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Coronary Artery Disease

Rotablation for Octogenarians in a Modern Cathlab: Short- and Intermediate-Term Results

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Background: There are limited reports on the treatment of complex calcified lesions using rotational atherectomy (RA) in octogenarians, particularly in high-risk patients.
Objective: To evaluate procedural and clinical outcomes of RA in octogenarians.
Methods: Consecutive RA patients from 2010 to 2018 were selected from our catheterization laboratory database, stratified into two groups (≥ or < 80 years old), and analyzed.
Results: A total of 411 patients (269 males and 142 females) with a mean age of 73.8 ± 11.3 years were enrolled, of whom 153 were ≥ 80 years old and 258 were < 80 years old. Most of the patients displayed high-risk features. The baseline Syntax scores were high in both groups, and most lesions were heavily calcified (96.1% vs. 97.3%, p = 0.969, respectively). The use of hemodynamic support intra-aortic balloon pump was more frequent in the octogenarians (21.6% vs. 11.6%, p = 0.007), but the RA completion rate was similarly high (95.9% vs. 99.1%, p = 0.842). There was no difference in acute complications. The total/cardiovascular (CV) death rate within one year was higher in the octogenarians, along with higher major adverse cardiovascular event (MACE)/CV MACE rates in the first month. Cox regression analysis showed that age ≥ 80 years, acute coronary syndrome, ischemic cardiomyopathy/shock, multi-vessel disease and serum creatinine were all predictors of MACE, and that these factors plus peripheral artery disease were predictors of all-cause mortality in these patients.
Conclusions: RA is feasible with a very high success rate in high-risk octogenarians with complex anatomies, and with equal safety and no increase in complications. The higher rates of all-cause death and MACE were attributed to an older age and other traditional risk factors.

Key Words: Complex and high-risk indicated procedure (CHIP) • Coronary artery disease • Octogenarians • Rotational atherectomy • Very elderly

INTRODUCTION

Increasing evidence has shown that the very elderly (octogenarians) benefit from percutaneous coronary intervention (PCI) for stable angina, unstable angina, non-ST elevation myocardial infarction (NSTEMI) and ST elevation myocardial infarction (STEMI).[1-3] However, octogenarians are susceptible to periprocedural complications of PCI due to their old age, multiple co-morbidities, complex anatomies and heavy calcifications.[3] Calcifications are more often found in octogenarians, which can result in a lower PCI procedure completion rate than in younger counterparts.[4] Octogenarians are also prone to bleeding events with dual antiplatelet therapy and anticoagulation therapy.[5-8]

Rotational atherectomy (RA) is frequently performed in complex and high-risk indicated procedures (CHIPs) which are carried out for highly calcified coronary le-

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Abbreviations

ACS	Acute coronary syndrome
ACT	Activated clotting time
BMS	Bare metal stents
BP	Blood pressure
CABG	Coronary artery bypass grafting
CAD	Coronary artery disease
CHIP	Complex and high-risk indicated procedure
CIN	Contrast induced nephropathy
CKD	Chronic kidney disease
Cr	Creatinine
CTO	Chronic total occlusion
CV	Cardiovascular
DAPT	Dual antiplatelet therapy
DEB	Drug-eluting balloon
DES	Drug-eluting stent
DM	Diabetes mellitus
DVD	Double vessel disease
ECMO	Extracorporeal membrane oxygenation
FBS	Fasting blood sugar
HDL	High density lipoprotein
IABP	Intra-aortic balloon pump
ICM	Ischemic cardiomyopathy
LDL	Low density liproprotein
LM	Left main coronary artery
LVEF	Left ventricle ejection fraction
MACE	Major adverse cardiovascular event
MI	Myocardial infarction
MV	Main vessel
MVD	Multi-vessel disease
NSTEMI	Non-ST elevation myocardial infarction
PAD	Peripheral artery disease
PCI	Percutaneous coronary intervention
RA	Rotational atherectomy
SB	Side branch
STEMI	ST elevation myocardial infarction
SVD	Single vessel disease
Syntax	Synergy between percutaneous coronary intervention with Taxus and coronary artery bypass surgery study
TLR	Target lesion revascularization
TVD	Triple vessel disease
TVR	Target vascular revascularization

