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Early graft failure after coronary artery bypass grafting: diagnosis and treatment

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ABSTRACT

Early postoperative graft failure after coronary artery bypass grafting (CABG) is still a significant problem that results in high morbidity and mortality. Different therapeutic options are available to manage this complication which include reoperation, balloon angioplasty, angioplasty along with stenting and conservative medical management. Herein, we review the existing literature in diagnosis and treatment options for overcoming early graft failure immediately following CABG.

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Keywords: Coronary artery bypass grafting; graft failure; percutaneous coronary intervention

Introduction

The success of coronary artery bypass grafting (CABG) depends on constructing quality anastomoses with durable conduits on to appropriate target coronary arteries. Despite its highly favorable outcomes, a significant number of patients suffer early graft failure after CABG. Several angiographic studies have demonstrated that up to 15% of saphenous vein grafts and 8% of left internal thoracic artery grafts are occluded in the very early postoperative period of CABG [1-6]. If identified, this problem may be repaired shortly after or at the time of the operation because it is thought to be mainly a result of a surgical or technical problem. Besides poor graft patency has been clearly correlated with markedly increased 30-day and late mortality [4].

Patency rates after CABG

The gold standard for detecting the patency of the bypass grafts is coronary angiography. Regarding the type of bypass grafts, the left internal thoracic artery grafts achieve improved long term patency when compared with the saphenous vein grafts that have a 10-12% incidence of failure within the early postoperative period after CABG [1, 6]. There are several studies in the literature that demonstrated up to 12 % early graft failure especially in the saphenous vein grafts by using coronary angiography. Fittzgibbon *et al.* [1] showed 565 (12%) occlusions in 4592 vein grafts and 25 (5%) occlusions in 456 arterial grafts in the early postoperative period.

Wiklund *et al.* [7] performed coronary angiography in the first five days of the postoperative

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period in eighty-four consecutive patients undergoing CABG without the use of cardiopulmonary bypass. The mean number of grafts (n=113 grafts) was 1.4±0.1. One hundred and two arterial grafts and 11 saphenous vein grafts were used in their study and they showed occlusion of the internal thoracic artery in four patients and occlusion of a vein graft to the right coronary artery in one patient. These results meant a 96% overall graft patency. In their recent study Kim *et al.* [5] performed early postoperative angiography to assess anastomosis accuracy and patency after off-pump coronary artery bypass grafting in 1345 patients between 1998 and 2007. Of the 1345 patients, 1278 patients (95.0%) underwent early postoperative angiography on postoperative 1.6±1.2 days. A total of 3857 distal anastomoses were evaluated and they found arterial graft patency as 98.9%, and saphenous vein graft patency as 88.2%. Similar to aforementioned studies Jokinen *et al.* [8] found a 5% failure in the left internal thoracic artery and 17% failure (26/149) in the saphenous veins.

Detection of graft failure

Graft failure during or following CABG results in acute myocardial ischemia/infarction which is an important clinical problem because it is closely associated with increased morbidity and mortality. The development of myocardial infarction is often preceded by a period of myocardial ischemia. Therefore early detection of perioperative myocardial ischemia and an emergent secondary revascularization procedure may relieve the ischemia and decrease the incidence and the size of myocardial injury that will preserve ventricular function and improve the patients' outcome.

The pathogenesis of myocardial cell damage during the postoperative course of CABG has been the subject of intensive clinical research and it is shown by several studies that ischemia appearing shortly after CABG could either be graft-related or non-graft related [1, 9, 10]. The most common graft-related reasons for peroperative myocardial infarction are graft occlusion due to acute graft thrombosis, kinking or overstretching of the graft, subtotal anastomotic stenosis, injury of the graft during harvesting and graft spasm [4, 11]. Non-graft-related peroperative myocardial infarction might be induced by different mechanisms during surgery, including inadequate cardioplegic perfusion and myocardial protection, incomplete revascularization, and distal coronary microembolization due to surgical manipulation [6, 12]. These graft-related or non-graft-related etiologies induce myocardial hypo or malperfusion with regional myocardial dysfunction, leading to myocardial cell damage extending from the subendocardium to the subepicardium in a time-dependent fashion which may all lead to myocardial necrosis with elevations of cardiac biomarkers and enzymes.

