A comparison of early mortality and morbidity after single and bilateral internal mammary artery grafting with the free right internal mammary artery

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Abstract

Objective—To compare differences in early mortality and morbidity in patients receiving a single internal mammary artery graft (SIMA) with those receiving bilateral internal mammary artery grafts (BIMA) with a free right internal mammary artery (RIMA).

Design—Retrospective analysis of 150 patients undergoing BIMA grafting between 1989–1992 who were carefully matched with 150 patients undergoing SIMA grafting between 1987–1992 for known cardiovascular risk factors, extent of coronary disease, left ventricular function, and number of coronary grafts. Operative variables noted included aortic cross clamp time and bypass time. Postoperative cardiac, respiratory, and wound complications were also noted.

Results—Operative mortality was 2% in the SIMA group and 1.3% in the BIMA group (NS). Other than the prevalence of ventricular arrhythmias ($P = 0.025$), which were more common in the BIMA group, there were no significant differences between the two groups in terms of postoperative morbidity. At median (interquartile range) follow up of 27.94(0.86) and 23.94(0.74) months for the SIMA and BIMA groups respectively there were no deaths. 87% of the SIMA group and 91% of the BIMA group were free of symptoms at follow up.

Conclusions—The earlier fears regarding increased early mortality and morbidity after BIMA surgery were not confirmed by this study. All patients receiving both mammary arteries had a free rather than pedicle right internal mammary graft. The early mortality and morbidity reported here compares favourably with previous reports on the use of a pedicle graft.

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used as grafts. Bilateral IMA grafting has been carried out in North America since the late 1970s, but in the United Kingdom only from the mid to late 1980s in most cardiothoracic units. In several reviews increased long-term clinical benefit was reported after the use of both IMAs compared with a single IMA.^{4–7} Some reports suggested that the use of both IMAs increases early mortality and morbidity; especially cited were increased bleeding and respiratory and wound complications.^{8–14} To examine this we have looked at several preoperative and operative factors known to influence postoperative mortality and morbidity in a series of 150 patients who had bilateral IMA grafts, and carefully matched them with 150 patients who had left IMA grafting. In our unit we use the free right IMA artery instead of a pedicle graft.

Patients and methods

Bilateral IMA grafting in our unit started in 1989. One hundred and fifty consecutive patients who had bilateral IMA grafts from March 1989 to April 1992 were chosen. They were then computer matched with 150 patients who had coronary artery bypass surgery with a single IMA graft between 1987 and 1992. They were matched for age, sex, risk factors for coronary artery disease (diabetes, hypertension, presence of cholesterol >6.5 mmol/l, and smoking), extent of coronary disease, left main stem disease, angina class, left ventricular function, number of coronary grafts performed, and operative state (emergency or elective). All operations were performed by one surgeon (DK), and all were primary myocardial revascularisation procedures.

Cardiac catheterisation findings included the number of diseased main coronary vessels (vessel wall >70% obstruction of luminal diameter in any plane on coronary angiography) and the presence of left main stem coronary artery disease (>50% obstruction of luminal diameter in any plane). Left ventricular function was measured by cross sectional echocardiography and by left ventricular ventriculography; it was recorded as left ventricular ejection fraction.

Regular medications apart from aspirin were continued up to the morning of the operation. A standard anaesthetic technique was used and there was no substantial change in surgical technique over the period of the study, apart from the use of the free right IMA graft after 1989. All vessels ≥ 1 mm in diame-

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The superior early and long-term patency of internal mammary artery (IMA) grafts compared with vein grafts has led to their increasing use in myocardial revascularisation.^{1,2} Patients receiving a left IMA graft to the anterior wall have an increased long-term survival, a reduction in the rate of reoperation, and greater freedom from cardiac morbidity—that is, angina, myocardial infarction, and congestive cardiac failure.³ Later both IMAs were

ter distal to a proximal coronary lesion were grafted, and this explains the high number of total grafts placed in both groups (in an attempt to achieve complete revascularisation). Advanced age, poor ventricular function, emergency operation, and diabetes were not considered contraindications to IMA grafting. The only contraindication was operative definition of an inadequate IMA.

