CHRONIC TOTAL OCCLUSION IN PATIENTS AFTER CORONARY ARTERY BYPASS GRAFTING: A REVIEW OF POSSIBLE INTERVENTIONS AND RESULTS WITH A CASE STUDY

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ABSTRACT

Within 10 years following a coronary artery bypass graft (CABG), only 60% of vein grafts and 90% of internal mammary artery (IMA) grafts remain patent. Chronic total occlusion (CTO) in patients after a CABG exhibits more advanced stable atherosclerosis. Although the precise mechanism of atherosclerosis in these patients is unknown, several clinical studies have reported that atherosclerotic progression occurs more rapidly in grafted arteries than in non-grafted arteries. These data support the fact that the IMA has a favourable metabolic effect not only in the bypass, but also in the bypassed artery, which is defined by nitric oxide products.

The occlusion frequency of the initial stenotic artery in the proximal or distal segment was ~22% after application of the IMA, and on average 48% after an autovenous bypass. In multivariate analyses, bypass interventions are independently associated with higher hospital mortality and peri-operative complications. Mortality was 2.6% if artery recanalisation was successful, 5.2% in the case of partial success, and 8.2% in the case of failure.

However, due to the difficulty of access, spastic reactions, the small diameter of the artery, and a large area of myocardium that feeds the IMA, use of the IMA for CTO recanalisation is limited. A case study of CTO intervention is used to describe the retrograde approach to CTO of the left anterior descending coronary artery through the IMA and diagonal branch in a patient after a CABG 10 years ago. Two microcatheters were used, and the operation was successfully completed in two stages because of unstable patient condition.

Keywords: Chronic total occlusion (CTO), coronary artery bypass graft (CABG), venous graft, internal mammary artery (IMA), retrograde approach.

INTRODUCTION

The need for repeated interventional/surgical procedures in patients after a coronary artery bypass graft (CABG) is determined by the condition of the coronary bypass grafts and progressive atherosclerosis of the native coronary arteries. Within 10 years following a CABG, only 60% of vein grafts and 90% of internal mammary artery (IMA) grafts remain patent. According to other data, up to 20% of autovenous grafts occlude within the first post-operative year.[1-3] Results of a post-operative coronarography show an accelerated progression of the process in the bypassed coronary artery, which leads to the progression of stenotic lesions to total coronary occlusion, which is determined not so much by the progression of the atherosclerotic process itself, but by changes to intracoronary circulation after the insertion of bypasses. With the improvement of interventional techniques, the number of repeat CABGs at recurrence clinics has declined

significantly and are carried out in 3% of all repeated interventions. A repeat CABG carries a higher risk than an initial CABG. Percutaneous coronary intervention (PCI) is the most common revascularisation procedure after a CABG.

Occlusions of coronary arteries following a repeat CABG surgery are different from those in patients without a previous CABG. Chronic total occlusion (CTO) in patients after a CABG exhibited more advanced stable atherosclerosis. Although the precise mechanism of atherosclerosis in these patients is unknown, several clinical studies have reported that atherosclerotic progression occurs more rapidly in grafted arteries than in non-grafted arteries.[4-6] Blood stasis and low shear stress resulting from competitive flow between native and bypass grafts may serve as the underlying mechanism of greater calcification in the grafted native arteries. Furthermore, the progression from severe atherosclerosis to total occlusion, which is usually located proximal to the anastomosis, is common in grafted arteries.[7-9] PCI on such occlusions are usually more time consuming and more difficult for recanalisation, which partly defines solid 'distal cup' occlusion, formed under the influence of high perfusion pressure, supported by functioning grafts.[10]

CTO treatment of native coronary arteries in patients after a CABG is less effective and more frequently performed by retrograde access through both collaterals and functioning or stenosed venous bypasses.[11-13] Interventions on stenotic venous anastomosis are quite often performed with an efficiency comparable to native coronary arteries, but with a slightly higher rate of complications.[14] Lesions of the IMA in patients after bypass surgery occurs less frequently, but artery stenting is also possible.

