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Rescue Percutaneous Coronary Intervention Following Coronary Artery Bypass Graft—A Descriptive Analysis of the Changing Interface between Interventional Cardiologist and Cardiac Surgeon

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Summary

Background: Despite decreasing rates of acute and subacute complications of percutaneous coronary intervention (PCI), these procedures are generally only performed in centers where it is possible for failed PCI to be treated by rescue coronary artery bypass graft (CABG). Case reports and case series have documented successful PCI following failed CABG. We sought to confirm this decrease in the need for rescue CABG following failed PCI and to examine trends in the utilization of rescue PCI following failed CABG.

Hypothesis: The interface between interventional cardiologist and cardiac surgeon is characterized by changing practice patterns and resource utilization.

Methods: We examined the medical records of all patients admitted to the Brigham and Women's Hospital over a 7-year period and identified 169 patients who required both PCI and CABG during the same hospital admission. We describe and compare three predetermined groups of patients defined by the sequence of, and indication for, the relevant myocardial revascularization procedures.

Results: In all, 100 patients required CABG for failed PCI, 46 patients had planned hybrid procedures involving both CABG and PCI, and 23 patients required PCI following failed CABG. There was a decrease in the need for rescue CABG following failed PCI, both in total numbers and as a percentage of total cases (2.5% in 1994 and 0.22% in 1999). There was a simultaneous increase in the utilization of rescue PCI following failed CABG (0% in 1994 and 1.6% in 2000). Hybrid procedures were identified as a source of innovative solutions to a variety of challenging clinical problems.

Conclusions: Changing patterns of resource utilization should be considered when planning hospital facilities and patient triage, and these patients undergoing percutaneous or surgical revascularization may benefit from close cooperation between the cardiac surgeon and the interventional cardiologist.

Key words: angioplasty, bypass, revascularization, complication

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Introduction

Coronary artery bypass graft surgery (CABG) and percutaneous coronary intervention (PCI) are both effective in controlling the symptoms of myocardial ischemia;[1, 2] however, both of these treatment modalities carry a small but significant risk of myocardial infarction and death.[3–5] It is apparent that the need for rescue CABG following failed PCI is decreasing in this contemporary era of increased stent utilization and potent antiplatelet therapies, but PCI is still generally only performed in centers where it is possible for failed PCI to be treated by rescue CABG.[6–8] Although it is also possible for failed CABG to be treated by rescue PCI, less attention has been focused on the availability of and need for appropriate facilities for PCI following failed cardiac surgery.[9]

We sought to characterize the interface between interventional cardiologist and cardiac surgeon at our institution, confirming this reported decrease in the need for rescue CABG following failed PCI, and examining trends in utilization of rescue PCI following failed CABG.

Methods

Patient Selection

The Patient Information Systems/Chase Systems department, using ICD-9 coding, reviewed the records of all patients admitted to the Brigham and Women's hospital between January 1994 and March 2000. Over this period, 7,529 percutaneous interventional procedures and 6,684 coronary artery bypass graft operations were performed. In all, 169 patients underwent both cardiac surgery and PCI during the same admission. The medical records and procedural records were available for all 169 patients. These data were analyzed to determine the clinical profiles and outcomes of these patients and to determine the roles of cardiac surgery and PCI in each case. This protocol was approved by the local Human Research Committee.

Definitions

The selected cases were classified into three groups. Group 1 was defined as patients who underwent a failed PCI requiring CABG during the same admission. This group consisted of patients with complicated or failed PCI (postprocedure luminal diameter narrowing of > 60%) in whom there was threatened or evolving myocardial infarction (chest pain and/or ST-segment elevation on electrocardiogram) or hemodynamic instability; and patients with failed PCI when the patient was asymptomatic and surgery was not required emergently. Group 2 consisted of "hybrid" procedures, which was defined as a plan to perform both PCI and cardiac surgery prior to the initiation of either procedure, and included patients who required surgery due to a complication of myocardial infarction (ventriculoseptal defect or mitral regurgitation) after successful PCI for acute myocardial infarction. However, patients in whom the PCI could not be performed or was complicated were assigned to Group 1. Group 3 was defined as patients who required PCI following cardiac surgery complicated by threatened or evolving myocardial infarction, and those with unsuccessful surgery when there was no acute event.

