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Symposium: Rotational atherectomy updating **· Open Access ·**

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Rotablation in the treatment of high-risk patients with heavily calcified left-main coronary lesions

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Abstract

Objective Heavily calcified left-main coronary diseases (LMCA) remain a formidable challenge for percutaneous interventions (PCI). This study was to investigate the safety and efficacy of using rotational atherectomy (RA) in treating such lesions in actual practice. **Methods** From February 2004 to March 2012, all consecutive patients who received RA for heavily-calcified LMCA lesions in our cath lab were enrolled. The relevant clinical and angiographic characteristics at the time of index PCI, as well as the clinical follow-up outcomes, were retrieved and analyzed. **Results** A total of 34 consecutive patients were recruited with a mean age 77.2 ± 10.2 years. There were 82.4% presented with acute coronary syndrome and 11.8% with cardiogenic shock. Chronic renal disease and diabetes were seen in 64.7% and 52.9%, respectively. Triple-vessel coronary disease was found in 76.5% of them. The mean SYNTAX score was 50 ± 15 and EuroSCORE II scale 5.6 ± 4.8. The angiographic success rate was 100% with a procedural success rate of 91.2%. The mean number of burrs per patient was 1.7 ± 0.5. Crossing-over stenting was used in 64.7%. Most stents were drug-eluting (67.6%). Intra-aortic ballon pump was used in 20.6% of the procedures. Three patients died during hospitalization, all due to presenting cardiogenic shock. No major complication occurred. Among 31 hospital survivors, the major adverse cardiac events (MACE) rate was 16.1%, all due to target lesion revascularization or target vessel revascularization. **Conclusions** In high-surgical-risk elderly patients, plaque modification with RA in PCI of heavily-calcified LMCA could be safely accomplished with a minimal complication rate and low out-of-hospital MACE.

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1 Introduction

Coronary artery bypass surgery (CABG) has been considered the gold standard for treatment of unprotected left-main coronary disease (LMCA) based on the results of several trials which have shown reductions in mortality.[1-3] The current guidelines also see CABG as a class I indication for significant unprotected LMCA disease in patients which are eligible for surgery.[4,5] However, a lot of the elderly patients are associated with multiple co-morbidities and at high surgical risk. Though in the study of Yanagawa *et al*.[6], the overall mortality of CABG declined from 6.0% (49/817) in the earliest era (1990–1996) to 1.9% (22/1132) in the most recent era (2003–2010; $P < 0.001$), the mortality rate could be as high as 9.1% with an appreciable morbidity rate of 16.4%.[7] Elderly patients who had prior CABG are also in unfavorable anatomical conditions for repeated bypass surgery. Furthermore, in some countries, religion and traditional thinking usually preclude the patients from open heart surgery. Over the past 10 years, advances in percutaneous intervention (PCI) techniques, devices and operator skills all contributed to the increased numbers of and studies on LMCA PCI.[8] However, limited information is available for clinical outcomes of LMCA PCI in high-risk elderly patients. Furthermore, coronary artery calcification, especially in the LMCA, imposes a big challenge for PCI, in terms of vessel rigidity and device delivery difficulties. Rotational atherectomy (RA), with the ability to differentially ablate

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calcified and fibrotic plaques, is particularly useful in these lesions.[9,10] RA has been advocated in the bare metal stent (BMS) era, but is often under-used due to technical difficulty, cumbersome setup and no additional benefit in the reported literature.[11,12] In recent years, revival of RA use in the drug eluting stent (DES) era in the treatment of complex lesion treatment has been witnessed. However, there have been very limited reports on using RA for LMCA PCI in the literature. The aim of this study was to investigate the safety and clinical efficacy of incorporating RA for plaque debulking during PCI for heavily-calcified LMCA lesions in actual practice.

2 Methods

2.1 Patient population

From February 2004 to March 2012, all consecutive patients who received RA treatment for heavily-calcified LMCA lesions were queried from the cath lab database for all-inclusive recruitment. The relevant clinical and angiographic characteristics at the time of index PCI, as well as the clinical follow-up outcomes, were retrieved from the database, and collected after a thorough review of the medical chart records. This study protocol was approved by the Institutional Review Board for Human Research of our hospital.

2.2 Angiographic characterization and measurements

The angiographic measurements were made on a viewing workstation with software for quantitative analysis of angiograms (Medcon/Horizon/TCS, Israel). The angiographic characterization of target lesions in the index coronary angiogram was made by reviewing the session cine thoroughly. The LMCA was defined as any segment of the left main ≥ 50% diameter stenosis. The coronary artery disease (CAD) vessel numbers were defined as the number of each of the three major coronary vessels ≥ 70% diameter stenosis. Severe coronary artery calcification was defined as readily apparent radio-opacities within the vascular walls in more than one projection on the cine before contrast medium injection. Exact definition of severe calcification was described in the SYNTAX classification.[13]

Patients with left main lesions and high Syntax scores were indications for bypass surgery. This was the principle strictly followed at our cath lab. In all of our patients, the merits and demerits of both PCI and CABG were fully explained to both the patients themselves and their families after diagnostic angiograms were completed. The final decision to undertake PCI was made after taking into account the multiple factors and personal preference. Patients who signed the informed consent and subsequently completed PCI with rotablation were retrospectively recruited into this study.

