

# Long-term clinical outcome following coronary artery bypass grafting for isolated stenosis of the left anterior descending coronary artery

T. G. Hennessy\*, M. B. Codd†, S. Donnelly\*, C. Hartigan\*, H. A. McCann\*, C. McCarthy\*, M. Neligan‡, A. E. Wood‡, D. Luke‡, E. McGovern‡, T. Aherne§ and D. D. Sugrue\*

Departments of \*Clinical Cardiology, †Epidemiology/Health Services Research and ‡Cardiothoracic Surgery, Mater Misericordiae Hospital (University College), Dublin and §Department of Cardiothoracic Surgery, Cork Regional Hospital, Cork, Ireland

**Aims** To detail the clinical and angiographic profile, and long-term outcome in consecutive patients with isolated stenosis of the left anterior descending coronary artery undergoing bypass surgery.

**Methods** A retrospective study of all patients (n=301) (January 1984–December 1990) and undergoing coronary artery bypass grafting for isolated left anterior descending disease, in the Irish Republic, was performed. Survival was compared with that of an exact age- and gender-matched cohort.

**Results** Mean age was 53 ( $\pm 9.3$ ) years. There were 238 (79%) males. In 241 (80%) patients an internal thoracic arterial bypass graft was used. Operative mortality was 1.3%. Of the 280 (93%) patients alive (16 cardiac deaths) at 7.1 ( $\pm 1.9$ ) years, 105 (35%) had angina, 26 (9%) suffered an

interval myocardial infarction, and repeat revascularization was required on 29 (10%). Female gender ( $P=0.002$ ), pre-operative myocardial infarction ( $P=0.02$ ), significant diagonal disease ( $P=0.04$ ) and postoperative myocardial infarction ( $P=0.0001$ ) were independently associated with survival. Females were more likely to develop congestive cardiac failure ( $P=0.01$ ) or postoperative angina ( $P=0.03$ ) than their male counterparts.

**Conclusions** Survivorship (97%) and event-free survival (96%) at 5 years following coronary artery bypass grafting for isolated left anterior descending coronary artery disease is excellent and equivalent to an age-matched and gender-matched cohort.

(*Eur Heart J* 1998; 19: 447–457)

**Key Words:** Bypass, grafting, coronary disease, survival.

## Introduction

The use of reversed saphenous vein autografts for bypassing severe segmental coronary artery stenoses was first described by Favaloro in 1968<sup>[1]</sup>. In the ensuing quarter of a century, there have been major improvements in surgical technique and postoperative care resulting in better outcomes<sup>[2]</sup>. In addition there has been an increase in the use of the internal thoracic artery as a conduit, in particular for bypassing left anterior descending coronary artery stenoses.

Clinical and angiographic studies suggest that when a significant stenosis is located proximal to the

first major septal perforator of the left anterior descending coronary artery the prognosis may be especially poor<sup>[3–7]</sup>, hence the terminology 'widow-maker' lesion. These are a group of special interest to cardiologists and cardiac surgeons. Despite the lack of a scientifically documented mortality benefit of coronary artery bypass grafting for isolated left anterior descending coronary artery lesions, the presumed unfavourable outcome for medical therapy has led to a low threshold for recommending revascularization, either by coronary artery bypass grafting or percutaneous therapies.

This retrospective historical cohort study details the clinical and angiographic profile, morbidity, mortality and long-term outcome of coronary artery bypass grafting for isolated stenosis of the left anterior descending coronary artery. The results should act as a benchmark for assessing the benefit of percutaneous strategies.

Revision submitted 31 August 1997, and accepted 5 September 1997.

*Correspondence:* Dr Declan Sugrue, Dept of Clinical Cardiology, Mater Misericordiae Hospital (University College), Eccles Street, Dublin 7, Ireland.

## Patients and methods

Ireland has a population of 3.5 million, of whom approximately 1.3 million live in the greater Dublin area. With a population of this size centralization of complex medical and surgical services is essential. The Mater Misericordiae Hospital, Dublin, was designated the National Cardiac Surgical Centre, and until 1986 remained the only centre performing open heart surgery. This presented a unique opportunity to record all open heart operations for the country on one database. Thus the National Cardiac Surgical Register came into being in 1983<sup>[8]</sup>. The importance of the register as a repository of all open heart operations became more apparent with the development of cardiac surgical facilities in three further locations (two private) in 1986 and afterwards. The Cardiac Surgical Register thus represents a truly population-based registry of open heart operations for the country.

The Cardiac Surgical Register thus described was the pivotal source of information for this historical cohort study, in which all patients who underwent coronary artery bypass grafting for isolated left anterior descending coronary artery stenosis in Ireland during the 7-year period from 1 January 1984 to 31 December 1990 were identified. Permission to retrieve and review pre-operative angiograms and case records was granted by all physicians and surgeons concerned in the care of these patients. All angiograms were reviewed by two cardiologists (D.S. and H.McC.) to confirm normality of the left circumflex and right coronary arterial systems and to score the severity and site of disease in the left anterior descending coronary artery system. Scoring of disease severity was by consensus of opinion in all cases. The left anterior descending coronary artery was divided into proximal, middle and distal segments. Each segment was scored visually using orthogonal views as follows: 0=no disease, 1=stenosis  $\leq$  50%, 2=stenosis 51–75%, 3=stenosis 76–95%, 4=stenosis  $>$  95%, 5=total occlusion, 9=unknown. The diagonal branch of the left anterior descending coronary artery was also scored using a similar system. The distal left anterior descending coronary artery was also scored based upon size (normal, large, small) and presence or absence of atherosclerosis. Contrast left ventriculography was visually scored for ejection fraction as follows: 1= $>$  55%, 2=40–54%, 3=20–39%, 4= $<$  19%, 9=unknown. Contrast left ventriculograms were also scored for wall motion abnormalities as outlined: 0=normal, 1=hypokinesis, 2=akinesis, 3=dyskinesis, 9=unknown. Angina class prior to operation was classified according to the Canadian Cardiovascular Society<sup>[9]</sup>. The presence and time of myocardial infarction pre-operatively was ascertained. The performance of percutaneous transluminal coronary angioplasty prior to coronary artery bypass grafting was detailed where appropriate and the reason for failure of this intervention was documented.