In the early postoperative period, patients are usually monitored with frequent biochemical analysis and routine ECG recordings. Myocardial infarction diagnosed by these two methods is associated with adverse outcome. Several studies have been reported the issue of diagnosing myocardial infarction by serial blood sampling for determination of CK-MB troponin I, and troponin T, and various cut-off limits have been suggested [9, 10, 12, 13]. The diagnostic performance of these markers in the nonsurgical setting is very well described in numerous studies [14]. Holmvang *et al.* [12] reported their study in 103 patients with a conclusion that serial postoperative biochemical data, preferably CK-MB mass and troponin T can identify a subgroup of patients with a high rate (20 to 27%) of early graft occlusion. However, diagnosis of peroperative myocardial infarction is associated with several problems. Due to the surgical trauma and cardiopulmonary bypass, the usual non-invasive indicators of myocardial infarction such as pain, ECG changes, and elevated biochemical markers have less diagnostic value than in nonsurgical patients [11, 12]. Transesophageal echocardiography will be able to identify an area with reduced contractility, but will be unable to provide the detailed information about the underlying cause.

Recently observations with cardiac troponin I showed promising results in detecting peroperative myocardial infarction. Thielman *et al.* [10] in their prospective study, performed acute re-angiography in 94 of 3308 consecutive CABG patients because of evidence of peroperative myocardial infarction and found that perioperative cardiac troponin I elevation after CABG was significantly higher in patients with graft-related peroperative myocardial infarction than in patients with non-graft- related myocardial infarction. This finding might be due to the fact that the size of myocardial infarction induced by graft failure was potentially greater than myocardial infarction induced by non-graft-related mechanisms.

The major limitation of this was that cardiac troponin I reach to a prognostic value at least 12 to 24 hours after the surgical procedure which leads to a delay in reintervention time. But the possible benefit of re revascularization for preserving the ventricular function is time dependent.

This brought out an interest for detecting the early graft failure intraoperatively which led to the use of new tools for intraoperative patency assessment which were described in literature. Indocyanine green fluoroscopy and transit-time ultrasound flowmetry are validated and easy to use means of identifying graft errors and surgical correction intraoperatively [8, 15-19]. However, they pose potential risks to the patient by prolonging cross-clamp and cardiopulmonary bypass times, and they may theoretically could lead to poorer anastomosis quality and patency by inappropriate revision.

Early graft occlusion is frequently responsible for peroperative myocardial infarction when it is manifested by acute ST-segment changes, rise in cardiac biomarkers (especially cardiac troponin I), hemodynamic instability, or sustained ventricular arrhythmia. Most of the cardiac surgeons experience addressing this problem was that occlusion of a graft was a constant finding in patients that suffers circulatory collapse early after CABG and survival after immediate re-operation is possible. This may lead one to the hypothesis, that if early graft failure and/or incomplete revascularization are the most common causes of myocardial ischaemia early after CABG, this should be diagnosed by angiography and treated by a re-intervention either re-CABG or PCI [11, 20, 21].