sions.[9] When intravascular imaging reveals highly calcified coronary atheroma, coronary stenting is prone to delivery failure or under-expansion. Complications such as stent dislodgement or fracture at critical lesion sites can occur, resulting in compromised coronary flow and unstable hemodynamics.[10] Although RA is effective in modifying heavily calcified lesions, it also carries the risk of intraprocedural complications such as slow/no flow, vasospasm, intimal dissection, atrial-ventricular block, coronary perforation, and even death.[11] With growing experience and improved skills regarding RA in complex PCI, RA for both the main vessel and side branches is currently feasible.[12] Furthermore, the use of both intra-aortic balloon counterpulsation (IABP) and extracorporeal membrane oxygenation (ECMO) as hemodynamic support enables the use of RA in high-risk patients with existing or expected left ventricular dysfunction.[13] Due to the aging population, CHIPs with RA in very elderly high-risk patients is being increasingly utilized in modern catheterization laboratories (cath labs). Only a very limited number of reports have been published regarding RA for octogenarians in the literature, and most of them have limitations including a limited number of patients,[14,15] being limited to acute coronary syndrome (ACS), simpler lesions or single artery disease,[16] only parts of the treated lesions were heavy calcified,[17] or treatment was not performed in the contemporary manner of PCI with RA.[18] This study aimed to investigate patient profiles, as well as the procedural and short- to intermediate-term results of contemporary RA for complicated octogenarians compared with non-octogenarian patients in our cath lab database.

METHODS AND MATERIALS

Patient population

Consecutive patients who received RA therapy for coronary lesions from April 2010 to April 2018 at our cath lab were identified from the cath lab database and selected upon manual inspection for recruitment. The indications for PCI and RA, procedure details and complications at the time of index PCI were retrieved. The electronic medical chart records of each patient were reviewed in detail, with relevant clinical information and biochemical findings at the time of hospitalization and during follow-up retrieved and recorded in case record forms. The patients were stratified into two groups based on their age at the time of the index procedure, either ≥ 80 or < 80 years of age.

Angiographic characterization and measurements

A workstation with dedicated software (Rubo DICOM Viewer, version 2.0, build 170828, Rubo Medical Imaging, Aerdenhout, The Netherlands) was used to review coronary angiograms and make quantitative measurements. Synergy between percutaneous coronary intervention with Taxus and coronary artery bypass surgery study (Syntax) scores both before and after PCI were calculated using the standard calculator software available on the website. The number of vessels with coronary artery disease (CAD) was defined as the number of the three major coronary vessels with stenosis $\geq$ 70% in diameter. Severe coronary artery calcification was defined as apparent abluminal radio-opacity on two sides of the vascular walls appearing in two different projections on the cine without cardiac movement before the injection of contrast medium.