All operative data were retrieved. Target arteries (left anterior descending coronary artery  $\pm$  diagonal) and graft type (reversed saphenous vein or left internal

thoracic artery) were noted. Postoperative complications, defined as any of the listed complications occurring within 30 days of surgery, were recorded. Complications included: death, cardiac tamponade, cerebrovascular accident, Q wave myocardial infarction, unstable sternum requiring re-wiring, wound infection and other.

For all patients follow-up was complete to September 1994, giving a minimum of 4 years follow-up for even the most recently treated patients in the study cohort. Follow-up was by self-administered postal questionnaire in the first instance. For those who failed to reply, contact was made by telephone with the patient, family member or general practitioner. Information sought at follow-up included the following: vital status, clinical status, i.e. presence or absence of angina, congestive cardiac failure, myocardial infarction since coronary artery bypass grafting, need for further revascularization, and use of aspirin and anti-anginal therapies.

## Data handling and statistical analysis

All data were recorded on standardized data sheets pre-coded for computer entry. Data were analysed using SAS for Windows (version 6.08). Statistical procedures employed included the Student t-test for comparison of continuous variables and the chi-square test for discrete variables. Variables significant on univariate analysis were subjected to multivariate analysis using logistic regression.

Survival in the study cohort was compared with that of an exact age- and gender-matched cohort from the general population using Kaplan–Meier survival analysis. Data on survival for the general population was derived from the Irish Life Tables for 1990–1992 as compiled by the Central Statistics Office<sup>[10]</sup>. This time period was chosen to coincide with the follow-up period of the study group. The data presented in the Irish Life Tables include the number surviving to exact age X, and the complete expectation of life at each year of age, for males and females separately. Five and ten year survival for an age-frequency matched (to the study cohort) cohort of the general population aged 25–74 were thus calculated.

Event-free survival for the study cohort examined survival up to 10 years free from myocardial infarction, revascularization or angina, again using Kaplan–Meier methodology.

## Results

During the 7-year period 1984–1990, 301 patients had surgery for isolated left anterior descending coronary artery disease. Table 1 details the pre-operative demographic and clinical features in these patients. The mean age was 53 years, more than three quarters of the cohort

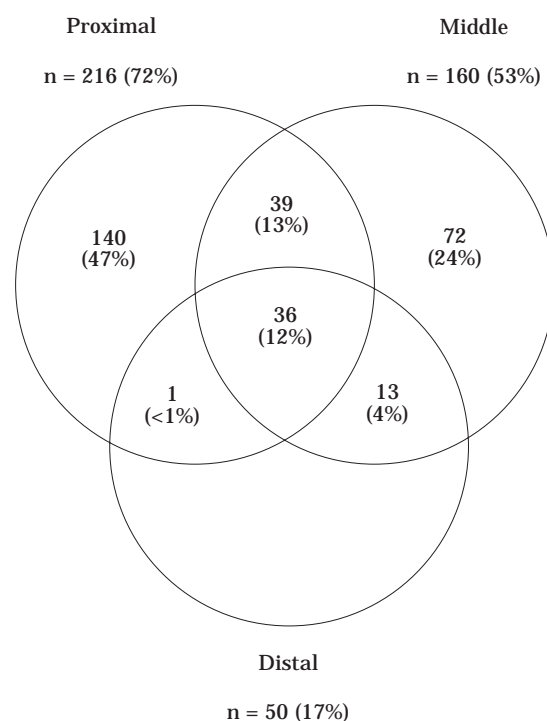
**Table 1 Pre-operative demographic and clinical features in 301 patients undergoing coronary artery bypass grafting for isolated left anterior descending coronary artery stenosis. Values are n (%) except for years**

Age (years)		
mean (SD)	53.1	(9.3)
Gender		
male	238	(79)
female	63	(21)
Angina		
none	8	(3)
I/II	115	(38)
III/IV	178	(59)
Myocardial infarction		
<1 month	8	(3)
1–3 months	21	(7)
3–12 months	42	(14)
>12 months	35	(12)
Left ventricular ejection fraction		
>55%	214	(72)
40–54%	70	(23)
20–39%	13	(4)
<19%	1	(<1)

were men; 178 (59%) had severe angina and one third had had a prior myocardial infarction. Three quarters of the patients had normal left ventricular function.

The pre-operative angiographic status of the left anterior descending coronary artery and first diagonal branch (D1) are detailed in Table 2 and Fig. 1. A total of 202 (67%) patients had a stenosis >50% proximal to the first septal perforator ('widowmaker' anatomy). All patients with either no disease or <50% stenosis of the proximal left anterior descending coronary artery had significant mid left anterior descending coronary artery disease (defined as stenosis >50%). Over two-thirds of patients (208; 69%) had normal diagonal vessels, whilst the remaining 93 (31%) patients had varying degrees of disease ranging from mild stenosis to total occlusion (Table 2).

Percutaneous transluminal coronary angioplasty had been performed in 40 (13%) patients prior to coronary artery bypass grafting. Emergency coronary artery bypass grafting for abrupt closure was performed on 14 of these patients, elective coronary artery bypass grafting in 10, while 16 had elective coronary artery



**Figure 1 Segmental distribution of left anterior descending coronary artery disease in 301 consecutive patients undergoing isolated coronary artery bypass grafting.**

bypass grafting for restenosis after percutaneous transluminal coronary angioplasty.