Rasmussen *et al.* [11] reported their study including 71 patients among 2003 isolated CABGs that underwent acute re-angiography or immediate reoperation (Table 1). In this study, their objective was to study causes of perioperative ischaemia and infarction by acute re-angiography and to treat incomplete revascularization caused by graft failure or any other cause. Of the 71 patients 59 underwent acute re-angiography and 12 underwent reoperation due to circulatory collapse. In the acute re-angiography group graft failure/incomplete revascularization was demonstrated in 43 patients (73%). Their angiographic findings were: occluded vein graft in 19 (32%); poor distal run-off to the grafted coronary artery in 10 (17%); internal thoracic artery stenoses in 4 (7%); internal thoracic artery occlusion in 3 (5%); vein graft stenoses in 3 (5%); left internal thoracic artery to subclavian artery steal in 2 (3%); and the wrong coronary artery grafted in 1 (2%). According to these findings, 27 patients were re-operated and re-grafted with a 30-day mortality of 3 (7%) patients. In the immediate reoperation group, graft occlusions were found in 11 patients (92%) and

Table 1. Angiographically controlled study results from literature

Authors	Patients with graft failure	Angiographically evaluated graft failure	Treatment (number of patients)	Effected Graft
Thielman *et al.* [6]	67	84 failure -70 occlusion -5 kinking graft -9 stenosis)	PCI (25) Re-operation (15) Medical (27)	LITA=35 RITA=1 SVG=48
Price *et al.* [24]	14	9 failure -2 occlusion -6 stenosis -1 poor runoff	PCI (10) Medical (4)	LITA=2 SVG=6
Rasmussen *et al.* [11]	55	41 failure -22 occlusion -6 stenosis -10 poor runoff -2 subclavian steal -1 wrong coronary	Reoperation(27) Emergent op (12) Medical (16)	LITA=7 SVG=22
Fabricius *et al.* [4]	86	70 failure -41 occlusion -29 stenosis	PCI (9) Reoperation (34) Emergent surgery (23) Medical (20)	Not available

PCI=percutaneous coronary intervention, LITA=left internal thoracic artery, RITA=right internal thoracic artery; SVG=saphenous vein graft

the 30-day mortality was 6 (50%) patients. As a conclusion they recommended that acute re-angiography demonstrates graft failure or incomplete revascularization in the majority of patients with myocardial ischemia early after CABG and reoperation for re-revascularization can be performed with low risk besides a few patients with circulatory collapse can be saved by an immediate reoperation without preceding angiography.

In another study Fabricius *et al.* [4] studied 131 (6.4%) patients among 2052 isolated CABGs those met the criteria of perioperative myocardial ischemia/infarction, which was defined as: increase in the isoenzyme ratio of CK/CK-MB above 10%; ischemic electrocardiographic findings (defined as a new onset of elevated ST-segment change lasting at least 1 min and involving a shift from baseline of greater than or equal to 0.1 mV of ST-depression and a new association of a postoperative Q wave; recurrent episodes of sustained ventricular tachyarrhythmia as well as ventricular fibrillation; hemodynamic deterioration despite adequate inotropic support). Angiography was performed in 108 (5.3%) of 131 patients whereas other 23 patients (1.1%) were immediately re-operated due to severely compromised hemodynamics. Results of the angiographic group showed regular grafts in 45 patients; in 63 patients there were 41 occluded grafts, 29 incorrect anastomoses, 14 graft stenosis, 6 graft spasm, 6 displaced grafts, 5 poor distal run-off and 2 incomplete revascularizations. Of these 45 patients, 43 underwent a re-operation (34 patients) or an early angioplasty (9 patients). Due to poor coronary artery status no intervention was performed in the remaining 20 patients with angiographic findings (Table 1).

Operative findings in immediately operated 23 patients showed graft occlusion in 10 patients (43.5%), incorrect anastomoses in 5 patients (21.7%), bleeding, stretched graft, venous graft spasm and displaced graft in one patient (4.3%) each, and no patho-morphological finding in 4 patients (17.4%). Thirty-day mortality rate was 10 patients (9.3%) with angiographic findings opposed to 9 patients (39.1%) in immediately operated group without performing angiography. They also concluded that the combination of ST segment change and CK/CK-MB ratio is effective in detecting graft failure and acute re-angiography should be performed in stable patients with the event of perioperative ischemia after CABG which allows safe and precise diagnosis and enables early re-intervention.

