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ORIGINAL ARTICLE

Impact of prior coronary artery bypass graft surgery on chronic total occlusion revascularisation: insights from a multicentre US registry

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ABSTRACT

Objective To investigate the impact of prior coronary artery bypass graft (CABG) surgery on the outcomes of percutaneous coronary intervention (PCI) for chronic total occlusions (CTO).

Design Observational retrospective study.

Setting Three tertiary hospitals in the USA.

Participants 1363 consecutive patients who underwent CTO PCI between 2006 and 2011.

Main outcome measures Procedural success and inhospital complications, which were compared between patients with and without prior CABG.

Results Compared to patients without prior CABG, those with prior CABG were older, had more comorbidities, were treated more frequently with the retrograde approach (46.7% vs 27.1%, p<0.001) and had lower technical success rates (79.7% vs 88.3%, p=0.015). Of the 24 (1.8%) major inhospital complications, 11 occurred in patients with prior CABG and 13 in patients without prior CABG (2.1% vs 1.5%, p=0.392). In multivariable analysis prior CABG was independently associated with lower technical success rate (OR 0.49, 95% CIs 0.35 to 0.70, p<0.001).

Conclusions In a large multicentre registry, CTO PCI was frequently performed among patients with prior CABG, with higher use of the retrograde approach and similar complications but lower technical success rates compared to patients without prior CABG.

INTRODUCTION

Patients with prior coronary artery bypass graft (CABG) surgery often have complex coronary anatomy, (a) because complex coronary atherosclerosis may have led to the earlier decision for CABG, and (b) because CABG can accelerate the development of coronary atherosclerosis.[1 2] Approximately half the patients with prior CABG undergoing coronary angiography have a coronary chronic total occlusion (CTO).[3] Patients with prior CABG often develop recurrent symptoms and events due to development of saphenous vein graft disease or progression of native coronary atherosclerosis.[4 5] Percutaneous coronary intervention (PCI) of native coronary arteries is preferred as revascularisation strategy among these patients, especially those with patent left internal artery bypass grafts, given the increased risk of saphenous vein graft interventions[6] and the fact that repeat CABG is technically difficult, has higher mortality compared with initial CABG and provides less symptomatic improvement.[7]

However, procedural success with CTO PCI is challenged among patients with prior CABG by lesion complexity that limits both antegrade and retrograde strategies.[8] In the present study we sought to characterise the prevalence of CTO PCI and outcomes in this subgroup of interest, especially as it represents an increasing fraction of CTO PCI.[9]

METHODS

Patient population

We performed a retrospective review of the procedural and clinical records of consecutive patients who underwent CTO PCI between January 2006 and November 2011 at three US centres: St Joseph Medical Center, Bellingham, Washington, USA; Piedmont Heart Institute, Atlanta, Georgia, USA; and VA North Texas Healthcare System, Dallas, Texas, USA. The study was approved by the institutional review board of each institution.

Study endpoints and definitions

Coronary CTOs were defined as angiographic evidence of a total occlusion with thrombolysis in myocardial infarction grade 0 or grade 1 and estimated duration of at least 3 months. Estimation of occlusion duration was based upon first onset of angina, prior history of myocardial infarction in the target vessel territory or comparison with a prior angiogram. Patients were considered to have had retrograde CTO PCI if a guide wire was introduced into a collateral channel that supplied the target CTO vessel distal to the lesion.

Procedural success was defined as achievement of technical success with no inhospital major adverse cardiac events (MACE). Technical success was defined as successful CTO recanalisation with achievement of <50% residual diameter stenosis within the treated segment and restoration of thrombolysis in myocardial infarction grade 3 antegrade flow. Inhospital MACE included any of the following adverse events prior to hospital discharge: Q wave myocardial infarction, recurrent angina requiring urgent repeat target vessel revascularisation with PCI or coronary bypass surgery,

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tamponade requiring pericardiocentesis or surgery, or death from any cause.

Statistical analysis

Clinical characteristics, angiographic measures and inhospital outcomes were reported using descriptive statistics. Continuous variables are presented as mean with SD and compared using the t test or Wilcoxon rank-sum test, as appropriate. Categorical variables are expressed as percentages and compared using the χ^2 or the Fisher's exact test, as appropriate. Logistic regression analysis was performed to identify predictors of technical success. Variables known to be associated with more advanced coronary artery disease and more challenging PCI (diabetes mellitus and history of myocardial infarction) as well as variables with $p<0.25$ on univariable analysis (age, gender, years since start of CTO PCI, prior CABG) were included in the model. JMP V.9.0 (SAS Institute, Cary, North Carolina, USA) was used for all statistical analyses.