The left internal thoracic artery was used as a conduit in 241 patients (80%) with the remaining 60 patients having a saphenous vein graft to the left anterior descending coronary artery. A second graft was placed to a diagonal branch in 133 patients (44%).

Table 3 documents the operative and postoperative complications. There were four deaths (1.3%), two of which occurred in patients undergoing emergency coronary artery bypass grafting for abrupt vessel closure during percutaneous transluminal coronary angioplasty. The three cases of tamponade were successfully treated by re-operation. One patient suffered a right hemiplegic stroke and one a mild left upper limb hemiparesis. There were two peri-operative myocardial infarcts. The 'other'

**Table 2 Pre-operative angiographic status of the left anterior descending coronary artery and its first diagonal branch in 301 patients undergoing coronary artery bypass grafting**

Stenosis severity	Any disease	≤50%	51–75%	76–95%	>95%	100%
LAD						
Proximal	216 (72%)	14	44	116	17	25
Middle	160 (53%)	30	27	61	4	38
Distal	50 (17%)	17	2	—	—	31
First diagonal	93 (31%)	6	26	33	4	24

LAD=left anterior descending coronary artery.

complications included nine patients with pneumonia, and 57 patients with minor complications including delayed wound healing, atrial fibrillation and other arrhythmias.

### Follow-up

Follow-up was complete in all patients through September 1994. The mean (SD) duration of follow-up was 7.1 ( $\pm$  1.9) years. At last follow-up 280 patients (93%) were alive (there had been 16 cardiac and five non-cardiac deaths: three malignancies, one suicide, one cerebrovascular accident), 105 (35%) had angina (median of 3.3 years, range 0–10.2 years following coronary artery bypass grafting), 26 (9%) had suffered an interval myocardial infarction (median of 6 years, range 0–10.4 years following coronary artery bypass grafting) and 38 (13%) had congestive cardiac failure (median of 3.5 years, range 0–10.4 years following coronary artery bypass grafting). Coronary angiography had been repeated in 66 patients (22%). Further revascularization was required in 29 (10%). Percutaneous transluminal coronary angioplasty was performed on the native left anterior descending coronary artery in three patients with occluded grafts. Coronary angioplasty for new significant disease in other vessels was performed in eight patients (five left circumflex, three right coronary). Repeat coronary artery bypass grafting was performed on 18 (6%) patients at a mean of 5.2 ( $\pm$  2.1) years from the index operation. Two redo single bypass operations to the left anterior descending coronary artery for graft occlusion were performed. Of the 16 multiple graft redo procedures, seven required repeat revascularization of the left anterior descending coronary artery territory, in addition to grafting of their circumflex and right coronary arteries.

At last follow-up, 227 patients (75%) were taking regular aspirin. The mortality in this group was identical to the group not taking aspirin. Approximately one third of patients (106) were using one or more anti-anginal medications.

Survival in this cohort of patients undergoing left anterior descending coronary artery surgery is illustrated in Fig. 2 and documented in Table 4. Five-year survival was 97%; survival to 10 years was 87%. Compared with an age- and gender-matched cohort from the general population this is an excellent result. As is evident from Fig. 2, there is essentially no difference in the observed vs expected (population) survival. In fact the patients undergoing bypass grafting for isolated left anterior descending coronary artery disease showed a marginal survival advantage at 5 and 10 years.

Event-free survival in the study cohort is shown in Fig. 3. Four plots documenting (a) survival, (b) survival free of myocardial infarction, (c) survival free of infarction and/or revascularization, (d) survival free of all events including angina are shown. Data supporting Fig. 3 are given in Table 4. After 5 years of follow-up, an increasing proportion of patients developed symptoms

**Table 3 Peri-operative complications in 301 consecutive patients undergoing coronary artery bypass grafting for isolated left anterior descending coronary artery stenosis**

Complications	n	(%)
Death		
all operations	4	(1.3)
elective operations	2	(0.6)
Tamponade	3	(1)
Stroke	2	(0.6)
Infarction	2	(0.6)
Unstable sternum	3	(1)
Wound infection	6	(2)
Other	66	(22)

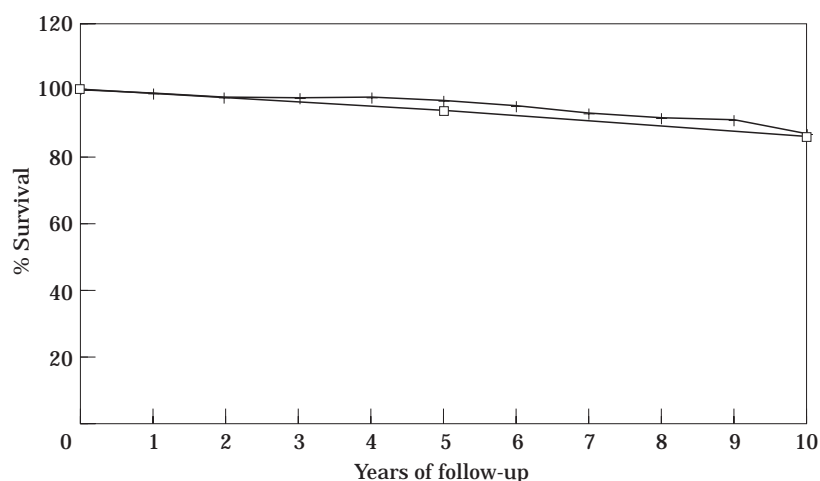
and/or required revascularization. At 10 years, only 34% were completely symptom or intervention free.