All PCIs were performed by experienced, credentialed operators using standard practice in our cath lab. Patients were pretreated with aspirin and clopidogrel, or a minimum of 300 mg loading dose of clopidogrel was administered if, in rare cases, patients were not pretreated. Calcium channel blocker and nitrate were also prescribed for prevention of coronary artery spasm. Heparin was administered to maintain an activated clotting time (ACT) of > 300 s. The decision to do RA was made at the discretion at the operator if device delivery or full lesion dilatation was deemed impossible by the heavy coronary artery calcification at the beginning of the procedure. A 0.009-inch floppy RotaWire™ was advanced by the wire exchanging technique through a microcatheter or over-the-wire balloon. RA was carried out using the Rotablator™ RA system (Boston Scientific Corporation), starting with a 1.25 mm or 1.5 mm burr at a speed of 180,000–200,000 r/min and mostly supplemented by another burr one size larger (Figure 1). Each advance time was not longer than 30 s. Normal saline with heparin and isosorbide dinitrate was infused during the atherectomy. RA of one or both major branches of LM was made at the discretion of the operators. If RA of both major branches was needed, usually the vessel with more critical lesions was treated first. After the blood flow in the first treated vessel was secured, rotawiring of the another branch was made and no regular wire was left in the treated vessel. After the rotablation, both major branches were rewired with usual wires and the procedure then proceeded with balloon dilatation with, or without, stent implantation to achieve optimal angiographic results with minimal residual stenosis. The use of DES or BMS was determined by patient option (affordability), physician discretion or other co-morbidities (impending non-cardiac surgery, drug compliance to dual antiplatelets or drug allergy). Use of glycoprotein 2b3a antagonist, intra-aortic ballon pump (IABP) or intravascular ultrasound (IVUS) were at the discretion of the operator as indicated by the clinical requirements. Patients with cardiogenic shock were managed with standard practice, including IABP support, intravenous inotropes and pulmonary capillary wedge pressure monitoring. Emergent coronary angiography and revascularization were intended for every patient to achieve re-opening of the culprit vessel with grade III Thrombolysis In Myocardial Infarction (TIMI 3) flow as fast as possible.

Angiographic success was defined as achievement of a residual stenosis < 20% in the presence of TIMI 3 flow. Procedural success was defined as achieving angiographic success without in-hospital major adverse cardiac events (MACE), including all-cause death, myocardial infarction (MI), and repeat revascularization. Clinical success was defined as successfully discharged without in-hospital complications. MI was defined according to current guidelines.[14] Target lesion revascularization (TLR) was defined as a repeat revascularization for a restenosis > 50% in the target segment. Target vessel revascularization (TVR) was defined as any repeat revascularization within the treated vessel. Indication for repeat revascularization was based on the clinical criteria.

Cardiac biomarkers including creatine kinase (CK), creatine kinase-MB (CK-MB), and Troponin-I were routinely measured in patients after the procedure. Myonecrosis was defined as exceeding three times the level of CK-MB or Troponin-I compared to the baseline value. Clinical follow-up was carried out through reviews of medical records, or telephone contact.

2.3 Statistical analysis

Descriptive analyses were used and made in this study. Continuous variables were reported as mean ± SD. Categorical variables were presented as frequencies with percentage.

3 Results

During the study period, a total of 34 patients met the all-inclusion criterion and were recruited into this study for retrospective analysis. The baseline patient characteristics are presented in Table 1. The mean age was 77.2 ± 10.2 years. Eighteen (52.9%) patients had diabetes mellitus and twenty-two (64.7%) chronic kidney disease. Ten (29.4%) had prior CABG, fourteen (41.2%) prior PCI, and nine (26.5%) recent (within four weeks) MI. Regarding clinical presentation, ten (29.4%) patients presented with unstable