RESULTS

Patient characteristics

A total of 1363 consecutive patients underwent CTO PCI during the study period at three US institutions: St Joseph Medical Center, Bellingham, Washington, USA (N=728); Piedmont Heart Institute, Atlanta, Georgia, USA (N=360); and VA North Texas Healthcare System, Dallas, Texas, USA (N=275). All procedures were performed by experienced CTO operators at the respective institutes. A single operator (WL) performed all CTO PCI cases at St Joseph's, two operators (ESB, SB) at VA North Texas Healthcare System and five operators (DK, NL, AK, HC, DK) at Piedmont Heart Institute. The baseline clinical and angiographic characteristics of the study patients are shown in table 1. Five hundred and eight (37%) of patients had prior CABG, 40% had diabetes, 85% were men and the mean age was 64.5±11 years. Fifteen per cent of patients had at least one prior failed attempt for CTO revascularisation. In most patients the target vessel was the right coronary artery (55%), followed by the left circumflex (23%) and left anterior descending arteries (21%). Compared with patients without prior CABG, those who had prior CABG were older, had higher prevalence of coronary artery disease risk factors and more frequently had prior stroke (table1).

Table1 Clinical characteristics and outcomes of 1363 patients undergoing CTO PCI, classified according to whether they had undergone CABG

Variable	Overall (n=1363)	With prior CABG (n=508)	Without prior CABG (n=855)	p Value
Clinical characteristics				
Age (years)*	64.5±10.8	67.7±9.0	63.3±10.4	<0.001
Men (%)	85.1	86.2	84.4	0.371
Hypertension (%)	89.0	92.6	87.2	0.005
Hyperlipidaemia (%)	94.0	96.0	92.6	0.016
Diabetes (%)	40.0	44.3	36.8	0.011
Heart failure (%)	24.0	24.7	23.1	0.540
Ejection fraction <40% (%)	22.0	21.0	22.5	0.701
History of myocardial infarction (%)	42.0	44.9	39.8	0.092
History of stroke (%)	6.0	8.0	4.5	0.015
Prior PCI (%)	42.0	43.4	40.8	0.337

*Mean±SD.
CABG, coronary artery bypass graft surgery; CTO, chronic total occlusion; PCI, percutaneous coronary intervention.

Procedural characteristics and outcomes

The technical and procedural success rates among the entire study population were 85.5% and 84.2%, respectively. In a subset of 275 patients in whom the reason for CTO PCI failure was available, inability to cross the CTO lesion with a guidewire was the most common reason for failure (in 92.7%) followed by failure to dilate the lesion after successful wire crossing (7.3%). The technical success rate was lower among patients with prior CABG (79.7% vs 88.3%, p=0.015). The retrograde approach to CTO crossing was more frequently used among patients with prior CABG (47.6% vs 27.1%, p<0.001, table 2). In univariate analysis, prior CABG, older age and target CTO vessel in the right coronary artery were associated with failed CTO PCI attempt. In multivariable analysis, prior CABG (OR 0.49, 95% CI 0.35 to 0.70, p<0.001), male gender (OR=0.51, 95% CI 0.28 to 0.87, p=0.012) and years since initiation of CTO PCI at each centre (OR=1.52 per 1 year increase, 95% CI 1.36 to 1.70, p<0.001=0.012) remained associated with technical success.

The total procedure time, fluoroscopy time and air kerma radiation exposure were higher in patients with prior CABG compared with those without. A total of 24 patients (1.8%) experienced at least one major procedural complication. The incidence of major complications was similar in those with and without prior CABG, 2.1% vs 1.5%, p=0.392. Eleven major complications occurred in patients with prior CABG: deaths (n=2; one due to coronary perforation; one due to intracranial bleeding), donor vessel dissection (n=1), perforations requiring emergency surgery or pericardiocentesis (n=2), equipment entrapment (n=1), transient ischaemic attack (n=1) and acute myocardial infarctions (n=4). Thirteen major complications occurred in patients without prior CABG: death (n=1; due to delayed tamponade), donor vessel dissection (n=1), perforations with tamponade requiring emergency surgery or pericardiocentesis (n=8), equipment entrapment (n=1), stent thrombosis (n=1) and acute myocardial infarction (n=1).