In their recent study, Thielman *et al.* [6] tried to identify the source of peroperative myocardial infarction and to pursue the appropriate re-revascularization strategy, coronary re-angiography was performed in 118 among 5427 consecutive isolated CABG patients with evidence of peroperative myocardial infarction. As a result, patients immediately underwent acute PCI, emergency reoperation, or were treated conservatively. Re-angiography revealed early graft failure in 67 of 118 patients and 84 of 214 bypass grafts after CABG (see Table 1). Acute PCI was applied in 25 patients, redo-CABG in 15 patients, and conservative treatment in 27 patients. Global left ventricular ejection fraction was reduced during the acute ischemic event when compared with preoperative values ($p<0.01$). Left ventricular ejection fraction improved during follow-up within each group ($p<0.001$), but did not differ between the three groups. In-hospital and 1-year mortality rates were 12.0% and 20.0% in PCI group, 20.0% and 27% in reoperation group, and 14.8% and 18.5% in the conservatively treated group, respectively (p=NS). In this prospectively designed but not a randomized trial to compare the three treatment groups, they concluded that emergency re-revascularization with PCI may limit the extent of myocardial cellular damage when compared with the surgical-based treatment strategy in patients with acute perioperative myocardial ischemia due to early graft failure following CABG because it seems be quicker and less invasive.

Hanratty *et al.* [22] reported their experience with 5 patients those underwent PCI to the distal anastomosis early after CABG. In all of the patients PCI was preferred over reoperation because the vessel was initially difficult to graft or because of excessive risks of reoperation due to co-morbidity. There was no mortality and no procedural complication. In a similar study, Laflamme *et al.* [23] reported 32 patients suffering from early postoperative graft failure. Fifteen of the patients were treated with PCI, four of the patients underwent reoperation and thirteen of the patients were treated conservatively. The authors concluded that acute reintervention either PCI or reoperation was superior to conservative management in terms of myocardial cellular damage.

Price *et al.* [24] reported their recent study in which they examined the angiographic and clinical outcomes of ten patients who underwent percutaneous

coronary intervention for myocardial infarction or ischemia soon after CABG. In this study, they analyzed 14 (4.3%) of 321 patients in a two years period whom underwent unplanned cardiac catheterization after the procedure was analyzed of these four patients were treated medically (3 without a culprit lesion and 1 with an atretic free right internal mammary artery graft that led to an obtuse marginal that was believed to be suitable to PCI). The remaining 10 patients underwent emergency PCI and 6 received drug-eluting stents. The etiology of myocardial ischemia/infarction was venous graft occlusion in 2 patients, venous graft stenosis in 4 patients, left internal mammary artery stenosis in 2 patients, incomplete revascularization in 2 patients, and poor distal run-off in one patient (1 patient had a venous graft stenosis and occlusion). Mortality rate was 20% with 2 patients, major bleeding occurred in 40 % (4 patients; one patient with sirolimus-eluting stent, one patient with a heparin-coated stent, and 2 patients with standalone balloon angioplasty). The site of bleeding was cardiac tamponade within 24 hours after PCI in 2 patients, gastrointestinal in one patient, and significant chest tube drainage in one patient. As a major finding they stated that rescue PCI for perioperative myocardial ischemia is feasible, but that angiographic complications are not uncommon and postprocedural bleeding is frequent, especially in patients who undergo intervention acutely after CABG and added that their findings support the contention that PCI of freshly sutured anastomosis may pose a significant risk of graft/native coronary rupture ,especially if high-pressure stent deployment is involved which means that the use of drug-eluting stents in this patient group should be carefully considered.