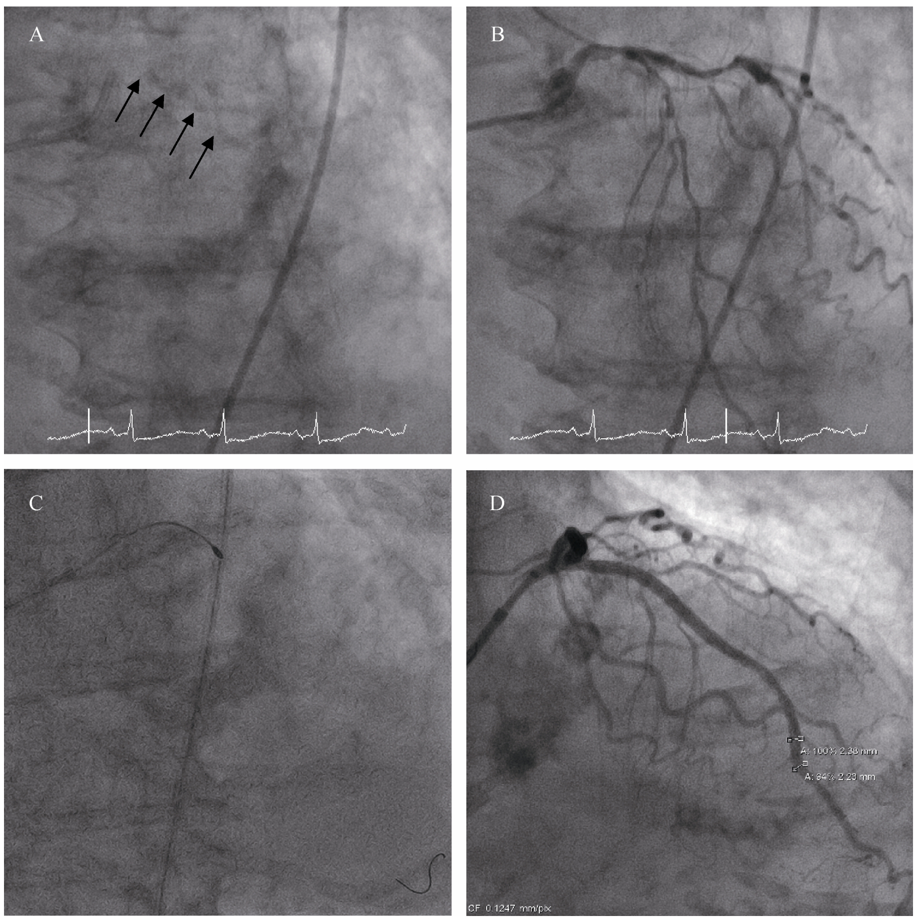

Figure 1. A 90-year-old woman with unstable angina was admitted for PCI. The SYNTAX score was 48, the EuroSCORE II scale was 3.54. (A): Severely-calcified LMCA, LAD and LCX could be found readily by apparent radio-opacities within the vascular walls before contrast medium injection (as indicated by black arrows); (B): Coronary angiography revealed LM shaft and distal true bifurcation lesions, both LAD and LCX showed diffuse atherosclerosis change with heavy calcification; (C): Rotaburr could successfully advance to the LAD; (D): The final flow was good without residual stenosis. LAD: left anterior descending artery; LCX: left circumflex artery; LMCA: LMCA: left main coronary artery; PCI: percutaneous coronary intervention.

Table 1. The baseline patient characteristics (n = 34).

Characteristics	
Age (yrs)	77.2 ± 10.2
Gender	
Males, *n* (%)	22 (64.7%)
Female, *n* (%)	12 (35.3%)
DM, *n* (%)	18 (52.9%)
Hypertension	94.1% (32/34)
Smoking	2.9% (1/34)
Hypercholesterolemia (≥ 200 mg/dL)	23.5% (8/34)
Clinical presentation	
Stable angina, *n* (%)	17.6% (6/34)
Unstable angina	29.4% (10/34)
NSTEMI	44.1% (15/34)
STEMI	8.8% (3/34)
Cardiogenic shock	11.8% (4/34)
eGFR (mL/min)	37.8 ± 22.2
CKD, *n* (%)	64.7% (22/34)
PAD	44.1% (15/34)
Prior PCI	41.2% (14/34)
Prior CABG	29.4% (10/34)
Recent MI < 4 weeks	26.5% (9/34)
LVEF (%)	39.68 ± 11.80
Total cholesterol (mg/dL)	172.7 ± 51.6
LDL-cholesterol (mg/dL)	103.6 ± 36.5
Triglyceride (md/dL)	113.9 ± 55.8
Fasting plasma sugar (mg/dL)	126.8 ± 46.7
Serum creatinine (mg/dL)	1.9 ± 1.7
Coronary diseases	
Left main, *n* (%)	0% (0/34)
Single vessel	5.9% (2/34)
Double vessels	17.6% (6/34)
Triple vessels	76.5% (26/34)
Concomitant RCA disease (> 70% stenosis), *n* (%)	73.5% (25/34)
SYNTAX Score	50 ±15
EuroScore II (%)	5.6 ± 4.8

CABG: coronary artery bypass graft; CKD: chronic kidney disease; DM: diabetes mellitus; eGFR: estimated Glomerular Filtration Rate; LDL: low density lipoprotein; LVEF: left ventricular ejection fraction; MI: myocardial infarction; NSTEMI: non-ST segmental elevation myocardial infarction; PAD: peripheral artery disease; PCI: percutaneous intervention; RCA: right coronary artery; SBP: systolic blood pressure; STEMI: ST segmental elevation myocardial infarction.

angina, fifteen (44.1%) with non-ST-elevation MI (NSTEMI) and three (8.8%) with ST-elevation MI (STEMI). Furthermore, the estimated glomerular filtration rate (eGFR) was 37.8 ± 22.1 mL/min. No patient had isolated LMCA. Twenty-six (76.5%) patients had triple-vessel disease. The mean SYNTAX score was 50 ± 15, and the surgical mortality rate of the cohort according to the EuroSCORE II scale was 5.6 ± 4.8%.