The chest was opened through a median sternotomy incision and the long saphenous vein harvested simultaneously. The left IMA was mobilised distally down to its bifurcation, keeping it attached proximally to the subclavian artery. Clips were used for side branches on the arterial side and side branches to the chest wall were diathermised. All proximal branches were divided to prevent IMA steal. Care was taken to retract the IMAs gently and to divide the small branches at some distance from the main IMA. The right IMA was dissected in a similar way and divided both proximally and distally to use as a free graft. At this stage systemic heparin was given and further surgery was performed under standard hypothermic (28–30°C) cardiopulmonary bypass with a membrane oxygenator. The distal anastomoses were conducted after the institution of aortic cross clamping and cold blood cardioplegic arrest. In almost all cases the left IMA was grafted to the left anterior descending coronary artery; however, due to technical reasons such as shortness of the left IMA or extensive distal disease affecting the left anterior descending coronary artery, the left IMA was grafted to diagonal branches in certain instances. The right IMA was used as a free graft for coronary arteries >1.5 mm that were thought to be prognostically important—that is, supplying a large region of functioning myocardium. Proximal anastomoses of the vein and free right IMA grafts to the aorta were done during rewarming. Before closure of the chest both pleural cavities and mediastinum were drained by chest tube. A temporary right ventricular epicardial pacing wire was left in situ. In addition to prophylactic

systemic antibiotics we applied vancomycin to the cut sternal edges.

We noted operative variables including the number of grafts, bypass time, clamp time, and destination of the IMA grafts. Postoperative complications were noted, these were the use of inotropes (for >24 h), the occurrence of left ventricular failure (radiological and clinical evidence), arrhythmias, blood loss, respiratory complications (including ventilation duration), and myocardial infarction (defined as new Q waves on the electrocardiogram during the postoperative period). Moderate sized pleural effusion before discharge (considerable accumulation of pleural fluid without respiratory symptoms and not needing thoracentesis), postcardiotomy syndrome (raised sedimentation rate, pericardial rub, and high titres of antimyocardial antibodies), and sternal wound complications were also noted. Clinical information of survival and subsequent cardiac events were recorded from the notes and also telephone interview. Operative mortality was defined as any death occurring when in hospital or within 30 days of the operation.

The data were analysed with the SPSS for windows package. The χ^2 test was used to determine significance for discrete variables. In cases in which the expected cell frequencies were small (<5), Fisher's exact test was used to compare the groups. Because the distribution of continuous variables was generally skewed we used the Mann Whitney U test for comparisons. Values are expressed as medians. Minimum-maximum values, interquartile range, and 95% confidence intervals (95% CIs) are also given in tables.

Results

Table 1 shows the preoperative features in both cohorts, the two groups were carefully matched with respect to these factors. Table 2 shows operative and haemodynamic variables (after bypass) for patients receiving one or two IMAs. The two groups were similar in total graft numbers, aortic cross clamp time, bypass time, and postoperative haemodynamic measurements. Durations of operation and ventilation were, however, significantly increased in the bilateral IMA group. The two groups were also similar in severity of angina, 77% in the single and 79% in the bilateral IMA group, and in Canadian heart classes III and IV.

There were no significant differences in blood loss, hypotension after operation, and inotropic and transfusion requirements between the two groups. Despite the increased ventilation duration in the bilateral IMA patients, chest infection rates were similar between the two cohorts (table 3). Moderate sized pleural effusions during the stay in hospital were also similar in the two groups. One patient in each group developed a large pleural effusion that needed drainage. Postoperative myocardial infarction was seen in three patients receiving both IMAs and in two patients receiving one IMA ($P = 0.25$).