All PCIs were performed by certified interventional cardiologists in accordance with the standard practices followed at our cath lab. Patients were pretreated with a standard dose of aspirin and clopidogrel (or ticagrelor). Calcium channel blockers and nitrates were also used to prevent any coronary artery spasm. Heparin was administered to maintain an activated clotting time (ACT) of $\geq$ 300 seconds during the procedure. The decision to perform RA was determined by standard practice, as well as the discretion of the operator. Prior to RA, a 0.009-inch floppy RotaWire™ (Boston Scientific®, USA) was advanced through the lesion using the wire-exchange technique. A bolus of 1,200-1,600 ug of isosorbide dinitrate was administered intra-coronarily prior to the start of RA, during which normal saline mixed with heparin and isosorbide dinitrate was slowly infused. RA was implemented using a Rotablator™ (Boston Scientific®, USA) RA system, starting with a 1.25 or 1.5 mm burr at a speed of 160,000-180,000 rpm, and often supplemented with a second burr one size larger. Each burr advance time was less than 20 seconds. For patients who required side branch (SB) rotablation, the sequence of RA of the SB or main vessel (MV) was determined according to which vessel was more critically diseased and would be potentially jeopardized if not treated first, as well as the discretion of the operator. After completion of RA, a workhorse wire was used to replace the RotaWire™ (Boston Scientific®, USA) using the same wire-exchange technique, with the procedure proceeding with balloon angioplasty with or without stent implantation in order to achieve optimal angiographic results and minimal residual stenosis. Whenever indicated, glycoprotein IIb/IIIa inhibitors or inotropes were administered. Unexpected cardiogenic shock during the procedure was managed conventionally and with IABP or ECMO if the hemodynamics did not respond to conventional treatment. Completion of RA was defined as full debulking of the target lesion without premature termination of RA before proceeding to subsequent treatment. After stent implantation, dual-antiplatelet therapy with aspirin (100 mg/day) and clopidogrel (75 mg/day; or ticagrelor 90 mg twice daily) continued for at least 12 months in the case of drug-eluting stent (DES) implantation, or three months in the case of bare-metal stent (BMS) implantation.

Clinical outcomes

Clinical follow-up and assessments were conducted in the hospital and also at 30 days, 90 days, 180 days and one year after the index PCI. Telephone contact was made if the patients missed any follow-up sessions for a period of over two months after their last visit. In cases of patient mortality, the cause of death as stated on the death certificate was retrieved.

Major adverse cardiovascular events (MACEs) were defined as all-cause death, myocardial infarction, stroke and coronary revascularization. Cardiovascular major adverse cardiac events (CV MACEs) were defined as cardiovascular death, myocardial infarction, stroke, and coronary revascularization. Target lesion revascularization (TLR) was defined as performing any procedure for $\geq$ 70% lumen narrowing attributed to restenosis of the index treated lesion. Target vascular revascularization (TVR) was defined as repeated PCI for a $\geq$ 70% stenotic lesion in another segment of the vessel not treated during the index procedure or when TLR occurred. This study protocol was approved by the Institutional Review Board for Human Research of Taichung Veterans General Hospital, Taiwan. The methods used have been reported previously.[12,13,19]

Statistical analysis

Categorical data were expressed as number and percentage. Continuous variables were presented as mean $\pm$ standard deviation or median (first quartile-third-quartile), depending on the results of the normality test for distribution. Differences in categorical data were tested by either the chi-square or Fisher's exact test as indicated. Differences in continuous variables were tested by an unpaired Student's t-test or Mann-Whitney U test, depending on whether there was normal distribution or not. Cox regression analysis using the enter method was performed to identify possible independent predictors of MACEs and all-cause mortality in this cohort. Survival curves for MACEs were plotted using the Kaplan-Meier method. All statistical analyses were performed using SPSS for Microsoft Windows, version 26.0 (IBM Corp., New York, US). Two-tailed p values < 0.05 were considered statistically significant.

RESULTS

Baseline patient characteristics

A total of 411 consecutive patients including 269 (65.5%) males and 142 (34.5%) females with a mean age of 73.8 ± 11.3 years were enrolled. Most of the patients had high-risk features [ACS, ischemic cardiomyopathy (ICM), and cardiogenic shock], and only 20.2% of the patients had stable angina. Overall, 73.5% of the patients had hypertension, 58.6% had diabetes, and 10.7% had peripheral artery disease (PAD).