Table 2. Angiographic characteristics of LMCA lesions

Angiographic characteristics	
Lesion type	
Type B2	20 (58.8%)
Type C	14 (41.2%)
Lesion location	
Ostium	3 (8.8%)
Shaft	20 (52.8%)
Distal with involvement of	
LAD	13 (38.2%)
LCX	4 (11.8%)
LAD + LCX	12 (35.3%)
None	5 (14.7%)
Eccentricity	31(91.2%)
Mild to severe calcification	34 (100%)
LMCA lesion length > 10mm	19 (55.9%)
Thrombus-containing	3 (8.8%)

Data are presented as *n* (%), n = 34. LAD: left anterior descending artery; LCX: left circumflex artery; LMCA: left main coronary artery;

The LMCA lesion characteristics are presented in Table 2. The LMCA bifurcation lesions involved the ostia of both left anterior descending (LAD) and left cirrumflex (LCX) coronary artery in twelve (35.3%) patients. Thirty-one (91.2%) lesions were eccentric, and three (8.8%) had thrombus. The angiographic success rate was 100% with rota burrs delivered to the target lesions in all of these patients, and there was no major procedural complication. The overall procedural characteristics of our patients are presented in Table 3. The average number of burrs used per patient was 1.7 ± 0.5 and the final burr size 1.6 ± 0.2 mm. Three (8.8%) patients underwent RA PCI without stenting. Regarding the LM stenting strategy, twenty-two (64.7%) were crossing-over, four (11.8%) simultaneous kissing or V, two (5.9%) culotte and one (2.9%) crushing. T-/Y-stenting technique was done in 2 (5.9%). Final kissing balloon dilatation was done in ten (29.4%). DES was used in twenty-three (67.6%) of these patients and BMS in eight (23.5%). Seven patients (20.6%) underwent intra-aortic balloon pump (IABP)-assisted procedures due to cardiogenic shock, or intractable ventricular tachycardia.

The angiographic data are presented in Table 4. The baseline and post-PCI diameter stenoses of LMCA rate were 70% ± 7% and 18% ± 5%, respectively. The post-PCI coronary flow was TIMI 3 flow in all patients.

Table 3. Procedural characteristics (*n* = 34).

Procedure characteristics	
Maximum rota burr size (mm)	1.6 ± 0.2
Number of rota burrs used/patient	1.7 ± 0.5
Stenting strategy, *n* (%)	
No stenting	3 (8.8%)
Crossing-over	64.7% (22/34)
T/Y-stenting	2 (5.8%)
Simultaneous kissing/V	11.8% (4/34)
Culotte	5.9% (2/34)
Crushing	2.9% (1/34)
Final kissing ballooning, *n* (%)	29.4% (10/34)
Number of stents used, *n* (%)	1.2 ± 0.6
No stent	3 (8.8%)
One stent	64.7% (22/34)
Two stents	26.5% (9/34)
Type of Stents used, *n* (%)	
No stent	3 (8.8)
DES	67.6% (23/34)
BMS	23.5% (8/34)
Main-vessel stent diameter (mm)	3.03 ± 0.40
Main-vessel stent length (mm)	24.2 ± 6.4
Side-branch stent diameter (mm)	2.8 ± 0.2
Side-branch stent length (mm)	19.2 ± 4.9
IABP use, *n* (%)	20.6% (7/34)
GP IIb/IIIa use, *n* (%)	2.9% (1/34)
IVUS use, *n* (%)	2.9% (1/34)

BMS: bare-metal stent; DES: drug-eluting stent; IABP: Intra-aortic balloon pump; GP IIb/IIIa: glycoprotein IIb/IIIa inhibitor; IVUS: Intravascular ultrasound.

Table 4. Quantitative coronary analysis of LMCA.

Angiographic data	
Pre-procedure	
Reference (mm)	2.9 ± 0.9
MLD (mm)	0.9 ± 0.4
Diameter stenosis (%)	70 ± 7
Lesion length (mm)	113 ± 3.6
TIMI flow	2.4 ± 0.7
Post-procedure	
Reference (mm)	3.3 ± 0.9
MLD (mm)	2.5 ± 0.8
Diameter stenosis (%)	17.7 ± 5.2
Lesion length (mm)	10.3 ± 3.9
TIMI flow	3.0 ± 0

LMCA: left main coronary artery; MLD: minimal lumen diameter; TIMI: thrombolysis in myocardial infarction.

The in-hospital and out-of-hospital follow-up outcomes are shown in Table 5. The interventional procedure success rate was 91.2% as three patients died during hospitalization, whom all presenting with cardiogenic shock complicating extensive anterior wall STEMI on hospitalization. The average age for these succumbed patients was 82 ± 1 years (range 81–83 years) and all had triple vessel disease. One of them received RA plus BMS for LM-LAD, one RA plus DES for LM-LAD and the other culotte DES for LM bifurcation lesion. Besides these three cardiac deaths, there was one asymptomatic myonecrosis and one acute limb ischemia which may be ascribed to IABP use. There was no Q-wave MI, emergent CABG, repeated PCI, or cardiac tamponade during hospitalization. The incidence of out-of-hospital MACE at a mean follow-up of 30.4 months (range 2–99 months) was 16.1%. Among thirty-one out-of-hospital follow-up patients, 12 patients (38.7%) received coronary angiographic follow-up. TLR was needed in three (9.7%) and TVR in two (6.4%) patients. All were successfully re-opened by PCI and no CABG was needed. No coronary aneurysm was found in the stented segment.