Table 1 Preoperative factors in patients who had single or bilateral IMA grafts

	Single	Bilateral
Patients (n)	150	150
Age (yr):		
Median (min-max)	59 (37-75)	57 (28-69)
IQR	52-50-65-00	49-62
95% CI	57-44 to 60-00	53-88 to 56-65
Sex (male (%))	119 (79)	116 (77)
Smokers (n(%))	102 (68)	96 (64)
Hypertension (n(%))	22 (14.6)	28 (18.6)
Diabetes (n(%))	16 (10.7)	15 (10)
Cholesterol > 6.5 mmol/l (n(%))	18 (12)	17 (11.3)
Previous myocardial infarction (n(%))	50 (33)	53 (35)
Left main stem disease (n(%))	18 (12)	19 (12.7)
No of vessels affected:		
Median (range)	3 (1-3)	3 (2-3)
IQR	3-3	3-3
95% CI	2.84 to 2.95	2.88 to 2.96
LV ejection fraction:		
Median (range)	58 (25-75)	55 (28-69)
IQR	49-50-60	49-62
95% CI	52-47 to 56-11	51-69 to 58-31
Emergency cases (n(%))	11 (7.3)	9 (6)
Aspirin or anticoagulants (n(%))	75 (50)	71 (47)
Patients in angina class	116 (77)	119 (78)
III and IV* (n(%))		

*Canadian heart classification. IQR, interquartile range; LV, left ventricular.

Table 2 Perioperative factors in patients who had single and bilateral IMA grafts

	Single		Bilateral		P value
		IQR		IQR	
Operation duration (min):					
Median (min-max)	210 (130-390)	200-240	240 (130-400)	220-270	0.001
95% CI	216.50 to 230.58		240.66 to 255.08		
Clamp time (min):					
Median (min-max)	54 (20-98)	44-61.50	60 (30-118)	50-70	0.01
95% CI	51.79 to 56.73		57.13 to 62.15		
Bypass time (min):					
Median (min-max)	105 (46-240)	90-121	110 (30-237)	90-132	0.06
95% CI	103.70 to 113.34		109.33 to 119.33		
Graft (n):					
Median (min-max)	6 (2-9)	5-6	6 (3-10)	5-7	0.32
95% CI	5.51 to 5.92		5.96 to 6.42		
Hypotension (n(%))	17 (11.33)		18 (12)		0.91
Inotropic support (n(%))	37 (24.62)		41 (27.3)		0.47
Central venous pressure:					
Median (min-max)	12 (4-20)	10-12	12 (5-17)	10-13	0.79
95% CI	10.96 to 12.76		10.92 to 12.64		
Pulmonary wedge pressure (mmHg):					
Median (min-max)	9 (5-18)	8-10	9 (4-16)	8-10	0.45
95% CI	8.55 to 9.69		8.69 to 9.21		
Cardiac output (l/min):					
Median (min-max)	4.80 (1.80-6.8)	4.43-5.20	5 (2.10-7)	4.60-5.40	0.18
95% CI	4.72 to 5.04		4.87 to 5.10		
Cardiac index (l/min/m ²):					
Median (min-max)	2.4 (1.30-3.50)	2.10-2.90	2.8 (1.50-3.40)	2.3-3	0.16
95% CI	2.26 to 2.54		1.96 to 2.73		
Ventilation duration (h):					
Median (min-max)	9 (3-72)	7-16	12 (5-66)	9-16	0.02
95% CI	8.40 to 13.90		11.62 to 15.70		

Cardiac output, cardiac index, central venous pressure, and pulmonary wedge pressure values are the averages of readings taken at 30 min, 6 h, and 24 h after operation. IQR = interquartile range.

Although there were no differences between the two groups in documented postoperative supraventricular arrhythmia requiring treatment, documented ventricular arrhythmias that needed treatment were significantly more common in patients receiving two IMAs (*P* = 0.025). Sternal wound infection rates were not significantly different between the two groups (2% (three patients) for the single IMA group and 1.3% (two patients) for the bilateral IMA group). One of the single IMA patients with sternal infection required open debridement in the operating room as well as intravenous antibiotics.