Cardiac risk factors such as hypercholesterolemia, hypertension, family history, smoking, diabetes, and peripheral vascular disease were defined as present or absent based on a positive recorded history documented in their medical records. Stable angina was defined as stable exertional chest pain for at least 6 months, and unstable angina as any rest pain or change in symptoms in the preceding 6 months. The diagnosis of acute myocardial infarction was based on symptoms, electrocardiographic changes, and a subsequent rise in cardiac enzymes. Significant coronary artery stenoses were defined as luminal diameter stenoses of at least 60%, and severity was defined by the presence of single-, double-, or triple-vessel disease. A rise in creatine kinase was defined as a rise of more than twice the upper limit of normal. Function on discharge from the hospital was assessed as discharge to home and self-caring (class 1), discharge to home with some assistance (class 2), discharge to a rehabilitation facility, but medically stable (class 3), discharge to a rehabilitation facility and requiring mechanical ventilation and/or hyperalimentation (class 4).

Statistics

Categorical variables are expressed as percentage of the total group or as raw figures where stated, and continuous variables as mean ± standard deviation. When the three groups of patients are compared, analysis of variance (ANOVA) is used with Scheffe's test for post-hoc comparisons. Correlations within groups are assessed using standard linear regression techniques. All p values were two-tailed, and values of < 0.05 were considered to indicate statistical significance.

Results

Clinical Characteristics

The clinical characteristics of the three groups are summarized in Table I. There was a trend toward a male preponderance in Group 3, and there was a younger mean age in Group 1 (62 ± 12 vs. 68.4 ± 8.4 and 69.3 ± 11.5 years, $p < 0.01$). There was also a higher incidence of previous CABG and cerebrovascular disease in Group 3. Group 1 had significantly less severe coronary artery disease than Groups 2 and 3 (Group 1 2.0 ± 0.8, Group 2 2.7 ± 0.7, and Group 3 3.0 ± 0.9 vessel disease, $p < 0.01$). The indications for the primary procedure are shown in Table II. In both Groups 1 and 3, the majority of cases were performed for either stable or unstable angina.

Percutaneous Coronary Intervention Requiring Rescue Coronary Artery Bypass Graft

Of the 100 patients in Group 1, 61 had failed or complicated PCI with threatened or evolving myocardial infarction, and 39 were stable at the end of the failed PCI. The reason for progression to CABG in these 100 patients is summarized in Table III. Reasons for urgent surgical intervention included abrupt vessel closure, dissection, perforation, and delayed closure, including stent thrombosis. Of those with threatened myocardial infarction, 3.2% were in cardiogenic shock, and 67% underwent placement of an intra-aortic balloon pump in the cardiac catheterization laboratory prior to CABG. These patients had a mean number of 2.6 ± 1.0 grafts, and the left internal mammary coronary artery was used in 58.5% of cases.

Hybrid Procedures

Group 2 consisted of 46 patients, 33 of whom required PCI as primary or rescue treatment for acute myocardial infarction when the procedure was planned as a bridge to CABG due to left main coronary artery or triple-vessel disease. In nine cases, successful PCI was performed for acute myocardial infarction, but cardiac surgery was performed for a structural complication of the infarction. Four patients in Group 2 underwent

TABLE I Patient characteristics

	Failed PCI (n = 100)	Hybrid (n = 46)	Failed CABG (n = 23)
Males (%)	61	56.5	73.9
Age (years)	62.0 ± 12.0 [b]	68.4 ± 8.4	69.3 ± 11.5
Hypercholesterolemia (%)	68	69.6	73.9
Hypertension (%)	53	56.5	52.2
PVD (%)	12	19.6	26.1
Baseline creatinine	0.99 ± 0.30	1.15 ± 0.5	1.04 ± 0.4
Family history of CAD	30.0	21.7	17.4
Smoking (%)	55.0	47.8	65.2
Pack-years (%)	32.0 ± 19.0	28.4 ± 18.0	46.7 ± 45.6
Diabetes (%)	25.0	30.4	21.7
Cerebrovascular disease (%)	7.0	15.2	43.5 [a]
Previous CABG (%)	14.0	8.7	39.1 [a]
Previous PCI (%)	21.0	13.0	17.4
Previous AMI (%)	34.0	21.7	30.4
Number of diseased vessels	2.0 ± 0.8 [a]	2.7 ± 0.7	3.0 ± 0.9