Factors significantly related to survival are outlined in Table 5. They include female gender ( $P=0.002$ ), pre-operative myocardial infarction ( $P=0.02$ ), distal left anterior descending coronary artery disease ( $P=0.007$ ), significant diagonal disease ( $P=0.004$ ), impaired left ventricular function ( $P=0.003$ ) and saphenous vein bypass graft to the left anterior descending coronary artery ( $P=0.03$ ). Myocardial infarction during the follow-up interval also decreased the likelihood of survival ( $P<0.0001$ ). Age, presence or class of angina postoperatively ( $P=0.08$ ), congestive cardiac failure, need for revascularization or placement of an additional vein graft to the diagonal did not impact on survival. Using multivariate logistic regression analysis, only female gender ( $P=0.002$ ), pre-operative myocardial infarction ( $P=0.02$ ), significant diagonal disease ( $P=0.04$ ), and occurrence of a myocardial infarction in the follow-up period ( $P=0.0001$ ) were independently associated with mortality (Table 5 and 9).

Table 6 documents factors related to development of congestive cardiac failure, Table 7 factors related to occurrence of myocardial infarction, and Table 8 factors related to development of angina during follow-up. On multivariate logistic regression analysis, female gender was associated with the presence of congestive cardiac failure ( $P=0.01$ ) and postoperative angina ( $P=0.03$ ). Furthermore the presence of post-operative angina was associated with the occurrence of an interval myocardial infarction ( $P=0.001$ ) (Table 9).

## Discussion

This study confirms the excellent outcome of coronary artery bypass grafting for isolated left anterior descending coronary artery stenosis both in terms of survival, freedom from symptoms and re-interventions.



**Figure 2** Survival following bypass grafting for isolated left anterior descending coronary artery disease, 1984–1990: comparison with an age and gender matched population. Numbers remaining at each year of follow-up in the study group are given in Table 4. □ = population cohort; + = study cohort.

**Table 4** Coronary artery bypass grafting for isolated left anterior descending coronary artery disease in 301 consecutive patients: survival, event free survival and cumulative number of events on follow-up

Years of follow-up	Number remaining	Vital status EFS events		Vital status or MI EFS events		Vital status, MI or revasc EFS events		Vital status, MI, revasc angina EFS events	
		%	n	%	n	%	n	%	n
1	297	98.7	4	98.7	4	98.7	4	98.7	4
2	296	98	5	98	5	98	5	98	5
3	296	98	5	98	5	98	5	98	5
4	295	98	6	98	6	98	6	98	6
5	273	97	9	97	10	96	11	95	15
6	212	95.5	13	94	16	92.5	21	87	36
7	142	93	17	90	23	87.6	30	78	58
8	98	92	19	88	26	84	35	68	73
9	55	90	20	85	29	76.6	42	52	93
10	24	87	21	76	33	60	51	34	108

EFS=event free survival; Events=cumulative number of events; MI=myocardial infarction; Revasc=revascularization.

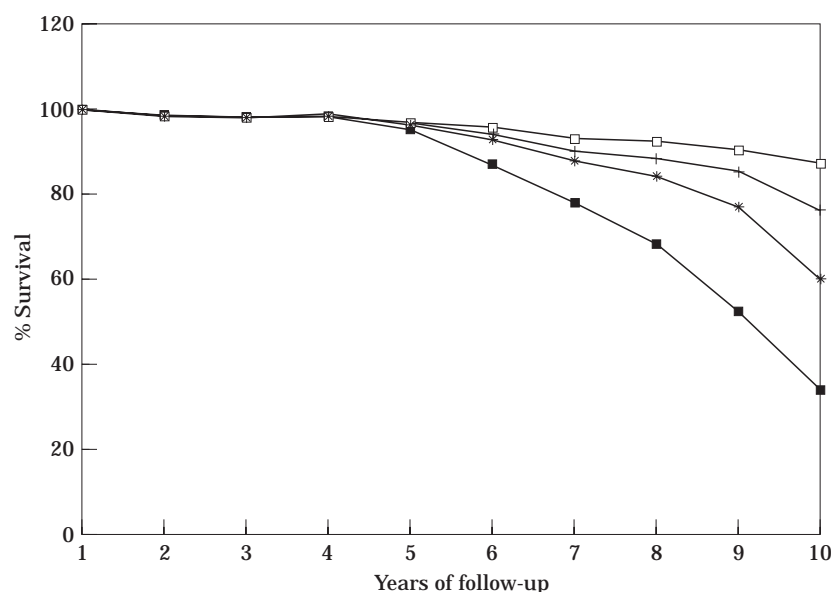
### *Outcome of surgery for isolated left anterior descending coronary artery disease — the present study*

The patient population undergoing coronary artery bypass grafting for isolated left anterior descending coronary artery disease were generally of a young age (mean age=53 years), with almost two-thirds having Canadian Cardiovascular Class III or IV angina, and one-third a prior myocardial infarction (Table 1). The medium to long-term survival for the group as a whole was excellent: 97% of patients were alive at 5 years, 87% at 10 years (Table 4, Fig. 2). In the 202 patients with widowmaker anatomy, 190 (94%) were alive at follow-up. Females were more likely to die, develop angina or heart failure (Table 9). Pre- and postoperative myocardial infarction not surprisingly reduced the probability of survival. Presumably by indicating a more diffuse

disease process the presence of diagonal disease was also associated with reduced survival at follow-up (Table 9). Selection bias for bypass grafting resulted in few patients having significant distal left anterior descending coronary artery stenoses (n=33), or small atheromatous distal vessels (n=54) (Table 2), which probably accounts for a lack of influence of these variables on outcome on multivariate logistic regression analysis. Similarly, impaired ventricular systolic function did not adversely effect survival because of the small number of patients with an ejection fraction less than 40%.