Of the 411 patients, 153 (37.2%, 105 males and 48 females) were ≥ 80 years old (octogenarian group; Table 1), while the other 258 (62.8%, 164 males and 94 females) were < 80 years old (non-octogenarian group). The octogenarians had a lower rate of diabetes and had lower HbA1c, but higher rate of cardiogenic shock (9.2% vs. 2.7%, p = 0.04), with a trend toward more cardiogenic

Table 1. Demographic data of rotational atherectomy in patients < 80 years old and ≥ 80 years old

Variables	Age < 80 (N = 258)	Age ≥ 80 (N = 153)	p value
Gender (M/F)	164/94	105/48	0.297
Age (years)	68.0 (60.5-74.0)	84.6 (82.6-87.2)	< 0.001
Clinical diagnosis (N, %)			0.254
Stable angina	53 (20.5%)	30 (19.6%)	
Unstable angina	102 (39.5%)	47 (30.7%)	
NSTEMI	57 (22.1%)	41 (26.8%)	
STEMI	11 (4.3%)	12 (7.8%)	
Ischemic CM	35 (13.6%)	23 (15.0%)	
Cardiogenic shock	7 (2.7%)	14 (9.2%)	0.004
Acute coronary syndrome	170 (65.9%)	100 (65.4%)	0.913
Ischemic CM or shock	41 (15.9%)	36 (23.5%)	0.055
Hypertension (N, %)	187 (72.5%)	115 (75.2%)	0.551
Diabetes (N, %)	176 (68.2%)	65 (42.5%)	< 0.001
PAD (N, %)	25 (9.7%)	19 (12.4%)	0.387
Baseline LVEF (%)	46.0 (36.0-57.0)	45.0 (36.0-56.0)	0.834
Systemic BP, systolic	161.0 (140.0-180.0)	153.0 (129.0-174.0)	0.011
Systemic BP, diastolic	71.0 (64.0-80.0)	65.0 (53.0-73.0)	< 0.001
Lab data			
Hemoglobin (mg/dl)	11.4 (10.0-13.3)	10.9 (9.7-12.7)	0.073
BUN (mg/dl)	27.0 (16.0-48.3)	29.0 (21.3-47.0)	0.149
Cr (mg/dl)	1.3 (0.9-4.3)	1.4 (1.1-2.2)	0.872
Cholesterol (mg/dl)	147.0 (126.3-168.0)	144.0 (125.0-168.8)	0.891
HDL-Chol (mg/dl)	42.5 (35.0-51.0)	44.0 (36.0-53.0)	0.538
LDL-Chol (mg/dl)	84.0 (68.0-98.0)	78.0 (63.0-103.0)	0.483
FBS (mg/dl)	122.0 (96.3-183.5)	111.5 (92.8-156.3)	0.191
HbA1c (mg/dl)	6.6 (5.9-7.6)	6.0 (5.5-6.6)	< 0.001
Total CK (U/L)	95.0 (63.8-169.3)	112.5 (68.8-235.0)	0.100
CK-MB (U/L)	7.00 (5.0-11.0)	8.0 (5.0-12.0)	0.167
Troponin (ng/ml)	0.159 (0.033-0.968)	0.341 (0.086-3.585)	0.009
CAD vessel numbers			0.004
SVD (N, %)	57 (22.1%)	33 (21.6%)	
DVD (N, %)	69 (26.7%)	42 (27.5%)	
TVD (N, %)	96 (37.2%)	46 (30.1%)	
LM disease (N, %)	24 (9.3%)	24 (15.7%)	
Prior CABG (N, %)	12 (4.7%)	8 (5.2%)	

BP, blood pressure; BUN, blood urea nitrogen; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CK, creatinine kinase; CK-MB, creatinine kinase MB form; CM, cardiomyopathy; Cr, creatinine; DVD, double vessel disease; F,female; FBS, fasting blood sugar; HbA1c, hemoglobin A1c; HDL-Chol, high density lipoprotein-cholesterol; Ischemic CM, ischemic cardiomyopathy; LDL-Chol, low density lipoprotein-cholesterol; LM, left main coronary artery; LVEF, left ventricle ejection fraction; M,male; NSTEMI, non-ST segment elevation myocardial infarction; PAD, peripheral artery disease; STEMI, ST-elevation myocardial infarction; SVD, single vessel disease; TVD, triple vessel disease.

shock plus ICM and lower systemic BP than the non-octogenarians. They also had higher cardiac troponin, and more left main (LM) disease. Otherwise, there were no significant differences in the prevalence of hypertension, admission diagnosis of CAD, or biochemistry data between the two groups.