[a] $p < 0.01$ compared with other two groups by ANOVA.
[b] $p = 0.02$ compared with other two groups by ANOVA.
Abbreviations: PVD = peripheral vascular disease, CAD = coronary artery disease, CABG = coronary artery bypass grafts, PCI = percutaneous coronary intervention, AMI = acute myocardial infarction.

TABLE II Indication for primary procedure

	Failed PCI (n = 100)	Hybrid (n = 46)	Failed CABG (n = 23)
Stable angina (%)	14.0	0	17.4
Unstable angina (%)	52.0	15.2	56.5
AMI (%)	24.0	60.9	13.0
Rescue AMI (%)	8.0	17.4	4.3
LVF (%)	2.0	2.2	4.3
Valve disease (%)	0	4.3	4.3

Abbreviation: LVF = left ventricular failure. Other abbreviations as in Table I.

TABLE III Reasons for failed percutaneous coronary intervention (n = 100)

Abrupt closure (%)	19.0
Dissection (%)	24.0
Perforation (%)	2.0
Delayed closure or thrombosis (%)	15.0
Continued symptoms with open artery (%)	15.0
Unable to pass wire (%)	8.0
Unable to deliver balloon/stent (%)	10.0
Suboptimal result (%)	5.0
Other (%)	2.0

complex hybrid procedures: three patients with previous CABG underwent PCI of graft stenoses to allow mitral valve repair via a thoracotomy and in the fourth patient a saphenous vein graft was surgically anastomosed to the left anterior descending coronary artery, utilizing a beating-heart technique, to facilitate protected stenting of the left main coronary artery.

Cardiac Surgery Requiring Rescue Percutaneous Coronary Intervention

Group 3 comprised 21 patients with evolving myocardial infarction following CABG and 2 who were stable requiring nonurgent additional revascularization by PCI (Table IV). In both nonurgent cases, the target vessel was in the left circumflex coronary artery territory and it was not possible to graft. Threatened or evolving myocardial infarction was the result of failure of graft anastamoses in eight patients, thrombosis of

TABLE IV Failed coronary artery bypass graft

Indication for rescue PCI	
Periprocedural ischemia/infarction (%)	21 (91)
Stable—failed grafting target vessel (LCx) (%)	2 (9)
Site of graft complication	
Graft anastamosis (%)	8 (38)
Body of graft (%)	4 (19)
Graft thrombosis (%)	8 (38)
Coronary artery embolism (prosthetic aortic valve) (%)	1 (4)
> 1 graft occluded (%)	1 (4)
Rheolytic thrombectomy (%)	4 (17)
Angiographic success (%)	21 (91)

Abbreviations: PCI = percutaneous coronary intervention, LCx = left circumflex artery.

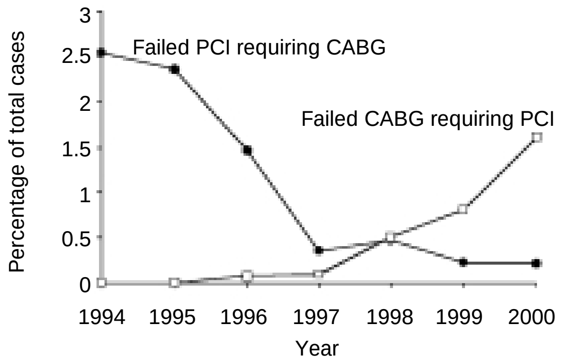

FIG. 1 Reduction in the need for rescue coronary artery bypass graft surgery (CABG) for failed percutaneous coronary intervention (PCI) between January 1994 and March 2000. There has been a simultaneous increase in the utilization of rescue PCI for failed CABG such that these events are now occurring with similar frequency.