### *Natural history of proximal left anterior descending coronary artery disease*

Califf reported that in patients with angiographically significant left anterior descending coronary artery



**Figure 3** Survival and event free survival following bypass grafting for isolated left anterior descending coronary artery disease, 1984–1990. Number remaining at each year of follow-up in the study are given in Table 4. □ = death; + = death or myocardial infarction; \* = death, myocardial infarction or revascularization; ■ = death, myocardial infarction, revascularization or angina.

lesions proximal to the first septal perforator, the 5-year survival was 90% vs 98% survival in patients with a more distal left anterior descending coronary artery stenosis<sup>[11]</sup>. However, in 96 medically treated patients with proximal left anterior descending coronary artery lesions and normal left ventricular function 95% were alive at 5 years and only 13% had suffered a non-fatal myocardial infarction. Kouchoukas reported no mortality in 24 medically treated patients with left anterior descending coronary artery disease followed to 3.5 years<sup>[12]</sup>. Other series have reported annual mortality rates of 2.3–7.7%<sup>[13–16]</sup>. An autopsy study showed a preponderance of complete occlusions of the proximal left anterior descending coronary artery in patients who died following myocardial infarction<sup>[17]</sup>.

### *Outcome of surgery for isolated left anterior descending coronary artery disease — reported studies*

Between 1972 and 1984, there were seven randomized trials in which coronary artery bypass grafting was compared with contemporary medical treatment in 2649 patients<sup>[18]</sup>. In total 1324 patients were randomly assigned to surgery, and 1325 to medical treatment. The proximal left anterior descending coronary artery was affected in 1549 patients (59%). Of those patients randomized to surgery, 131 (10%) received an internal thoracic artery graft. Only 524 patients had left anterior descending coronary artery disease as part of single or double vessel disease<sup>[18]</sup>. The presence of proximal left anterior descending coronary artery stenosis increased

the 5-year mortality rate in medically treated patients with single or double vessel disease (14.6% mortality vs 8.3% if no left anterior descending coronary artery disease). This supports the concept that the greater the amount of myocardium in jeopardy the larger the potential prognostic advantage of revascularization<sup>[19]</sup>.

The European Coronary Surgery Study group reported that in patients with  $\geq 50\%$  stenosis of the proximal third of the left anterior descending coronary artery constituting a component of either two- or three-vessel disease there was a highly significant survival difference between the surgically and medically treated patients at 5 years follow-up (92.7% vs 82.0% survival,  $P=0.0004$ )<sup>[20]</sup>. In the Coronary Artery Surgery Study (CASS) no significant advantage in survival or event-free survival for an initial strategy of surgery was observed in patients with left anterior descending coronary artery disease, irrespective of whether the lesion was proximal or mid-vessel in location, or whether in conjunction with one-, two- or three-vessel disease<sup>[21]</sup>. In the MASS (Medicine, Angioplasty or Surgery Study) 214 patients with widowmaker anatomy, stable angina and normal left ventricular function were randomized to internal thoracic artery bypass surgery ( $n=70$ ), balloon angioplasty without new devices ( $n=72$ ) or medical therapy alone ( $n=72$ ). At a mean follow-up of 3 years, a primary end-point (cardiac death, myocardial infarction, revascularization for refractory angina) had occurred in two (3%) of the surgery group, 17 (24%) of the angioplasty group, and 12 (17%) assigned to medical therapy<sup>[22]</sup>. All three strategies resulted in a similar outcome with regard to death or infarction. The majority of the surgical (98%) and angioplasty (82%)

**Table 5** Coronary artery bypass grafting for isolated left anterior descending coronary artery stenosis in 301 consecutive patients: factors related to vital status at follow-up. Values are n (%) except for years

	Vital status		Significance	
	Alive (n=280)	Dead (n=21)	Univariate analysis	Multivariate analysis
Age (years) mean (SD)	52.8 (9.1)	56.2 (11.6)	ns	
Gender				
Male	227 (81)	11 (52)		
Female	53 (19)	10 (48)	$P=0.002$	$P=0.002$
Angina pre-op.				
0/I/II	118 (42)	5 (24)		
III/IV	162 (58)	16 (76)	ns	
Myocardial infarct pre-op.	92 (33)	14 (67)	$P=0.002$	$P=0.02$
LAD segmental disease				
Proximal-normal/<50%	90 (32)	9 (43)		
50-95%	153 (55)	7 (33)	ns	
>95%-occluded	37 (13)	5 (24)		
Middle-normal/<50%	162 (58)	9 (43)		
50-95%	83 (30)	5 (24)	ns	
>95%-occluded	35 (12)	7 (33)		
Distal-normal/<50%	253 (91)	15 (71)		
>50%	27 (9)	6 (29)	$P=0.007$	ns
Diagonal-normal/<50%	204 (73)	10 (48)		
50-95%	54 (19)	5 (24)	$P=0.004$	$P=0.04$
>95%-occluded	22 (8)	6 (28)		
Ejection fraction				
>55%	203 (73)	11 (52)		
40-54%	64 (23)	6 (29)	$P=0.003$	ns
≤39%	10 (4)	4 (19)		
Wall motion				
normal	169 (61)	9 (43)		
abnormal	108 (39)	12 (57)	ns	—
Prior angioplasty	38 (14)	2 (10)	ns	—
Saphenous vein graft only	52 (19)	8 (38)		
Internal thoracic artery graft	228 (81)	13 (62)	$P=0.03$	ns
Vein graft to diagonal	126 (45)	7 (33)	ns	—
Any operative complication	69 (25)	7 (33)	ns	—
Angina at follow-up	94 (34)	11 (52)	( $P=0.08$ )	—
Interval myocardial infarct	17 (6)	9 (43)	$P<0.0001$	$P=0.0001$
Heart failure at follow-up	34 (12)	4 (19)	ns	—
Angiography at follow-up	62 (22)	4 (19)	ns	—
Angioplasty at follow-up	11 (4)	0 (0)	ns	—
Repeat surgery	17 (6)	1 (5)	ns	—
Aspirin	211 (75)	16 (76)	ns	—
Antianginal medications	96 (34)	10 (48)	ns	—

group were angina free in contrast to those treated medically (32%).