Most PCIs performed in prior CABG patients are undertaken in native coronary artery lesions. Compared with native PCI, bypass graft PCI is independently associated with higher in-hospital mortality.[15] As has been demonstrated, with any CTO intervention, patients in whom CTO PCI was successful had better outcomes compared with those in whom CTO PCI failed. The presence of CTO may adversely affect outcomes in patients who develop an acute coronary syndrome, as this may affect an even larger myocardial area than the target-vessel distribution.[16-18] Treatment of a native coronary artery CTO has been described for an acutely thrombosed saphenous vein graft that could not be recanalised, but it can be a challenging procedure requiring specialised equipment and expertise.[19-21]

Calcification is also associated with difficulty in obtaining success during PCI in CTO. Extensive and larger areas of calcification may explain the lower success rate of PCI in CTO patients with a prior CABG (>2 years ago) compared with CTO without a prior CABG.[8,9]

PHYSIOLOGICAL EFFECTS OF GRAFTS ON NATIVE CORONARY ARTERIES

The main advantages of a CABG with IMA use are determined not only by the duration of the bypass operation itself, but also by differences in endothelial metabolic effects of the IMA, venous bypass, and the stented segment, especially in patients with severe coronary endothelial dysfunction or in diabetes patients with multivessel disease.

In 1990, Werner et al.[22] investigated the vasoactive properties of the IMA and venous bypass in CABG patients after acetylcholine indication and found that the IMA is biologically more active than venous bypass because of more active production of endothelial factors.[6] Moreover, the study by Kitamura[23] defines different responses of the lumen depending on the artery bypassed; the presence of the IMA graft resulted in vasodilation of the bypassed coronary artery by an average of 7%, whereas the use of venous bypass leads to narrowing of the bypassed artery by 9% ($p<0.018$).[23] These data support the fact that the IMA has a favourable metabolic effect not only in the bypass, but also in the bypassed artery, which, according to the authors, is defined by nitric oxide (NO) products.[24]

Contemporary data suggest that negative remodelling of human CTOs occurs in two phases. In the early phase, a fibrin-rich, organising thrombus becomes a proteoglycan-rich thrombus. In the late phase, the proteoglycan-rich thrombus becomes replaced by dense collagen within the CTO. Furthermore, there was significantly less negative remodelling in calcified CTOs than in non-calcified, collagen-rich CTOs; severe calcification may provide a solid frame that prevents the CTO vessels from negative remodelling. As CTO with a CABG had the highest calcification, severe calcification may explain the moderate negative remodelling observed in CTOs with a CABG,

compared with the CTOs without a CABG and severe negative remodelling.[8]

CHRONIC TOTAL OCCLUSION PATTERNS IN PATIENTS AFTER CORONARY ARTERY BYPASS GRAFTS

The occlusion cups are known to influence CTO recanalisation success. Sakakura et al.[4] analysed the lumen of coronary segments proximal and distal to CTOs to determine the nature of the lumen (abrupt or tapering). The reported prevalence of the proximal abrupt lumen pattern by angiography varied from 39.1–66.1%. The prevalence of the proximal abrupt pattern was highest in CTOs with CABG surgery (58.8%). Results demonstrated that the majority of distal segments of CTO have a tapered pattern, explaining why the true lumen position of wire is greater in the retrograde approach. Additionally, the tapered pattern of a CTO lumen is a better predictor of successful PCI based on a more favourable accessibility of guidewires into true lumens. Histological correlates of angiographic CTOs have shown the influence of the duration of total occlusion on the presence of calcification, inflammation, and neovascularisation. Another important finding in angiographic CTOs was the absence of complete occlusion on histological examination (70%). The presence of a microchannel diameter of 160–230 μm in a human pathological study has thus encouraged the development of corresponding equipment.[4,7]

PROGRESSION OF NATIVE CORONARY ARTERY OBSTRUCTION

A number of researchers have studied the frequency and characteristics of lesion progression in the vessel-recipient with regard to the type of anastomosis used. The occlusion frequency of the initial stenotic artery in the proximal or distal segment was ~22% after the application of IMA, and 48% on average after autovenous bypass.[2,3,5]

Similar results were obtained by Kitamura,[23] who observed occlusion frequencies of 18% and 46%, respectively. Kitamura also provides the results of similar studies for comparison: Loop F et al. found 39% versus 67%; Manninen H et al. 26% versus 45%; and Hamada Y et al. 12% versus 38% for IMAs and the venous bypass procedure, respectively.