the graft in eight patients, problems with the body of the graft in four patients, and embolism from a prosthetic aortic valve in one patient. In three cases more than one graft was occluded, and in all 25 lesions were treated by PCI. These included the native left main coronary artery in three cases, the native left anterior descending coronary artery in six cases, the native left circumflex coronary artery in four cases, the native right coronary artery in one case, the left internal mammary artery graft in three cases, and saphenous vein grafts in eight cases. Coronary artery stents were used in 14 of the 25 lesions and rheolytic thrombectomy was utilized in four cases. Procedural success was achieved in 23 of the 25 lesions (92%).

Trends

There has been a significant reduction in the number of cases requiring surgical intervention during the same hospital admission following PCI between January 1994 and March 2000, with a significant trend between year and number of cases ($r = 0.44$, $p < 0.01$) (Fig. 1). The utilization of PCI as a treatment for threatened or evolving myocardial infarction following cardiac surgery has increased in the last 2 years, such that this occurs with similar frequency as the need for cardiac surgery following failed PCI (Fig. 1). There is a significant independent correlation between the year of treatment and both age of patients ($r = 0.21$, $p < 0.01$) and the severity of coronary artery disease ($r = 0.27$, $p < 0.01$).

In-Hospital and Late Outcome

These data are summarized in Table V. There was no significant difference in mortality among the three groups, although there was a trend toward a higher mortality in Group 3 ($p = 0.06$). On multivariate analysis, the only independent predictors of survival were age ($r = 0.21$, $p = 0.03$), and cardiogenic shock ($r = 0.17$, $p = 0.01$). Functional class at discharge was not significantly different in the three groups, and the only independent predictors of functional class were age ($r = 0.38$, $p < 0.01$) and baseline creatinine level ($r = 0.28$, $p < 0.01$). Follow-up was available for 100% of the patients in Group 3 (mean = 6.8 ± 3.4 months) and 92% of patients in Groups 1 and 2 (mean = 19.2 ± 13.4 and 19.4 ± 14.2 months, respectively). Significantly more revascularization procedures were performed on patients in Group 3 than in those in Groups 1 and 2 (25 vs. 8.5 and 7.1%, $p = 0.05$).

Discussion

In this retrospective, single-center, descriptive study, we have confirmed the widely reported decrease in the need for rescue CABG following failed PCI, and documented an increase in the utilization of rescue PCI following failed CABG. The need for rescue CABG has diminished to such an extent in the last 7 years that it is now equally common for patients to require rescue PCI following CABG. We have also identified a heterogeneous subgroup that might benefit from hybrid procedures, facilitating timely yet complete myocardial revascularization.

TABLE V In-hospital and late follow-up

	Failed PCI (n = 100)	Hybrid (n = 46)	Failed CABG (n = 23)
CK rise (%)	75.0	91.3	78.3
CKMB rise (mean)	95.9 ± 103.3 [a]	135.4 ± 127.9	161.0 ± 160.9
Days in hospital	12.5 ± 8.9 [a]	19.0 ± 14.1	20.2 ± 12.7
Days in ICU	4.0 ± 6.0 [a]	7.3 ± 8.9	10.1 ± 10.7
Survival at discharge (%)	92.0	91.3	78.3
Repeat revascularization (%)	8.5	7.1	25 [b]

[a] $p < 0.01$ compared with other two groups by ANOVA.
[b] $p < 0.05$ compared with other two groups by ANOVA .
Abbreviations: CK = creatinine kinase, CKMB = creatinine kinase MB fraction, ICU = intensive care unit, Repeat revascularization = either coronary angioplasty or coronary artery bypass grafts during the period of follow-up. Other abbreviations as in Table I.