The operative mortality was 2% (three patients) in the single IMA group and 1.3% (two patients) in the bilateral IMA group (NS). The three deaths in the single IMA group occurred on days 2, 5, and 27 after operation, they were due to myocardial infarction (two patients) and stroke (one patient).

The two deaths in the bilateral IMA group occurred on days 4 and 28 after operation and were due to myocardial infarction and stroke.

Ninety five per cent of left IMAs were grafted to the left anterior descending coronary artery and 5% were grafted to diagonal branches. Sixty per cent of the right IMAs were grafted to the right coronary artery, 13% to the circumflex coronary artery, 25% to marginal branches, and 2% to diagonal branches. Median stay in hospital was eight days for both groups. Median (interquartile range) follow up was 28(20-36) months for the single IMA group and 23 (16-31) months for the bilateral IMA group. At follow up 87.1% of the single IMA groups and 91.2% of the bilateral IMA were free of cardiac symptoms (NS). Reoccurrence of angina was present at follow up in five (3.4%) of the single and three (2%) of the bilateral IMA group.

Table 3 Postoperative complications after single and bilateral IMA

Complication	Single		Bilateral	
		IQR		IQR
Blood loss (ml):				
Median (min-max)	490 (99-2000)	399-455	525 (170-2500)	360-590
95% CI	441.23-519.87		496.43-551.76	
Chest reopened (n(%))	9 (6)		7 (4.6)	
Supraventricular arrhythmias (n(%))	35 (23.3)		38 (25.3)	
Ventricular arrhythmias* (n(%))	3 (2)		9 (6)	
Myocardial infarction (n(%))	2 (1.3)		3 (2)	
Chest infection (n(%))	11 (7.3)		10 (6.6)	
Pleural effusion (n(%))	6 (4)		5 (3.3)	
Pneumothorax (n(%))	3 (2)		3 (2)	
Postcardiotomy syndrome (n(%))	2 (1.3)		3 (2)	
Wound infection (n(%))	2 (1.3)		1 (0.7)	
Renal failure (n(%))	1 (0.7)		2 (1.3)	
Discharge (days):				
Median (min-max)	8 (7-56)	7-10	8 (6-60)	8-10
95% CI	7.57 to 10.22		7.62 to 10.10	
Follow up (months):				
Median (min-max)	28 (2-44)	20-36	23 (3-50)	16-31
95% CI	26.27 to 29.63		22.34 to 25.54	
Angina at follow up (n(%))	5 (3.3)		3 (2)	

**P* = 0.025. IQR, interquartile range.

Discussion

Because of the rate of vein graft failure, with occlusion of 50% of vein grafts between five and 12 years,¹⁵ the IMA has become the conduit of choice in coronary artery bypass surgery. In contrast with vein grafts, IMA grafts have a long-term patency of 90%; together with the increased freedom from reoperation and reduction in the rate of late myocardial infarction and other cardiac morbidity, this has prompted the greater use of arterial grafts.^{2,6,16} The reason for the paucity of atherosclerosis in the IMA graft is not known, although it has been suggested that it may be due to the lack of smooth muscle in the thin walled media and a well formed internal elastic membrane.^{17,18} The IMA also retains a number of physiological processes that make it more suitable as an arterial conduit; these include vasomotor activity, a capacity to enlarge with increased flow, and an intact endothelium.¹⁹⁻²¹

Loop *et al* showed a highly significant improvement in five and 10 year survival in patients receiving a single IMA graft to the left anterior descending coronary artery alone or in combination with vein grafts compared with vein grafts alone.³ Although questions have been raised about possible bias in patient selection in this study, the differences in mid-term and long-term survival between the two groups (left IMA *v* vein graft) in this study were so large, that the findings are generally accepted. As a result of this study and the clear evidence of improved long-term patency of the IMA, we began to routinely use the left IMA in 1987. Mainly as a natural progression of this and the findings of several studies (showing excellent late results achieved with both IMAs), our practice changed further in 1989, when we began to use bilateral IMA grafts.^{6,7} There was a period of transition between 1989 and mid-1991 when both single and bilateral IMA grafts were used. After mid-1991 bilateral IMA grafts were used in all patients with multivessel disease. Single and bilateral IMAs were used regardless of age, left ventricular function, and diabetes.