DISCUSSION

The major findings of our study are that in a contemporary US registry: (1) patients with prior CABG represent a significant proportion of those undergoing CTO PCI, (2) patients with prior CABG were older and had more comorbidities, (3) patients with prior CABG were more likely to undergo retrograde CTO crossing attempts and (4) prior CABG was associated with lower technical success but similar major complication rates.

The proportion of prior CABG (37%) among patients in our registry was higher compared with other similar registries from Japan and Europe (5.0–15.9%, table 3).[10–15] This may be due to higher use of surgical revascularisation for coronary artery disease in the USA or it could reflect local practice patterns. The high proportion of prior CABG in this series is encouraging, as it suggests that patients with prior CABG are often offered percutaneous coronary revascularisation, in spite of increased procedural complexity and lower procedural success rates.

As has been repeatedly shown in studies comparing prior CABG with non-prior CABG in various clinical settings,[16] compared with patients without prior CABG, patients with prior CABG undergoing attempted CTO revascularisation were older, had more comorbidities and lower CTO PCI technical success rates. Similarly lower procedural success rates have been reported in some but not all studies. Thompson *et al*[8] reported

Table 2 Angiographic and procedural characteristics and outcomes of 1363 patients undergoing CTO PCI, classified according to whether they had undergone CABG

Variable	Overall (n=1363)	With prior CABG (n=508)	Without prior CABG (n=855)	p Value	Antegrade approach (n=901)	Retrograde approach (n=462)	p Value
CTO target vessel				<0.001			<0.001
Right coronary artery (%)	55	56.2	54.7		48.9	66.4	
Circumflex (%)	23	27.4	20.1		25.6	17.8	
Left anterior descending artery (%)	21	14.2	25.0		24.5	14.7	
Left main/bypass graft (%)	1.0	2.2	0.2		0.9	1.1	
Prior failed attempt for CTO PCI (%)	15	13.0	16.6	0.820	13.9	17.1	0.123
Antegrade wire escalation attempt (%)	96.7	94.2	97.5	0.206	100	85.9	<0.001
Antegrade dissection/re-entry attempt (%)	28.9	29.4	28.7	0.912	23.2	48.4	<0.001
Retrograde approach attempt (%)	34	46.7	27.1	<0.001	NA	NA	
Collateral vessel used for retrograde approach (%) (n=462)				<0.001			NA
Septal (%)	68	52.8	77.6		NA	68	
Epicardial (%)	24	31.0	22.4		NA	24	
Bypass graft (%)	8	17.2	NA		NA	8	
Technical success rate (%)	85.5	79.7	88.3	<0.001	87.8	80.9	<0.001
Procedural success rate (%)	84.2	78.1	87.2	<0.001	87.1	78.5	<0.001
Total procedure time (min)*	113±61	125±65	106±58	<0.001	87.8	80.9	<0.001
Total fluoroscopy time (min)*	42±29	49±30	38±27	<0.001	87.1	78.5	<0.001
Total air kerma radiation exposure (Gray)*	4.7±3.8	5.5±5.0	4.3±3.0	0.003	3.7±3.8	6.4±3.2	<0.001
Total contrast volume (ml)*	294±158	296±156	293±160	0.762	268±146	343±168	<0.001
Inhospital major complication, %	1.8	2.1	1.5	0.392	0.89	3.46	0.001

*Mean±SD.
CABG, coronary artery bypass graft surgery; CTO, chronic total occlusion; NA, not applicable; PCI, percutaneous coronary intervention.

that patients with prior CABG who required CTO PCI were more likely to be treated by a retrograde operator than by a non-retrograde operator (35.5% vs 12.9%, p<0.001).Although Galassi *et al*[11] reported no significant association between presence of prior CABG and procedural success of CTO PCI, the proportion of prior CABG was higher in the failed PCI group in several CTO PCI registries.[10 13–15]

In a large, multinational CTO registry of 1791 patients who underwent 1852 CTO PCIs, prior CABG was present in 20.9% of patients in the failed PCI group versus 13.6% in the successful PCI group (p<0.01).[10] Similarly, Jones *et al*[15] reported higher proportion of prior CABG in the failed CTO PCI group compared with those who had successful CTO recanalisation (16.5% vs 7.4%, p<0.001). Teramoto *et al*[17] analysed 1807 CTO PCI procedures performed at the Toyohashi Heart Center in Japan and reported initial angiographic success in 70% (156/224) of patients with prior CABG versus 81% (1279/1583) in patients without prior CABG.

