. Only one patient (Case 3) of the 17 surgical survivors has angina. Sixteen patients have had post-operative exercise tests. The mean maximum level achieved after operation was 684 kpm/min (111.8 Watts), with a range of 300 to 1050 kpm/min (49 to 171.7 Watts). In Fig. 2 a comparison of the mean preoperative with the latest postoperative exercise level achieved by 10 patients indicates a significant improvement in performance. The 6 patients who did not have a preoperative exercise test have a mean postoperative exercise performance of 700 kpm/min (114.5 Watts).

Discussion

The incidence of left main coronary artery stenosis among patients investigated for coronary artery disease in our department is 3 per cent. Wolfson, Grant, and Ross (1973), who also reported on left

FIG. 2 The results of pre- and post-operative exercise tests.

main coronary artery stenoses of 75 per cent or greater, found a similar incidence. Other authors (Cohen *et al.*, 1972; Khaja *et al.*, 1974; Proudfit, Shirey, and Sones, 1967) who reported on stenoses of more than 50 per cent found an overall incidence varying from 2.5 to 5.9 per cent.

The majority of our patients had severe angina. Cohen *et al.* (1972) while recognizing that there were no features specific to left main coronary artery stenosis, suggested it could be anticipated before angiography in patients showing a 'profound ischaemic response' on their electrocardiogram during exercise. 82 per cent of their group and 77 per cent of Khaja's group had a positive exercise test. Only 27 per cent of our group who exercised on a bicycle ergometer developed ST depression. This discrepancy may be related to the method of exercise testing used, or to the fact that we recorded from a single praecordial lead.

Major coronary lesions other than left main coronary artery stenosis were present in all our patients. This is the usual finding both at coronary angiography (Lavine *et al.*, 1972; Rosch *et al.*, 1973) and at necropsy (Bulkley and Roberts, 1974). Lavine *et al.* (1972) in their report comment that the clinical features of these patients may be as much a reflection of the generalized coronary artery disease as of the left main coronary artery lesion.

The risk of coronary angiography in these patients is well known (Cohen *et al.*, 1972; Lavine *et al.*,

1972). Some authors (Cohen *et al.*, 1972; Rosch *et al.*, 1973) have suggested a preliminary test injection in the left posterior sinus of Valsalva in patients with suspected left main coronary artery disease. As indicated above, however, we were seldom able to predict from clinical findings, exercise testing, or other parameters, those patients likely to have left main coronary artery stenosis. Nevertheless, there were no major complications and no fatalities associated with angiography in this series, nor in other recently reported series (Khaja *et al.*, 1974; Zeff *et al.*, 1974).

Surgical mortality for left main coronary artery stenosis from the reported series ranges from 8.2 to 39 per cent (Pichard *et al.*, 1973; Zeff *et al.*, 1974; Khaja *et al.*, 1974; Cohen *et al.*, 1972; Kisslo *et al.*, 1973). The surgical mortality for our group (5.5 per cent) lies between our overall figures of 1.9 per cent for patients with effort angina and 12.5 per cent for patients with cardiac pain at rest. Hypotension during induction of anaesthesia is a recognized hazard in these patients (Cohen *et al.*, 1972). The surgical death in our group was related to this complication, though precautions had been taken to avoid it. The striking symptomatic improvement among the surgically treated group has been mirrored in their improved exercise performance.

Our studies have led us to the conclusion that patients with left main coronary artery stenosis also have severe coronary lesions elsewhere but behave no differently from other patients with severe coronary artery disease, either from the clinical and investigative point of view, or in their distinct symptomatic improvement with surgical treatment.

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