Much of the experience of bilateral IMA surgery comes from North America. There has been concern that the use of bilateral IMA grafts might be associated with increased perioperative and early morbidity and mortality compared with single IMA grafts. In Barner's series of 100 patients the operative mortality was 8%,⁸ 12 had reoperation for bleeding, and four had considerable wound complications. Similar figures for operative mortality, reoperation, and wound infection were quoted in early reports by Culliford *et al* and Lytle *et al*.^{9,11} In Europe, Cron *et al*, in a study that compared 43 patients who had bilateral IMA grafts with 31 who had single IMA grafts, reported that increased perioperative mortality, postoperative infarction, and mediastinitis were significantly increased in the bilateral IMA group.¹³

In our series the patients who received both IMAs were carefully matched with patients who received one IMA, for main factors that

could influence the operative mortality. The operative mortality of 1.3% and 2% for the bilateral IMA and single IMA groups compares with those reported by Cosgrove *et al*.¹² It has been suggested that sternal devascularisation may result from the use of both IMAs, and this fact alone has prevented many surgeons from using bilateral IMA grafts.²²⁻²⁴ Originally Culliford *et al* noted that sternal wound infections developed in 1.1% of the patients receiving only vein grafts, in 2.3% of the patients when the left IMA was used, and in 8.5% of the patients who had bilateral IMA grafts.⁹ There was, however, no significant difference in sternal wound infection in our two groups (1.3% for single and 0.7% for bilateral IMA). Studies with a substantially larger number of patients have also found that sternal wound infection is not related to bilateral IMA grafting but to diabetes mellitus and advanced age.^{12,25} Our low rates of wound infection may also be due to the routine intraoperative use of topically applied vancomycin to the cut sternal edges, as well as the use of prophylactic systemic antibiotics. Vander Salim *et al* have reported a significant reduction in sternal or mediastinal infection with the use of this technique.²⁶ This study also noted no correlation between sternal wound infection and IMA grafts.

Although patients who received both IMAs had a marginally larger blood loss than the single IMA group, the difference was not significant and certainly was not reflected in other morbidity such as increased transfusion requirements, inotropic support, or development of shock. Several studies have noted that the reoperation for bleeding increases with the use of both IMAs,^{8,11} but there was no significant difference between the single and bilateral IMA groups in our study. The pleural space was opened during all IMA dissections. Previous reports suggest that respiratory function is impaired in patients when the pleural space is opened. This was not our finding.²⁷ Although duration of ventilation was significantly higher in the bilateral IMA group, this was not reflected in the frequency of chest infection in the two groups.

Despite previous studies,^{13,14} we found no difference for postoperative rates of myocardial infarction between single IMA and bilateral IMA groups. A recent study suggested that both supraventricular arrhythmias and pericarditis are more frequent in patients who had IMA grafts than in those who had saphenous vein grafts only.²⁸ Although there were no significant differences in supraventricular tachycardia or postcardiotomy syndrome in our two groups of patients, treated ventricular arrhythmias in the postoperative period were more common in the bilateral IMA group.