The lower CTO PCI success rates among patients with prior CABG are likely a reflection of the increased technical difficulty of performing intervention in such patients. CABG can accelerate the progression of coronary atherosclerosis.[1 2] Prior CABG is associated with longer duration of coronary occlusion and more pronounced calcification making CTO PCI more technically challenging. CABG may also cause tenting and distortion of the native coronary arteries hindering CTO crossing attempts. Patients with prior CABG undergoing CTO PCI often have severe tortuosity and blunt stump (although these variables are not systemically collected in our study). Moreover, patients may often have several CTOs or diffusely diseased vessels. On the other hand bypass grafts can be used as conduits (even when occluded)[6 18] that can facilitate CTO intervention via the retrograde approach.[19] On the other hand

Table 3 Summary of large contemporary CTO PCI registry publications that reported outcomes for the subgroup of patients with prior CABG

Author	Year	N (CTO lesions)	Prior CABG, (%)	Prior CABG in successful PCI group (%)	Prior CABG in unsuccessful PCI group (%)	Overall, retrograde (%)	Overall, technical Success (%)	Overall, major complications (%)	Overall, fluoroscopy time (min)	Overall, contrast use (ml)
Olivari *et al*[13]	2003	376	5.0	4.5	6.9	NR	77.2	5.1	NR	NR
Rathore *et al*[14]	2009	904	12.6	11.9	17.7	17	87.5	1.9	NR	NR
Morino *et al*[12]	2010	528	9.6	NR	NR	26	86.6	NR	45 (1–301)*	293 (53–1,097)*
Mehran *et al*[10]	2011	1791	15.9	13.6	20.9	NR	68.0	NR	NR	448±229
Galassi *et al*[11]	2011	1983	14.6	NR	NR	14	82.9	1.8	42.3±47.4†	313±184†
Jones *et al*[15]	2012	836	10.2	16.5	7.4	NR	69.6	2.3	NR	NR
Present study	2012	1363	37.0	35.0	50.8	34	85.5	1.8	42±29†	294±158†

*median (range)
†mean±SD
CABG, coronary artery bypass graft surgery; CTO, chronic total occlusions; NR, not reported; PCI, percutaneous coronary intervention.

CTO PCI may be particularly attractive in patients with prior CABG, because treatment of failing saphenous vein bypass grafts can be challenging with high rates of periprocedural myocardial infarction and subsequent failure and occlusion, even when using drug eluting stents.[4 5 20]

The higher use of the retrograde approach among patients with prior CABG could be related to (1) the complexity of CTO lesion in the patient requiring more aggressive crossing techniques after wire escalation crossing attempts fail and (2) the availability of bypass grafts, that can act as retrograde conduits (whether they are patent or occluded) in patients with prior CABG.[18 19] Use of a vein graft as a retrograde channel in CTO PCI has been reported in 3.1–8.2% of cases.[8 9 21 22] Moreover, (3) retrograde CTO PCI may be safer in patients with prior CABG (especially if epicardial collaterals are used) because pericardial adhesions may reduce the likelihood of tamponade in case of collateral vessel perforation (although tamponade can still occur, as shown in the present and prior studies).[23–25]

Our study has several potential limitations. First, the data were analysed retrospectively, although they were collected prospectively. Second, the coronary angiograms were not reviewed by an angiographic core laboratory and no adjudication of the clinical outcomes was performed by a clinical events committee, although adjudication would be unlikely to change the main adverse outcomes, such as death, emergency CABG and the need for urgent pericardiocentesis. Third, systematic measurement of cardiac biomarkers after CTO PCI was not performed, limiting the detection of subclinical myocardial infarction, although the latter may have limited clinical implications.[26]

In summary, our study suggests that in selected US programs, CTO percutaneous recanalisation was frequently performed in patients with prior CABG, often required use of retrograde crossing and was associated with lower technical success but similar complication rates.

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