Table 5. Clinical outcomes (*n* = 34).

Procedural success, *n* (%)	31 (91.2%)
Clinical success, *n* (%)	30 (88.2%)
In-hospital complication, *n* (%)	4 (11.7%)
Cardiac death	3 (8.8%)
Q wave MI	0
Emergent CABG	0
TLR/ TVR	0
Non-Q wave MI	2 (5.8%)
Asymptomatic myonecrosis	1 (2.9%)
Acute limb ischemia	1 (2.9%)
Out-of-hospital follow-up (*n* = 31)*	5 (16.1%)
Cardiac death	0
non-fatal STEMI	0
non-fatal NSTEMI	1 (3.2%)
CABG	0
TLR/ TVR	5 (16.1%)

*Excluded three in-hospital deaths; mean follow-up30.4 months. CABG: coronary artery bypass graft; MACE: major adverse cardiac event; MI: myocardial infarction; NSTEMI: non-ST segmental elevation myocardial infarction; STEMI: ST segmental elevation myocardial infarction; TLR: target lesion revascularization; TVR: target vessel revascularization.

4 Discussion

In summary, we found in this study that PCI incorporating RA for heavily calcified LMCA lesions could be safely carried out with minimal complication rates in high risk elderly patients, and this procedure was associated with very favorable angiographic and clinical outcomes in actual practice.

In recent years, more and more data demonstrate the safety and feasibility of PCI in unprotected LMCA disease.[15,16] Though the major adverse cardiovascular events of PCI seemed to be comparable to that of CABG in unprotected LMCA disease of low or intermediate SYNTAX scores, PCI was associated with more serious adverse events in patients with a high SYNTAX score,[17] and it had a significantly higher TVR risk in a meta-analysis.[18] Though in the current PCI guidelines, CABG remains the class I indication for unprotected LMCA disease, increasingly favorable PCI clinical results underscore the fact that PCI for unprotected left main has been upgraded to a class IIa or IIb alternative to CABG in anatomically suitable patients and those with high surgical risks.[19,20] In the actual practice, religious thinking and local traditions usually prevent elderly patients with complex LM lesions from undergoing open heart surgery. On the other hand, well-performed PCI was associated with short procedure time, short duration of hospitalization, and faster recovery, which are very important in high risk patients, whereas bypass surgery in elderly patients with multiple co-morbidities could be associated with very high surgical risk.[21,22] Furthermore, repeat bypass surgery for patients with previous CABG is usually complicated by lack of proper arterial conduits if those were used in previous surgery and higher peri-operative morbidity and mortality,[23] for which the independent risk factors included unstable angina, poor preoperative left ventricular function, renal insufficiency, insulin dependent diabetes and an interval shorter than one year of the initial operation.[24] Most of the previously-operated elderly patients have more than one of the above independent risk factors. Therefore, PCI for LMCA lesions is often performed on patients with graft occlusion after CABG despite complex coronary anatomies.[25] Sometimes, PCI is the "only," or at least, the "more favorable" choice of revascularization in morbid elderly patients who could hardly tolerate repeated bypass surgery.

On the other hand, LMCA PCI has inherent risks and challenges. The difficulties in LMCA PCI include the variations in main vessel and side branch vessel size, lesion location, involvement of distal bifurcation, differences in bifurcation angle, vessel calcifications, extent of other vessel involvement and occlusion of contra-lateral arteries.[26] Regarding vessel calcification, coronary artery calcification is an active and complex process that involves numerous mechanisms responsible for calcium depositions in arterial walls which progresses with ages.[27,28] Though the extent of coronary artery calcification was not strongly associated with age before the ninth decade,[29] it is not unusual that heavily calcified coronary lesions occurred in the elderly patient group. Up to date, there is no effective medical therapy that can reverse the calcium deposits in the coronary vessels. Very tight calcified LMCA lesions may resist dilation at low balloon inflation pressures, or even rupture at the highest possible pressure. Stent delivery through calcified lesions may also be difficult and stent expansion may be suboptimal due to high resistance of the calcified plaques. RA is particularly useful in these situations. The revival of RA in DES era, particularly in very complex heavily-calcified lesions,[30,31] underscores the importance the plaque modifications before DES could be successfully delivered, precisely placed and deployed to exert the expected effects. Though RA is an effective and reasonably-priced debulking modality in the cath lab, it is cumbersome to set up, more difficult to use, especially for distal lesions, and more prone to complications if not adequately prepared or performed. Acute no flow, severe vessel dissection with impending acute closure, atheroembolism and transient profound hypotension are the most frequently encountered risks in rotablation.[32] Most of these are also difficult to deal with in the middle of intervening complex lesions in high risk patients. Vessel perforation and entrapment of rotablator burr are less frequently met complications, but are also difficult to manage.[33,34] These are the reasons why rotablation are formidable to a lot of coronary interventionists. It is very important to prevent these events in advance while handling them adequately once they occur. On the other hand, thrombus-laden vessels, vessels with existing advanced dissections, last remaining vessels and saphenous venous grafts are traditionally considered contraindications to rotablation therapy.[35,36] Therefore, RA is usually under-used, even in the DES era.[37] These limitations were also present in our cath labs, in which rotablation was only used in 2.4% of all PCI cases. No insurance reimbursement is probably the major cause of under-use of this device in this region and probably many others. In the current study, RA for LMCA lesions was mostly done in patients with high clinical risks, including ACS, depressed LV function, cardiogenic shock, chronic renal insufficiency, old age and diabetes, and in very complex coronary lesions which were heavily calcified. A significant part of patients were previously PCI- or CABG-treated and many patients had triple coronary disease and true LM bifurcation lesions. The average Syntax score was high. Despite these unfavorable risks and settings, RA was successfully performed and LMCA PCI completed with very good angiographic documented success rates in these patients, and no complications noted. Though under-use, less familiarity, and resorting to RA only in heavily calcified complex lesions may increase the complication rate and decrease the angiographic and clinical outcomes, particularly in high risk patients, this, however, was not the case in our cath lab.