There were no deaths in either group during the postoperative period, but the follow up period in our cohorts was short (a median of 22 and 24 months for the single and bilateral IMA groups). The evidence of long-term clinical benefit to patients who received both IMAs compared with those who received one seem convincing (reoccurrence of angina and

myocardial infarction).⁴⁻⁷ There is, however, still controversy about whether bilateral IMA grafts confers a survival benefit. In a large scale prospective study comparing single *v* multiple IMA grafts, there were no differences between the two groups for mid-term (five year) survival and reoperation.²⁵ A retrospective study at the same time that looked at the outcome in patients who received one and two IMAs seemed to indicate that there was a long term survival benefit in those patients who received two IMAs arteries.⁵ Since this study was published in 1990, Fiore *et al* found that when the fate of untraced patients was discovered, the long-term survival advantage in the bilateral IMA group was abolished.²⁹ One particular problem of this study was that the cohort of patients who received bilateral IMAs were operated on in the very early days of bilateral IMA grafting. It is also possible that most of the survival benefit with IMA surgery may be provided by a single IMA, especially in the case of IMA grafts to the left anterior descending coronary artery and further use of the right IMA may be associated with smaller changes in long-term survival. If a difference is present it is more likely to be detected by prospective long-term follow up of many patients who had single and bilateral IMA grafts.

The median age of 57 in our bilateral IMA cohort (1989–92), is comparable with the age reported for American patients who had the same procedure from 1982 to 1984.⁴ During the period 1985–8, however, the mean age of American patients who had bilateral IMA grafts had increased to 64.1 in the same study. No such trend was evident in our cohort, but it is likely that the age of this group of patient will increase as more elderly patients undergo coronary angiography and revascularisation procedures.

One particular difference in our series is that all 150 patients who had bilateral IMA grafts had free right IMA grafts. Most published serial studies comment on the use of pedicled right IMA grafts only. Landmore recently showed that the vasa vasorum of the internal thoracic artery is confined to the adventitia and does not penetrate the media.³⁰ The medial layer is nourished entirely from the lumen, which suggests that harvesting the IMA as a free graft would not subject the artery wall to ischaemic injury. Free IMA grafting has now been going on for 20 years. It was initially used to gain additional length to reach a distal coronary artery branch. One pitfall of IMA grafting is the attempt to reach a distal coronary artery when the *in situ* mammary pedicle is too short. Although some techniques with the *in situ* mammary coronary artery add a few mm in length, stretching the IMA pedicle may result in stenosis of the internal mammary–coronary artery anastomosis. The *in situ* right IMA graft has several further particular problems. Firstly if the *in situ* right IMA is used to revascularise the left anterior descending, diagonal, or upper circumflex branches, the artery has to cross the midline. If reoperation is required at a later

date, this increases the risk of dividing or injuring the underlying artery during reentry. This can be avoided by placing the right IMA through the transverse sinus. Although this can be used to get to circumflex branches that lie close to the left atrial appendage, it makes it difficult to reach more lateral arteries. Also there is a suggestion that patency of the right IMA grafts in the transverse sinus is reduced and may be related to graft compression.³¹ The data on long-term graft patency of free grafts (including the right) are limited. Data from Loop *et al* showed, however, that patency at five and seven years was similar to *in situ* IMA grafts.³² With the free right graft versatility and applicability increase and for these reasons we have used this graft in our unit since 1989. Our results suggest that the early mortality and morbidity after bypass surgery with a free right IMA graft compares favourably with scientific publications throughout the world on the use of a pedicled right IMA graft. An association between lack of angina and the use of the free right IMA cannot be made at this stage, as the follow up period is short and the number of vein grafts used is large. These data will, however, become available with longer follow up and repeat angiographic studies to determine patency.

We are aware of certain limitations with the study design. Firstly with retrospective analysis complete adjustment for bias in patient selection cannot always be made, mainly because the interaction between confounding variables may not be detected. Secondly we appreciate that there was essentially a time frame difference for the two groups, but this was not particularly large and was also counteracted by the use of the same surgical techniques and same operator. Despite this it seems evident that both single and bilateral IMA grafts are equally successful in relieving symptoms (in the short term), with low operative mortality and postoperative complication rates similar in the two groups. Particularly there seems to be little difference between the two groups with respect to postoperative pulmonary, bleeding and sternal wound complications. One additional observation is that the use of free IMA grafts is also associated with low early risk.

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