### *Internal thoracic artery graft versus saphenous vein graft*

In the Coronary Artery Surgery Study, 5-year angiography was obtained in 197 patients and included 507 grafts, of which 35 were internal thoracic artery grafts. The patency rate for left anterior descending coronary artery grafts at 5 years was 87% (mainly vein grafts used)<sup>[21]</sup>. In an observational study, Loop reported a 96% internal thoracic artery graft patency rate at 10 years (n=855), compared to 81% for vein grafts

(n=1445), to the left anterior descending coronary artery<sup>[23]</sup>. In patients with single-vessel coronary artery disease of the left anterior descending artery, those with an internal thoracic artery graft (n=332) had a 93.4% survival rate at 10 years, as compared to 88% for those with a saphenous vein graft (n=440)<sup>[23]</sup>. This superior patency rate has led to the internal thoracic artery becoming the conduit of choice in recent years by bypassing left anterior descending coronary artery stenoses<sup>[23-31]</sup>. In the present relatively small study, there was no advantage to an internal thoracic artery graft compared to a saphenous vein graft with regard to vital status, angina presence or class, development of heart failure or need for repeat revascularization (Table 9).

**Table 6** Coronary artery bypass grafting for isolated left anterior descending coronary artery stenosis in 301 consecutive patients: factors related to congestive cardiac failure at follow-up. Values are n (%) except for years

	Congestive failure		Significance	
	Yes (n=238)	No (n=263)	Univariate analysis	Multivariate analysis
Age (years)				
mean (SD)	52.5 (8.3)	53.2 (9.4)	ns	
Gender				
Male	22 (58)	216 (82)		
Female	16 (42)	47 (18)	$P=0.001$	$P=0.01$
Angina pre-op.				
0/I/II	15 (39)	108 (41)		
III/IV	23 (61)	155 (59)	ns	—
Myocardial infarct pre-op.	18 (47)	88 (33)	ns	
Ejection fraction				
>55%	24 (63)	190 (73)		
40–54%	11 (29)	59 (23)	ns	
≤39%	3 (8)	11 (4)		
Wall motion				
normal	17 (45)	161 (62)		
abnormal	21 (55)	99 (38)	$P=0.04$	( $P=0.08$ )
Saphenous vein graft only	12 (32)	48 (18)		
Internal thoracic graft	26 (68)	215 (82)	$P=0.05$	ns
Angina at follow-up	31 (82)	74 (28)	$P<0.0001$	ns
Interval infarction	7 (18)	19 (7)	$P=0.022$	ns

**Table 7** Coronary artery bypass grafting for isolated left anterior descending coronary artery stenosis in 301 consecutive patients: factors related to myocardial infarction at follow-up. Values are n (%) except for years

	Myocardial infarction		Significance	
	Yes (n=226)	No (n=275)	Univariate analysis	Multivariate analysis
Age (years)				
mean (SD)	53.4 (8.9)	53.1 (9.3)	ns	
Gender				
Male	18 (69)	220 (80)		
Female	8 (31)	55 (20)	ns	
Angina pre-op.				
0/I/II	3 (12)	120 (43)		
III/IV	23 (88)	155 (57)	$P=0.002$	
Myocardial infarct pre-op.	12 (46)	94 (34)	ns	
LAD segmental disease				
Proximal-normal/<50%	11 (42)	88 (32)		
50–95%	8 (31)	152 (55)	$P=0.03$	
>95%–occluded	7 (27)	35 (13)		
Middle-normal/<50%	11 (42)	160 (58)		
50–95%	9 (35)	79 (29)	ns	
>95%–occluded	6 (23)	36 (13)		
Distal-normal/<50%	19 (73)	249 (91)		
>50%	7 (27)	26 (9)	$P=0.006$	$P=0.08$
Diagonal-normal/<50%	16 (62)	198 (72)		
50–95%	5 (19)	54 (20)	ns	
>95%–occluded	5 (19)	23 (8)		
Prior angioplasty	5 (19)	35 (13)	ns	
Saphenous vein graft only	8 (31)	52 (19)		
Internal thoracic artery graft	18 (69)	223 (81)	ns	
Angina at follow-up	23 (88)	82 (30)	$P<0.0001$	$P=0.001$



**Table 8** Coronary artery bypass grafting for isolated left anterior descending coronary artery stenosis in 301 consecutive patients: factors related to angina at follow-up. Values are n (%) except for years

	Angina at follow-up		Significance	
	Yes (n=105)	No (n=196)	Univariate analysis	Multivariate analysis
Age (years) mean (SD)	53.2 (8.6)	53.1 (9.7)	ns	
Gender				
Male	76 (72)	162 (83)		
Female	29 (28)	34 (17)	$P=0.04$	$P=0.03$
Angina pre-op.				
0/I/II	38 (36)	85 (43)		
III/IV	67 (64)	111 (57)	ns	—
Myocardial infarct pre-op.	44 (42)	62 (32)	$P=0.08$	ns
Saphenous vein graft only	27 (26)	33 (17)		
Internal thoracic artery graft	78 (74)	163 (83)	$P=0.07$	ns

**Table 9** Predictors of survival in 301 consecutive patients undergoing isolated coronary artery bypass grafting for left anterior descending coronary artery disease: a multivariate analysis

Variable	Angina	Myocardial infarction	Heart failure	Death
Age	ns	ns	ns	ns
Gender	$P=0.03$	ns	$P=0.01$	$P=0.002$
Pre-op. angina	ns	—	—	—
Pre-op. infarct	( $P=0.08$ )	ns	ns	$P=0.02$
Distal disease	ns	( $P=0.08$ )	ns	ns
Diagonal disease	—	ns	ns	$P=0.04$
LVEF pre-op.	—	ns	ns	ns
WMA pre-op.	( $P=0.07$ )	ns	( $P=0.08$ ) ns	—
Graft type	—	ns	ns	ns
Angina at FU	—	$P=0.001$	ns	ns
Interval infarct	$P<0.0001$	—	—	$P=0.0001$
CCF at FU	$P<0.0001$	ns	—	—

LVEF=left ventricular ejection fraction; WMA=wall motion abnormality; FU=follow-up; CCF=congestive cardiac failure; ns=not statistically significant on multivariate analysis; note,  $P$  values in parentheses approach statistical significance.