In general, DES was recommended for LM stenting, absolutely so in situations where two-stent techniques were needed. Once the DES is delivered and deployed after adequate debulking, good results could be anticipated.[30] In this study, a major proportion of patients were treated with DES, but a minor proportion treated with BMS. This was made at the discretion of the operators, taking into consideration of patient affordability. A small number of lesions in the current study was not stented, as full expansion and TIMI 3 final blood flow had been achieved after RA and balloon angioplasty of these lesions without any dissection. Regarding the stenting strategy for distal LMCA lesions, it is determined by multiple anatomical and angiographic factors.[38] Though crossing-over technique was most often used and associated with better outcomes,[39,40] the two-stent strategy was mandatory in certain anatomies.[41,42] In the current study, a quarter of our patients were treated by the two-stent technique. This was compatible with universal practice as published in the literature. Despite the complexity of our treated lesions, the angiographic success rate was 100%, which could be due to more complete lesion modification by more than one burr usage per lesion (1.7 ± 0.4). Though there were three (8.8%) in-hospital deaths in our patients, none were procedure-related and all were caused by underlying extensive myocardial infarction with cardiogenic shock. Use of IABP in a considerable proportion of our procedures may argument for the high risk nature of our patients on one hand, and may account for the very high procedure success and no major complication in this group on the other hand. IABP provides temporary circulatory support during the transient cease of blood flow while intervening major epicedial coronary vessels like the left main stem. It might be especially useful in intervening left main lesions with very invasive devices like rotablation, particularly when complicated by acute no flow, profound hypotension and severe vessel dissection. However, in our cath lab, these adverse events were very low with our refined rotablation practice of giving optimal premedications (oral dual antiplatelets, calcium channel blockers, nitrates) before admission, large dose intra-coronary nitrate prior to initiating rotation and familiarity with this device (quick procedure, use of two burr sizes in most cases). These are the reasons why IABP use was limited to certain high risk, but not most of patients. The clinical follow-up MACE in patients who could be successfully discharged from hospital was 16.1%, quite similar to that in another study of ours looking at RA followed by DES implantation in calcified coronary artery diseases, and to those in published studies.[43,44] It is interesting to notice that half of our patients were octogenarians or nonagenarians. These groups of patients were conventionally deemed inoperable. Dahdouh, *et al*.[45] reported 85.7% of LMCA lesions had moderate to severe calcification in the octogenarians. This finding suggests that increased numbers of extremely calcified lesions needed to be treated percutaneously, and this high demand dictates the incorporation of RA in PCI.

There were some limitations in our study. Firstly, the sample size in this single-center, observational study was relatively small. Because of the insurance reimbursement issue in our clinical practice, we had to limit RA to patients with very unfavorable angiographic characteristics which otherwise would preclude successful PCI treatment if without proper debulking. Despite this, use of RA in LMCA PCI in high risk elderly patients was quite promising and rewarding in our hands. Secondly, IVUS was used in only a very small portion of our patients. Though IVUS guidance during DES implantation could reduce both DES thrombosis and the need for repeat revascularization,[46] it was also underused due to no insurance coverage in our lab. Even given this, the risk of stent thrombosis was negligible and TLR/TVR was not high in our high risk elderly patients. Thirdly, there was no routine angiographic follow-up in our patients. However, clinical driven angiographic follow-up is a more reasonable approach and commonly accepted worldwide. Our practice was consistent with that approach.

5 Conclusions

In conclusion, plaque modification with RA to facilitate subsequent interventional procedures in very complex heavily-calcified LMCA lesions could be safely accomplished with a very low complication rate. This appears clinically rewarding with good angiographic results and a low follow-up MACE rate in high-surgical-risk elderly patients. The high procedural success rate, low TLR and very promising cumulative MACE rate convince us to sustain, and even broaden, the use of this novel, but underused, device in suitable patients.