Treatment options

In the light of the whole aforementioned studies postoperative myocardial ischemia following CABG adversely affects both short- and long-term prognosis. Early graft failure is the major cause of ischemia or

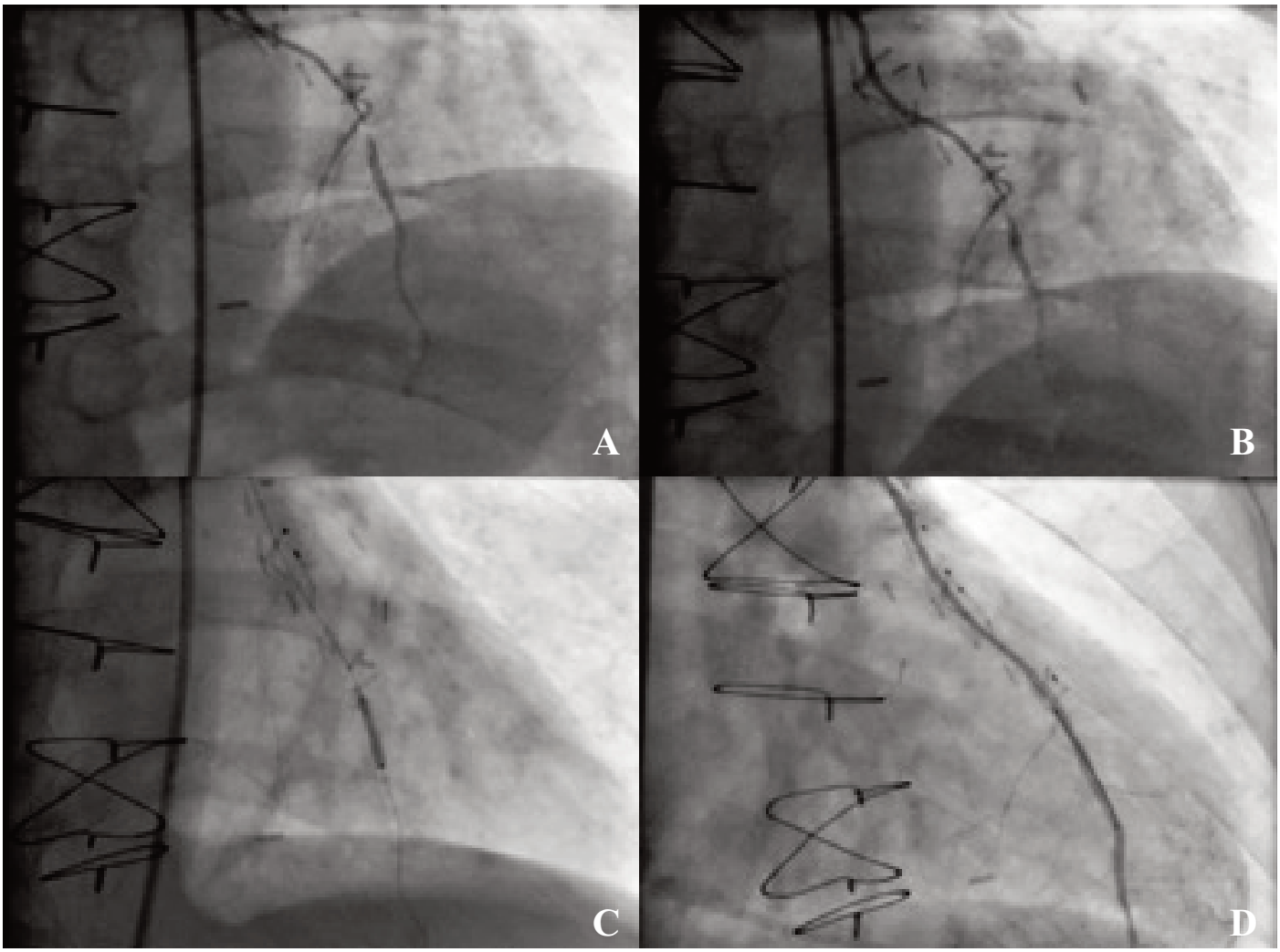

Figure 1. PCI for LITA graft stenosis on the 4th postoperative day (A and B: before intervention; C and D: during and after PCI)