One explanation for these differences may be the greater blood flow in the bypass compared with the IMA and the associated reduced blood flow in the stenotic segment of the coronary artery, leading to the total coronary obstruction. On the other hand, factors produced by the endothelium of IMA may have a protective effect against the progression of coronary stenosis, possibly due to higher levels of NO production than observed in autovenous bypass.

INTERVENTIONS

Brilakis et al.[10] analysed a National Cardiovascular Data Registry report that provided results of PCI in 300,902 patients that had undergone a prior CABG. PCI of native coronary arteries was carried out in 62.5% of patients, and intervention was performed on bypasses in the remaining patients, 34.9% of whom had venous bypass PCI and 2.5% of whom had arterial bypass PCI. The study found that bypass interventions were more frequently performed in males, incurred more risk factors, and cases of acute myocardial infarction often occured.[10] In a multivariate analysis, bypass interventions were independently associated with higher hospital mortality and peri-operative complications.[10] CTO PCI in native coronary arteries in patients who underwent a CABG was performed for 16,376 patients (5.4%) and was successful in 76.6% of cases; however, there was high hospital mortality in this subgroup (3.4%). Mortality was 2.6% if artery recanalisation was successful, 5.2% in the case of a partial success, and 8.2% in the case of failure.[10,25,26]

According to contemporary data, in the absence of a prior CABG, CTO is determined in 18.4% of patients through routine coronary angiography. The effectiveness of CTO revascularisation using modern recanalisation equipment exceeds 85%. In the case of previous myocardial bypass surgery, more than half of patients with recurrent symptoms have chronic coronary artery occlusion. Recanalisation of the occluded artery in this setting causes a number of complications, and the effectiveness of revascularisation is ~80%.

Literary sources indicate that retrograde access at recanalisation of chronic occlusions of coronary arteries is more common in patients after a CABG.[27,28] The modern concept of a retrograde approach was proposed and justified by Japanese operators in 2005, and its use has since increased.[19] The methodology is constantly being refined to improve patient experience, and the creation and clinical implementation of better recanalisation equipment is ongoing.

Currently, the retrograde approach can be classified by the following conditions: direct retrograde wire crossing, kissing wire crossing, controlled antegrade and retrograde subintimal tracking (CART), and reverse CART. In accordance with the data from the Japanese retrograde registry 2009–2011, during retrograde access the septal collaterals were used in 60–65% of cases, the epicardial in 30–40% of cases, and coronary bypasses in 2–3% of cases.[15,29] Important new opportunities in the implementation of retrograde recanalisation appeared after the introduction into clinical practice of a microcatheter 'Corsair' (Asahi Intecc Co.), that allowed safer crossing of the collateral channels.[11,14,21,28]

The possibility of PCI in patients after a CABG with arterial anastomosis also warrants discussion. In contrast to venous bypasses, IMA is less prone to atherosclerotic changes, yet is more prone to spasm. The left anterior descending artery (LAD), bypassed by the internal thoracic artery, remains prone to atherosclerotic processes even with a patent IMA, and could lead to a deterioration of the clinical condition of the patient.[30,31] In addition, septal collaterals may be the only point of access for retrograde recanalisation of the right coronary artery (RCA) and the left circumflex (LCX) artery.

In view of the difficulty of access, spastic reactions, small diameter of the artery, and the large area of myocardium that feeds the IMA, use of the IMA for CTO recanalisation is limited. Nevertheless, such cases have long been described in the literature. Taking into account a long route from the origin of the IMA to the LAD lesions, the need for use of special equipment may occur.