References

1 Yusuf S, Zucker D, Peduzzi P, *et al*. Effect of coronary artery bypass graft surgery on survival: overview of 10-year results from randomised trials by the Coronary Artery Bypass Graft Surgery Trialists Collaboration. *Lancet* 1994; 344: 563–570.

2 Kajimoto K, Miyauchi K, Yamamoto T, *et al*. Meta-analysis of randomized controlled trials on the treatment of unprotected left main coronary artery disease: one-year outcomes with coronary artery bypass grafting versus percutaneous coronary artery intervention with drug-eluting stent. *J Card Surg* 2012; 27: 152–157.
3 Wu C, Hannan EL, Walford G, *et al*. Utilization and outcomes of unprotected left main coronary artery stenting and coronary artery bypass graft surgery. *Ann Thorac Surg* 2008; 86: 1153–1159.
4 Levine GN, Bates ER, Blankenship JC, *et al*. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions. *Catheter Cardiovasc Interv* 2012; 79: 453–495.
5 Kolh P, Wijns W. Joint ESC/EACTS guidelines on myocardial revascularization. *J Cardiovasc Med* (*Hagerstown*) 2011; 12: 264–267.
6 Yanagawa B, Algarni KD, Yau TM, *et al*. Improving results for coronary artery bypass graft surgery in the elderly. *Eur J Cardiothorac Surg* 2012; 42: 507–512.
7 Farooq V, Girasis C, Magro M, *et al*. The CABG SYNTAX Score - an angiographic tool to grade the complexity of coronary disease following coronary artery bypass graft surgery: from the SYNTAX Left Main Angiographic (SYNTAX-LE MANS) substudy. *EuroIntervention* 2013; 8: 1277–1285.
8 Fajadet J, Chieffo A. Current management of left main coronary artery disease. *Eur Heart J* 2012; 33: 36–50b.
9 Warth DC, Leon MB, O'Neill W, *et al*. Rotational atherectomy multicenter registry: acute results, complications and 6-month angiographic follow-up in 709 patients. *J Am Coll Cardiol* 1994; 24: 641–648.
10 Pershad A, Buchbinder M. Management of calcified lesions in 2004. *Int J Cardiovasc Intervent* 2005; 7: 199–204.
11 Gruberg L, Mehran R, Dangas G, *et al*. Effect of plaque debulking and stenting on short- and long-term outcomes after revascularization of chronic total occlusions. *J Am Coll Cardiol* 2000; 35: 151–156.
12 Kwon K, Choi D, Choi SH, *et al*. Coronary stenting after rotational atherectomy in diffuse lesions of the small coronary artery: comparison with balloon angioplasty before stenting. *Angiology* 2003; 54: 423–431.
13 Sianos G, Morel MA, Kappetein AP, *et al*. The SYNTAX Score: an angiographic tool grading the complexity of coronary artery disease. *EuroIntervention* 2005; 1: 219–227.
14 Myocardial infarction redefined--a consensus document of The Joint European Society of Cardiology/American College of Cardiology Committee for the redefinition of myocardial infarction. *Eur Heart J* 2000; 21: 1502–1513.
15 Kappetein AP, Feldman TE, Mack MJ, *et al*. Comparison of coronary bypass surgery with drug-eluting stenting for the treatment of left main and/or three-vessel disease: 3-year follow-up of the SYNTAX trial. *Eur Heart J 2011*; 32: 2125–2134.
16 Caggegi A, Capodanno D, Capranzano P, *et al*. Comparison of one-year outcomes of percutaneous coronary intervention versus coronary artery bypass grafting in patients with unprotected left main coronary artery disease and acute coronary syndromes (from the CUSTOMIZE Registry). *Am J Cardiol* 2011; 108: 355–359.
17 Shiomi H, Morimoto T, Hayano M, *et al*. Comparison of long-term outcome after percutaneous coronary intervention versus coronary artery bypass grafting in patients with unprotected left main coronary artery disease (from the CREDO-Kyoto PCI/CABG Registry Cohort-2). *Am J Cardiol* 2012; 110: 924–932.
18 Naik H, White AJ, Chakravarty T, *et al*. A meta-analysis of 3,773 patients treated with percutaneous coronary intervention or surgery for unprotected left main coronary artery stenosis. *JACC Cardiovasc Interv* 2009; 2: 739–747.
19 Levine GN, Bates ER, Blankenship JC, *et al*. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention. A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions. *J Am Coll Cardiol* 2011; 58: e44–e122.
20 Wijns W, Kolh P, Danchin N, *et al*. Guidelines on myocardial revascularization. *Eur Heart J* 2010; 31: 2501–2555.
21 Rocha AS, Pittella FJ, Lorenzo AR, *et al*. Age influences outcomes in 70-year or older patients undergoing isolated coronary artery bypass graft surgery. *Rev Bras Cir Cardiovasc* 2012; 27: 45–51.
22 Saito A, Motomura N, Miyata H, *et al*. Age-specific risk stratification in 13488 isolated coronary artery bypass grafting procedures. *Interact Cardiovasc Thorac Surg* 2011; 12: 575–580.
23 Weintraub WS, Jones EL, Morris DC, *et al*. Outcome of reoperative coronary bypass surgery versus coronary angioplasty after previous bypass surgery. *Circulation* 1997; 95: 868–877.
24 Christenson JT, Schmuziger M, Simonet F. Reoperative coronary artery bypass procedures: risk factors for early mortality and late survival. *Eur J Cardiothorac Surg* 1997; 11: 129–133.
25 Brilakis ES, Rao SV, Banerjee S, *et al*. Percutaneous coronary intervention in native arteries versus bypass grafts in prior coronary artery bypass grafting patients: a report from the National Cardiovascular Data Registry. *JACC Cardiovasc Interv* 2011; 4: 844–850.
26 Palmerini T, Alessi L, Rizzo N, *et al*. Percutaneous revascularization of left main: role of imaging, techniques, and adjunct pharmacology. *Catheter Cardiovasc Interv* 2012; 79: 990–999.
27 Karwowski W, Naumnik B, Szczepanski M, *et al*. The mechanism of vascular calcification - a systematic review.