Surgical Back-Up for Percutaneous Coronary Interventions

Since the development of percutaneous transluminal coronary angioplasty, the ready availability of cardiac surgical facilities has been regarded as a cornerstone of optimal management.[10] Early experience with balloon angioplasty was characterized by the need for rescue CABG in as many as 20% of patients;[11, 12] however, this rate has recently fallen to less than one percent with the widespread use of coronary stents and the availability of effective antiplatelet agents.[12, 13] This has led some investigators to question the need for surgical support at every center performing PCI, particularly in the case of acute myocardial infarction.[14] The ability to perform coronary angioplasty without formal surgical support may be advantageous in some situations;[8] however, the ready availability of cardiac surgical support may be lifesaving in the event of coronary artery perforation with tamponade or left main coronary artery occlusion. This was the case in four patients in this current series, despite the use of modern coronary artery stents and antiplatelet agents. The prognosis following CABG for failed PCI is excellent, as demonstrated by published data and supported by the findings of this study.[15] Talley *et al.* demonstrated similar outcome at 5 years regardless of the success of the primary percutaneous coronary procedure, provided the patient underwent prompt surgical revascularization (CABG).[16] The need for rescue CABG should not preclude the use of internal mammary artery grafts.[17]

Interventional Back-Up for Cardiac Surgery

There have been many technical improvements in cardiac surgery in recent years; however, immediate postoperative ischemia remains a significant problem.[4] In fact, postoperative myocardial infarction has been reported to occur in 5 to 10% of cases, and it may account for 60 to 70% of in-hospital mortality.[3–5] In addition, postoperative myocardial infarction is associated with a decrement in late survival.[5] Although the incidence of graft failure may be reduced with the use of left internal mammary artery grafts, it is not eliminated.[5]

Compared with failed PCI, where vessel occlusion and threatened myocardial infarction may be obvious during the course of the procedure, graft occlusion following CABG may be less obvious. Graft failure may be suggested by localized ST-segment elevation, hemodynamic instability, or ventricular fibrillation. Coronary angiography is commonly required to confirm graft failure in the early postoperative period.[3] Because of the difficulty with recognition of myocardial ischemia or infarction in this clinical setting, some authors have proposed routine or standby coronary angiography following coronary CABG and have associated evidence of postoperative myocardial ischemia with early graft failure.[5, 18, 19] Balloon angioplasty of CABGs was first described over 10 years ago, and several series have described immediate success rates of 90–94%.[11, 20–23] In one series, 90% of patients remained free of symptoms up to 1 year after the intervention.[22] Balloon angioplasty of both saphenous vein and internal mammary artery grafts in the immediate postoperative setting, with excellent acute results, has been described in case reports.[24, 25] The availability of coronary stents may have further added to the potential for successful rescue percutaneous interventional procedures following failed CABG, although the high success rate of simple balloon angioplasty has meant that stents have only commonly been employed when balloon angioplasty has yielded a suboptimal result.[26, 27]

The utilization of coronary angioplasty in the setting of acute graft failure has increased at this center over the last 7 years. This may be due to increasing awareness of and technical improvements in PCI techniques, or may reflect systematic changes in the patient population referred for CABG. This group tended to be older, with a higher incidence of cerebrovascular disease. They had more severe coronary artery disease, a higher incidence of previous CABG, and follow-up revealed a poorer outcome with respect to the need for coronary revascularization. Novel approaches to CABG, including minimally invasive techniques and "beating heart" surgery, may also contribute to the increased incidence of graft failure.[28, 29] There is a clearly defined learning curve with these methods that may contribute to this phenomenon. No patients requiring rescue PCI following CABG in this series had been exposed to either of these novel techniques.

The mechanism of graft failure is not elucidated by this study. Coronary angiography and definition of the vessel lumen does not accurately define the cause of vessel stenosis or occlusion. Prior attempts to identify early postoperative graft failure have included novel thermographic and other methodologies, but these have not been widely adopted.[30] Prior series have identified a number of different etiologies of graft failure, including suture imposed strictures, intimal flaps, and thrombosis. It remains unclear whether the mechanism of stenosis should influence the approach to PCI in the immediate postoperative period.