In the literature, there are sporadic references to an effective CTO recanalisation in patients after a CABG, with access through the use of the IMA or vein bypass. Michael et al.[32] reported two cases of successful intervention in patients after CABG surgery using the retrograde approach and technology: the first case introduced the recanalisation equipment through the internal thoracic artery, and the second, in which the internal thoracic artery was used as a source of imaging in recanalisation of chronic coronary occlusion of RCA through collaterals from the native LAD, used three points of access. Torii et al.[33] described a case of successful RCA retrograde recanalisation in patients after CABG surgery and Q-wave myocardial infarction. For retrograde access septal collaterals were used, bypassed by the IMA and LAD. Access was carried out using a 5 Fr guide catheter, deeply intubating the IMA. Advance of the guiding catheter was carried out with the support of the microcatheter and stiff wire 'Grand Slam' (Asahi Intecc). Mibiki et al.[34] describe the case of successful recanalisation of CTO of the LAD via the gastroepiploic artery graft to the RCA. In this case, a 4 Fr guiding catheter was applied to the twisted gastroepiploic artery, which provided sufficient support for the recanalisation equipment.[34]

Park et al.[35] of University Hospital, Geneva, discussed the use of the 'Guideliner' catheter (Vascular Solutions Inc.) to ensure safe and successful advance of the equipment with adequate back-up. In addition, the use of 'mother and child technology' can be applied where there is insufficient visualisation of the distal part of the LAD with the existing competitive bloodstream through the left internal mammary artery (LIMA). It is worth noting that PCIs through the LIMA often pose a challenge. The procedure can be dangerous as the artery develops, straightening and accordioning after the guidewire and balloon are placed in the graft, preventing angiographic assessment if there is no flow through the graft.[30-32] In our practice, we have seen cases of significant spastic reactions during interventions in patients with distal anastomosis disease.

CASE STUDY

A 50-year-old man with a prior CABG 10 years ago (one IMA and four venous grafts) presented with severe angina and onsets of pulmonary oedema (Killip Class II) despite optimal medical treatment. A hypertension 2D echocardiography test showed an ejection fraction of 35% with anterior and inferior hypokinesia.

Coronary angiography revealed RCA CTO with graft occlusion and left main artery CTO. A venous graft to the LCX artery with 70% stenosis was patent. LIMA to the LAD was patent, but the LAD itself was diffusely diseased and occluded (Figure 1A).

After circumflex venous graft stenting, we started LAD recanalisation through the LIMA graft using a 7 Fr guiding catheter. We began with an antegrade approach, using a Corsair microcatheter (150 cm) and a 'Sion' wire, which easily navigated the large diagonals, connected by collaterals with the apical part of the occluded LAD. During our operation,

the patient experienced angina, particularly during the contrast injection. Avoiding excessive use of the contrast media injection, which can cause ischaemia and haemodynamic instability, and considering the negative aspects of subintimal LAD tracking in such a patient, we easily crossed the collaterals from the diagonal branch to the LAD retrogradely, and left the wire in the distal part of the LAD as a marker (Figure 1B). The size of the mammary artery allowed us to use one more microcatheter, the 'Finecross' (150 cm) (Terumo Interventional Systems) with a Fielder XT wire. With use of the kissing wire technique we recanalised the LAD with antegrade wire. After that, dilatation with a 1.5 mm balloon 'Trek' (Abbott Vascular) was performed. We left the Corsair in the diagonal branch to visualise the LAD without using a contrast injection through the guiding catheter (Figure 1C).

At that time the patient suffered a pulmonary oedema. We stopped the operation and started again the following day, at which point the patient's condition was stable. A coronarography demonstrated patent LAD with subocclusion at the apical part. We performed LAD stenting with Xience 2.25 mm/23 mm (Abbot Vascular) and a drug-eluting balloon angioplasty 2.0 mm/20 mm at the apical part with an acceptable angiographic and clinical result (Figure 1D).