Med Sci Monit 2012; 18: RA1–R11.
28 Kalra SS, Shanahan CM. Vascular calcification and hypertension: Cause and effect. *Ann Med* 2012; 44(Suppl 1): S85–S92.
29 Newman AB, Naydeck BL, Sutton-Tyrrell K, *et al*. Coronary artery calcification in older adults to age 99: prevalence and risk factors. *Circulation* 2001; 104: 2679–2684.
30 Abdel-Wahab M, Baev R, Dieker P, *et al*. Long-term clinical outcome of rotational atherectomy followed by drug-eluting stent implantation in complex calcified coronary lesions. *Catheter Cardiovasc Interv* 2013; 81: 285–291.
31 Benezet J, Diaz de la Llera LS, Cubero JM, *et al*. Drug-eluting stents following rotational atherectomy for heavily calcified coronary lesions: long-term clinical outcomes. *J Invasive Cardiol* 2011; 23: 28–32.
32 Wasiak J, Law J, Watson P, *et al*. Percutaneous transluminal rotational atherectomy for coronary artery disease. *Cochrane Database Syst Rev* 2003; 12: CD003334.
33 Chen WH, Lee PY, Wang EP. Left anterior descending artery-to-right ventricle fistula and left ventricular free wall perforation after rotational atherectomy and stent implantation. *J Invasive Cardiol* 2005; 17: 450–451.
34 Cunnington M, Egred M. GuideLiner, a child-in-a-mother catheter for successful retrieval of an entrapped rotablator burr. *Catheter Cardiovasc Interv* 2012; 79: 271–273.
35 Mokabberi R, Blankenship JC. Rotational atherectomy to facilitate stent expansion after deployment in ST-segment-elevation myocardial infarction. *Am Heart Hosp J* 2010; 8: 66–69.
36 Sakakura K, Ako J, Wada H, *et al*. Comparison of frequency of complications with on-label versus off-label use of rotational atherectomy. *Am J Cardiol* 2012; 110: 498–501.
37 Khattab AA, Richardt G. Rotational atherectomy followed by drug-eluting stent implantation (Rota-DES): a rational approach for complex calcified coronary lesions. *Minerva Cardioangiol* 2008; 56: 107–115.
38 Capodanno D, Calvi V, Tamburino C. A focused update on emerging prognostic determinants in distal left main percutaneous coronary intervention. *Int J Cardiol* 2012; 160: 4–7.
39 Tamura T, Kimura T, Morimoto T, *et al*. Three-year outcome of sirolimus-eluting stent implantation in coronary bifurcation lesions: the provisional side branch stenting approach versus the elective two-stent approach. *EuroIntervention* 2011; 7: 588–596.
40 Athappan G, Ponniah T, Jeyaseelan L. True coronary bifurcation lesions: meta-analysis and review of literature. *J Cardiovasc Med* (*Hagerstown*) 2010; 11: 103–110.
41 Murasato Y, Yamamoto T, Suematsu Y. Potential risk of provisional stenting in left main coronary artery bifurcation in multivessel-related acute coronary syndrome. *Catheter Cardiovasc Interv* 2011; 78: 737–744.
42 Chen JL, Gao RL, Yang YJ, *et al*. Short and long-term outcomes of two drug eluting stents in bifurcation lesions. *Chin Med J* (*Engl*) 2007; 120: 183–186.
43 Mezilis N, Dardas P, Ninios V, *et al*. Rotablation in the drug eluting era: immediate and long-term results from a single center experience. *J Interv Cardiol* 2010; 23: 249–253.
44 Furuichi S, Sangiorgi GM, Godino C, *et al*. Rotational atherectomy followed by drug-eluting stent implantation in calcified coronary lesions. *EuroIntervention* 2009; 5: 370–374.
45 Dahdouh Z, Roule V, Sabatier R, *et al*. Left main coronary stenting in a non surgical octogenarian population: a possible approach. *Cardiovasc Revasc Med* 2012; 13: 119–124.
46 Roy P, Steinberg DH, Sushinsky SJ, *et al*. The potential clinical utility of intravascular ultrasound guidance in patients undergoing percutaneous coronary intervention with drug-eluting stents. *Eur Heart J* 2008; 29: 1851–1857.