peroperative myocardial infarction after CABG. The most common reasons for early graft failure are likely to be due to technical problems, and the handling of the grafts. Diagnostic criteria of myocardial infarction early after CABG is less specific and more difficult to interpret than in the non-operative setting, acute graft failure is usually suggested by new ST-segment elevation, acute heart failure, hemodynamic instability, and life-threatening ventricular arrhythmias. Although cardiac specific markers such as cardiac troponin I have promising results to discriminate graft related and non-graft-related myocardial injury 12 or 24 hours detection time seems to be too long for emergent myocardial muscle salvage. Therefore prospective randomized trials with new biomarkers for myocardial ischemia such as heart type fatty acid binding proteins or ischemia modified albumin which have recently been reported to detect myocardial ischemia within the first 30 min, may enable early reintervention to restore myocardial perfusion [25-28].

If hemodynamic status permits an emergent re-angiography is safe and valuable to determine the cause of early postoperative myocardial ischemia and helps to define the optimal treatment strategy [4, 11]. Surprisingly, it is observed in some studies that 25% to 34% of patients undergoing coronary re-angiography for suspected early graft failure after CABG have patent grafts [4, 11, 18].This important finding suggests that early graft failure should be confirmed with re-angiography (if the hemodynamic status enables) instead of carrying out a blind reoperation.

The therapeutic strategies to treat patients with acute severe ischemia after CABG are conservative medical management with the help of the intra-aortic balloon pumping, direct reoperation, balloon angioplasty and stenting.

Rescue postoperative balloon coronary angioplasty for failed CABG is being performed for over 20 years but few cases have been published which demonstrates that the procedure can be performed safely and effectively [4, 11, 21-24] (Figures 1 and 2). As another option, intracoronary thrombolytic therapy has also been used in the