The discrepancy between the present and previously published studies in this regard probably reflects selection bias for internal thoracic artery grafts in non-randomized cohort studies. Interestingly, Goldman has reported similar patency rates for internal thoracic artery (92.8%–22.0 of 237) and vein grafts (90.1%–345 of 383) to the left anterior descending coronary artery at 1 year<sup>[32]</sup>. Furthermore, the recent results of CABADAS (prevention of Coronary Artery Bypass graft occlusion by Aspirin, Dipyridamole, and Acenocoumarol/phenprocoumon Study) adds further support to the notion of at least a short-term equivalence of vein grafts to internal thoracic artery grafts<sup>[33]</sup>. Early equivalence may relate to efficacy of antiplatelet agents in preventing vein graft occlusion, but later, more aggressive atherosclerotic occlusion of vein grafts might be expected to favour internal thoracic artery grafts<sup>[33]</sup>. In a recent retrospective review of the Coronary Artery Surgery

Study registry, Cameron *et al.* report that the presence of an internal thoracic artery graft (n=749) conferred a survival advantage throughout a 15-year follow up period as compared to saphenous vein grafts (n=4888)<sup>[34]</sup>.

The fact that event-free survival in patients taking aspirin was no better is not surprising as the majority had internal thoracic artery grafts. Aspirin probably does not impact on the patency of this conduit<sup>[32]</sup>.

### *Internal thoracic artery graft or percutaneous coronary angioplasty for proximal left anterior descending coronary artery disease?*

The majority of patients in the present study had discrete stenoses potentially suitable for percutaneous

transluminal coronary angioplasty. The Lausanne study prospectively compared coronary artery bypass grafting to percutaneous transluminal coronary angioplasty for isolated proximal left anterior descending coronary artery disease<sup>[35]</sup>. There was no death in the coronary artery bypass grafting group (n=66) and none in the percutaneous transluminal coronary angioplasty group (n=68) after 24 months of follow-up. However, 86% of patients treated by coronary artery bypass grafting were free from death, myocardial infarction, or repeat revascularization in comparison with 43% of patients treated with percutaneous transluminal coronary angioplasty. If one is prepared to accept the greater need for reintervention with percutaneous transluminal coronary angioplasty, then it remains a simpler initial treatment-strategy than coronary artery bypass grafting. The excellent medium-to-long-term outcome in our surgical group with isolated left anterior descending coronary artery disease, however, can be used as an argument in support of early surgical treatment. For the clinician and the individual patient the choice of initial strategy is influenced by many variables. The pendulum may swing more towards a percutaneous approach with the success of stents and adjunctive pharmacology in reducing restenosis. On the other hand, minimally invasive coronary artery bypass grafting without recourse to cardiopulmonary bypass might reduce the morbidity of coronary artery bypass grafting.

## Conclusion

In this historical cohort study, patients with angiographically significant disease of the left anterior descending coronary artery have an excellent long-term outcome following coronary artery bypass grafting. Survivorship was equivalent to an age-matched population. In advocating an alternative treatment strategy for this patient population, coronary artery bypass grafting should be the gold standard against which new therapies are judged. Percutaneous strategies reduce procedural morbidity and perhaps costs but are unlikely to give better event free survival than coronary artery bypass grafting.