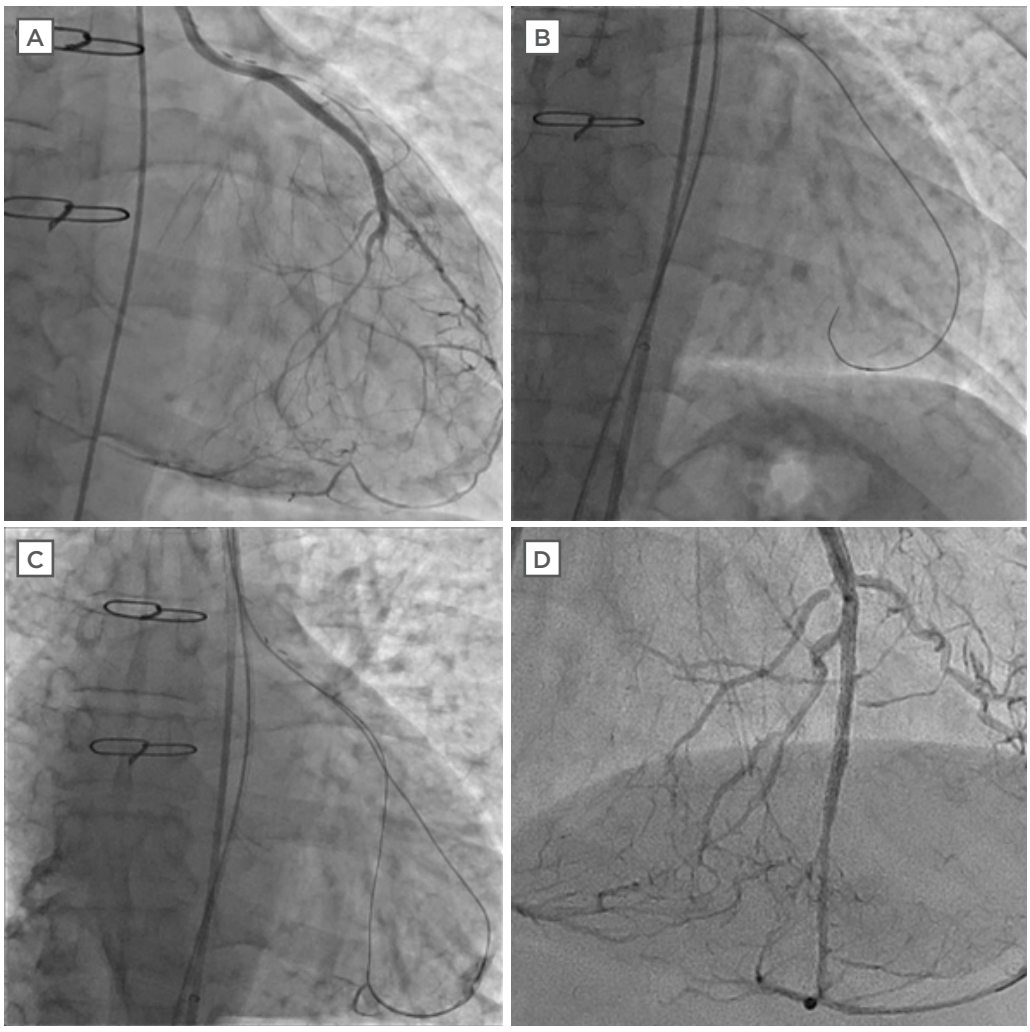

Figure 1: Case pictures.
1A: Left main total occlusion. Patent left internal mammary artery (IMA) to diffusely stenosed and occluded LAD. Retrograde collateralisation from diagonal branch to apical part of LAD; 1B: Mammary graft started using the retrograde approach with Corsair 150 cm + Sion wire through diagonal to distal LAD. Guidewire in LAD was used as a marker; 1C: Complete antegrade LAD recanalisation through IMA graft using Finecross microcatheter + Fielder XT wire. Visualisation performed using Corsair in diagonal branch; 1D: Final result. LAD stented with Xience 2.25 mm/23 mm + DEB 2.0 mm/20 mm at apical part.
DEB: drug-eluting balloon; LAD: left anterior descending artery.

CONCLUSION

- CTOs after a CABG have worse lesion characteristics and are more technically demanding than CTO without prior CABG
- Both arterial and venous grafts, either patent or occluded, can be used for retrograde interventions on native coronary arteries
- According to limited literary sources and personal experience, IMA bypass grafts are the least preferred route for retrograde wiring. Insertion of equipment into the IMA graft could result in pseudolesion formation and antegrade flow cessation. Additionally, disruption of the IMA graft may have catastrophic consequences
- Secondary interventions in patients with bypass graft failure can produce a marked influence on quality of life and also affect prognosis

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