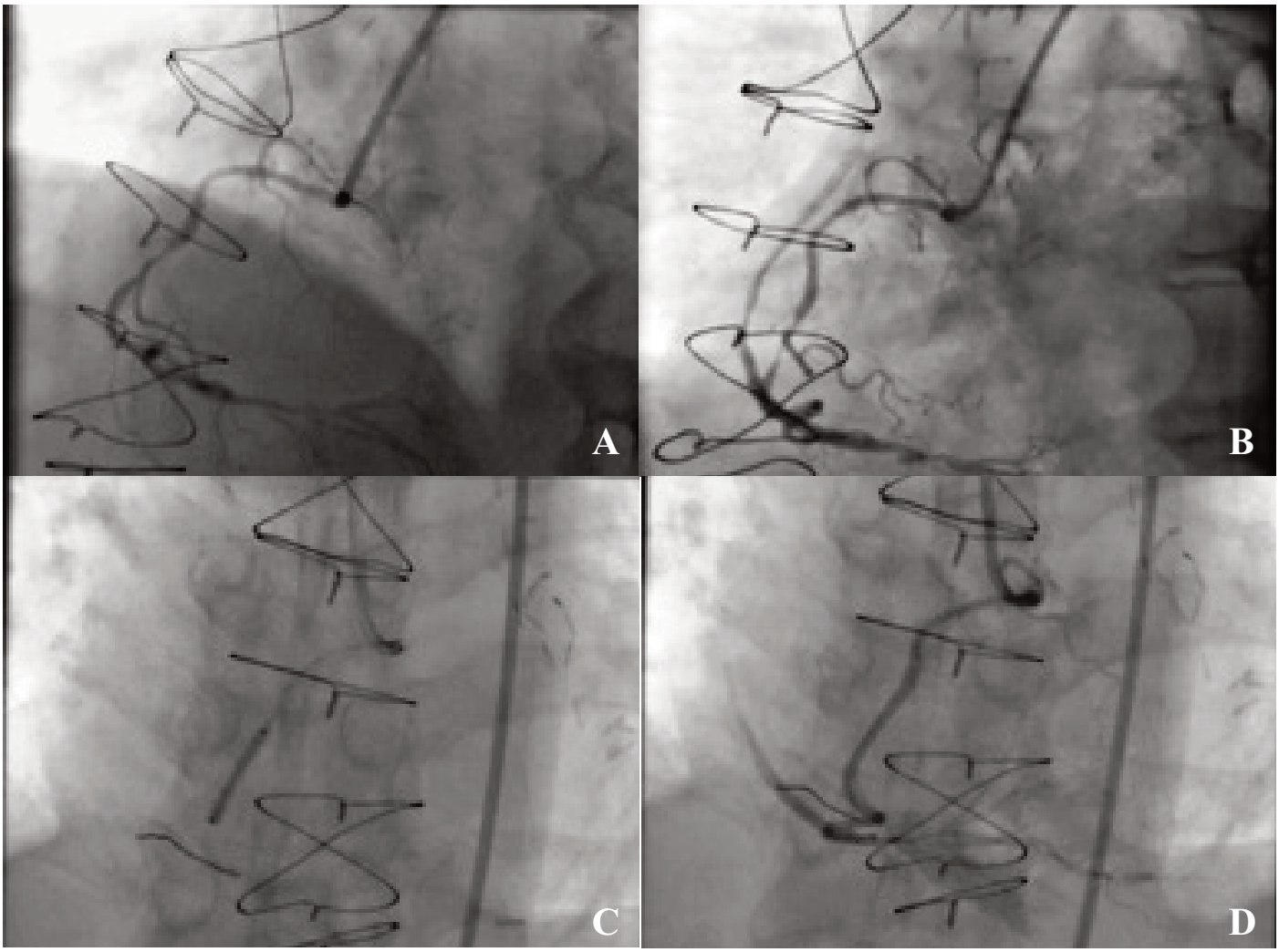

Figure 2. PCI for native right coronary artery due to saphenous vein graft failure on the 4th postoperative day (A and B: before intervention; C and D: during and after PCI)

treatment of graft closure immediately after CABG, but due to the inherent risk of hemorrhage, this has not been widely adopted in the early postoperative period [28].

Both PCI and reoperation are beneficial treatment options for early graft failure. With immediate PCI relief of ischemia is more rapid, potentially salvaging more myocardium. Repeat cardiopulmonary bypass may create additional reversible left ventricular dysfunction, and possibly elevates the risk of perioperative stroke and renal failure. On the other hand, the anticoagulation used for PCI may promote bleeding from surgical wounds, especially if glycoprotein IIb/IIIa inhibitors are used [22]. PCI also has a higher need for repeat target lesion revascularization.

Conservative medical management is the other treatment option in patients with severe ischemia after CABG. It may be considered in patients with advanced age, severe coronary artery disease, or coexisting medical problems that prevents the use of a more invasive approach. The decision of which strategy to choose should be made on an individual basis, taking the specific circumstances of each patient into account. The choice of best treatment strategy depends on individual patient characteristics.

Conclusions

To date, the best strategy for the treatment of acute graft failure after CABG is still unclear and remains controversial. Probably the majority of the cardiac surgery centers prefer to treat those patients conservatively. On the other hand the number of publications and surgeons preferring reintervention in this clinical setting are increasing. As a result in this new era emergent reintervention for the relief of postoperative ischemic complications after CABG with either catheter-based or surgical-based treatment strategies should require an integrated approach with the involvement of the cardiac intensive care physician, the interventional cardiologist, and the cardiac surgeon. This collaboration may improve the patients' outcome and lead to a new paradigm in which the cardiac cath-lab or a hybrid operating room is routinely available to help the surgeon when early postoperative ischemia is identified. Therefore, further multi-institutional randomized clinical studies are needed to clarify the appropriate treatment strategy in these patients.

Conflict of interest

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