## References

- [1] Favaloro RG. Saphenous vein autograft replacement of severe segmental coronary artery occlusions; operator technique. *Ann Thorac Surg* 1968; 6: 334-9.
- [2] Califf RM, Harrel Jr PE, Lee KL *et al*. The evolution of medical and surgical therapy for coronary artery disease: a fifteen year perspective. *JAMA* 1989; 261: 2077-86.
- [3] Kumpuria AG, Quinones MA, Kanon D, Miller RR. Isolated stenosis of left anterior descending or right coronary artery: relation between site of stenosis and ventricular dysfunction and therapeutic implications. *Am J Cardiol* 1980; 46: 15-20.
- [4] Brooks N, Cattel M, Jennings K, Balcon R, Honey M, Layton C. Isolated disease of left anterior descending coronary artery. Angiographic and clinical study of 218 patients. *Br Heart J* 1982; 47: 1-7.
- [5] Leong K, Jones RH. Influence of the location of left anterior descending coronary artery stenosis on left ventricular function during exercise. *Circulation* 1982; 65: 109-14.
- [6] Samaja JK, Connor MJ, Tribble R. Natural history of left anterior descending coronary artery obstruction: significance of location of stenoses in medically treated patients. *Clin Cardiol* 1985; 8: 415-22.
- [7] Holmes DR, Fisher L, Mock M, McConney M, Russel R, Schaff HV. Isolated proximal left anterior descending (LAD) stenoses: widow-maker, fact or fancy. An observational CASS registry study (Abstr). *Circulation* 1985; 72 (Suppl III): 458.
- [8] Griffin B, Blake S, Neligan M, Daly L. Irish Cardiac Surgical Register: Preliminary report. *Irish J Med Sci* 1984; 153: 87.
- [9] Campeau L. Grading of angina pectoris. *Circulation* 1976; 54: 522.
- [10] Expectation of life, Irish Life Table No 12, 1990-1992. Statistical Abstracts, Central Statistics Office, Cork, Ireland, 1995: Table 2.35: 58.
- [11] Califf RM, Tomabechi Y, Lee KL *et al*. Outcome in one-vessel coronary artery disease. *Circulation* 1983; 67: 283-90.
- [12] Kouchoukos NT, Oberman O, Russel RO, Jones WB. Surgical versus medical treatment of occlusive disease confined to the left anterior descending coronary artery. *Am J Cardiol* 1975; 35: 836-46.
- [13] Bruschke AVG, Proudfit WL, Sones FM. Progress study of 590 consecutive nonsurgical cases of coronary disease followed 5-9 years. *Circulation* 1973; 47: 1147-53.
- [14] Burggraf GW, Parker JO. Prognosis in coronary artery disease. Angiographic, haemodynamic, and clinical factors. *Circulation* 1975; 51: 146-56.
- [15] Webster JS, Moberg C, Rincon G. Natural history of severe proximal coronary artery disease as documented by cineangiography. *Am J Cardiol* 1974; 33: 195-200.
- [16] Hammermeister KE, DeRouen TA, Dodge HT. Variables predictive of survival in patients with coronary disease. Selection by univariate and multivariate analysis from the clinical, electrocardiographic, exercise, arteriographic, and quantitative angiographic evaluations. *Circulation* 1979; 59: 421-9.
- [17] Schuster EH, Griffith LS, Buckley BH. Preponderance of acute proximal left anterior descending coronary arterial lesions in fatal myocardial infarction: a clinicopathologic study. *Am J Cardiol* 1981; 47: 1189-95.
- [18] Yusuf S, Zucker D, Peduzzi P *et al*. Effect of coronary artery bypass graft surgery on survival: overview of 10-year results from randomised trials by the Coronary Artery Bypass Graft Surgery Trialists Collaboration. *Lancet* 1994; 344: 563-70.
- [19] Califf RM, Phillips HR, Hindman MC *et al*. Prognostic value of a coronary artery jeopardy score. *J Am Coll Cardiol* 1985; 5: 1055-63.
- [20] Klein LW, Weintraub WS, Agarwal JB. Prognostic significance of severe narrowing of the proximal portion of the left anterior descending coronary artery. *Am J Cardiol* 1986; 58: 42-9.
- [21] Alderman EL, Bourassa MG, Cohen LS *et al*. Ten-year follow-up of survival and myocardial infarction in the randomised coronary artery surgery study. *Circulation* 1990; 82: 1629-46.
- [22] Hueb WA, Bellotti G, deOliveira SA *et al*. The medicine, angioplasty or surgery study (MASS): A prospective, randomized trial of medical therapy, balloon angioplasty or bypass surgery for single proximal left anterior descending coronary artery stenosis. *J Am Coll Cardiol* 1995; 26: 1600-5.
- [23] Loop FD, Lytle BW, Cosgrove DM *et al*. Influence of the internal mammary artery on ten year survival and other cardiac events. *N Engl J Med* 1986; 314: 1-6.
- [24] Okies JE, Page US, Bigelow JC, Krause AH, Salomon NW. The left internal mammary artery: the graft of choice. *Circulation* 1984; 70 (Suppl I): I-213-I-221.
- [25] Grondin CM, Campeau L, Lesperance H, Enjalbert M, Bourassa MG. Comparison of late changes in internal mammary artery and saphenous vein grafts in two consecutive

- series of patients ten years after operation. *Circulation* 1984; 70 (Suppl I): I-208-I-212.
- [26] Barner HB, Standeven JW, Reese J. Twelve year experience with internal mammary artery for coronary artery bypass. *J Thorac Cardiovasc Surg* 1985; 90: 668-75.
- [27] Tector AJ, Schmahl TM, Canino VR. The internal mammary artery graft: the best choice for bypass of the diseased left anterior descending coronary artery. *Circulation* 1983; 68 (Suppl II): II-214-II-217.
- [28] Liddle HV, Gould BL, Jones PD, Clayton PD. Conditional probability of multiple coronary graft failure. *J Thorac Cardiovasc Surg* 1984; 87: 526-31.
- [29] Huddleston CB, Stoney WS, Alford WC. Internal mammary artery grafts: technical factors affecting patency. *Ann Thorac Surg* 1986; 42: 543-549.
- [30] Olearchyk AS, Magovern GJ. Internal mammary artery grafting: clinical results, patency rates, and long-term survival in 833 patients. *J Thorac Cardiovasc Surg* 1986; 92: 1082-7.
- [31] Acinapura AJ, Rose DM, Jacobowitz IJ. Internal mammary artery bypass grafting: influence on recurrent angina and survival in 2100 patients. *Ann Thorac Surg* 1989; 48: 186-91.
- [32] Goldman S, Copeland J, Moritz T *et al.* Internal mammary artery and saphenous vein graft patency. Effects of aspirin. *Circulation* 1990; 82 (Suppl IV): IV-237-IV-242.
- [33] Van der Meer J, Hillege HL, van Gilst WH *et al.* A comparison of internal mammary artery and saphenous vein grafts after coronary artery bypass surgery. No difference in 1-year occlusion rates and clinical outcome. *Circulation* 1994; 90: 2367-74.
- [34] Cameron A, Davis K, Green G, Schaff H. Coronary bypass surgery with internal thoracic artery grafts. Effects on survival over a 15 year period. *N Engl J Med* 1996; 334: 216-9.
- [35] Goy J, Eeckhout E, Burn and B *et al.* Coronary angioplasty versus left internal mammary artery grafting for isolated proximal left anterior descending artery stenosis. *Lancet* 1994; 343: 1449-53.