Interface of Cardiac Surgery and Percutaneous Coronary Intervention

Both PCI and CABG have proven effective in controlling the symptoms of myocardial ischemia.[1, 2] In many cases, both interventional and cardiac surgical procedures may be reasonable treatment alternatives. The choice of treatments should be individualized and requires careful consideration of evidence from the published medical literature and of patient preferences. The patient may benefit from close collaboration between the interventional cardiologist and the cardiac surgeon. Although the need for rescue cardiac surgery following PCI may have diminished, in certain cases it is lifesaving. In addition, this study suggests that PCI can effectively treat failed grafts and residual ischemia following CABG. Repeat surgery following failed CABG remains a viable alternative to emergent PCI. The relative rates of referral for rescue PCI and early repeat surgery are not addressed by this descriptive analysis. Finally, close cooperation between the cardiac surgeon and the interventional cardiologist appears to offer the opportunity for developing new strategies to effect timely and yet complete myocardial revascularization. A combination of percutaneous interventional techniques and minimally invasive cardiac surgery may facilitate protected treatment of left main coronary artery stenosis or complete revascularization without the need for cardiopulmonary bypass.[31, 32] These changing patterns of resource utilization should be considered when planning hospital facilities and patient triage.

Limitations

The current study is a single-center, retrospective study, and these results may not be applicable to all centers. The study was only designed to analyze patients who had failed PCI or CABG in hospital, and it is possible that some events may have occurred following discharge from the hospital. However, the scope of this study was to examine the need for rescue CABG or PCI during the patient's index hospital admission secondary to procedural failure, rather than restenosis or other causes of subsequent failure of the initial revascularization strategy.

Conclusions

Rescue CABG continues to play an important role in the management of failed PCI, but the need for rescue CABG has decreased over the last 7 years, and it may now be equally common for patients to require rescue PCI following failed CABG. Furthermore, hybrid procedures may facilitate innovative approaches to challenging clinical problems. Patients undergoing percutaneous or surgical revascularization benefit from close cooperation between the cardiac surgeon and the interventional cardiologist. The advantages of such a relationship and these changing patterns of resource utilization should be considered when planning hospital facilities and patient triage. Confirmation of these reported trends and study of the technical and logistical challenges posed by rescue PCI following failed CABG is necessary.

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A Global Perspective

The knowledge base and expertise in cardiology and cardiac surgery have developed exponentially during the last few decades. Global application of these advances to mankind has lagged behind. In an attempt to address some of these issues, Chain of Hope (UK) was established seven years ago. The mission of the charity is to develop sustainable services for the treatment of children in countries where these do not exist, and to bring children to the UK for cardiac surgery aimed at conditions chosen to have maximum impact on the lives of the children and their families.

Clinical Cardiology International is pleased to publish a series of news items designed to inform readers about the activities of Chain of Hope and to enlist their help in these various projects. In this issue the case record of Nesma, who underwent surgery at the University Hospital in Cairo, is described.

FIG. 1 Nesma, who suffered from severe tetralogy of Fallot, with an Egyptian nurse prior to her operation.

In May 1999, Nesma, who suffered from severe tetralogy of Fallot, received total repair performed by the Chain of Hope volunteer team. Like most young children she recovered quickly, and is now full of energy. Nesma is able to walk to school without help and is no longer teased by her friends for being sick.

Before her operation Nesma was bluish in color, and was so weak that her mother had to carry her to school. Once there, other children would not play with her in case they "caught" her heart disease. Her family was so poor they could not afford to pay for the echocardiography to diagnose her illness, and her life expectancy without treatment was not more than 20 years.

However, her local doctor and Chain of Hope correspondent recognized her symptoms and referred her case to the office in London. There the medical board examined her notes and made the decision that Nesma should travel to Cairo to be treated by the medical team.

FIG. 2 Nesma after surgery looking ahead to her new future.

Thanks to generous support, Chain of Hope has been able to give hope to many children like Nesma, and hundreds more around the world have benefited from the charity's activities in its first seven years.

Chain of Hope urgently needs equipment and funds. To obtain further details as to how to help, please contact Emma Scanlan at *emma@chainofhope.demon.co.uk.*

Chain of Hope is a registered charity in the UK, Charity Registration No. 1081384. Founder Patron: Professor Sir Magdi Yacoub, London.