Lesion characteristics and procedure details

The lesion characteristics and procedure details of the patients are presented in Table 2. Almost all of the lesions were heavily calcified, and both groups had high baseline Syntax scores. The octogenarians had more proximal coronary lesions treated with RA and used more 7F guides than the non-octogenarians. Otherwise, both groups had a similar severity of calcification, prevalence of vessel tortuosity, bifurcation lesions and type C lesions. There were no differences in RA vessels, total lesion length, total number of lesions, main vessel/side branch RA, burr size or baseline/post PCI Syntax scores between the two groups. The use of DESs was lower in the octogenarians, and the use of hemodynamic support (all patients used IABP but not ECMO) during the PCI/RA procedure was significantly more frequent in the octogenarians (21.6% vs. 11.6%, p = 0.007). In addition, more octogenarians required hemodynamic support for cardiogenic shock at the beginning of the procedure (39.4% vs. 13.3%, p = 0.038). The use of the glycoprotein IIb/IIIa inhibitor was also more frequent in the octogenarians due to thrombus in situ. Despite these findings, the RA completion rate was similarly high (95.9% vs. 99.1%, p = 0.842) in the two groups, with an even better improvement in SYNTAX score after PCI in the octogenarians.

Periprocedural complications and acute contrast-induced nephropathy (CIN)

Periprocedural complications and acute CIN after the procedure are shown in Table 3. There were no between-group differences in the incidence rates of acute slow/no flow, wire transection, vessel perforation, acute pulmonary edema, profound/refractory shock or ventricular arrhythmia. In addition, emergent coronary artery bypass grafting (CABG) was not performed and there were no immediate deaths related to the procedure in either group.

Clinical outcomes

The clinical outcomes of the patients are shown in Table 4. The all-cause and CV mortality rates were higher in the octogenarians through the first year, as well as higher MACEs/CV MACEs in the first month. On the other hand, the non-octogenarians had more TLR and TVR at 12 months. The Kaplan-Meier curve for all MACEs is shown in Figure 1.

Predictive factors for clinical outcomes at difference time points

Cox regression analysis showed that ACS presenta-

Table 2. Lesion characteristics and procedure details of rotational atherectomy for patients < 80 years old and ≥ 80 years old

Variables	Age < 80 (N = 258)	Age ≥ 80(N = 153)	p value
Access site			0.686
Radial (N, %)	80 (31.0%)	43 (28.1%)	
Femoral (N, %)	171 (66.3%)	104 (68.0%)	
Brachial (N, %)	7 (2.7%)	6 (3.9%)	
Guide size			0.049
6F (N, %)	90 (34.9%)	39 (25.5%)	
7F (N, %)	162 (62.8%)	113 (73.9%)	
8F (N, %)	6 (2.3%)	1 (0.7%)	
Rotablation vessels			0.391
Single vessel*	216	123	
Multiple vessels	42	30	
Lesions characteristics of rotablation vessel			
Location			
Ostial lesion	83 (32.2%)	66 (43.1%)	0.055
Proximal lesion	179 (69.4%)	127(83.0%)	0.002
Middle lesion	235(91.1%)	139(90.8%)	0.831
Distal lesion	185 (71.7%)	103(67.3%)	0.196

Table 2. Continued

Variables	Age < 80 (N = 258)	Age ≥ 80(N = 153)	p value
Tortuosity	129 (50.0%)	68 (44.4%)	0.732
Bifurcation	91 (35.3%)	44 (28.8%)	0.166
Severe calcification (N, %)	251 (97.3%)	147 (96.1%)	0.969
ACC/AHA lesion (N, %)			0.893
Type B2	25 (9.7%)	13 (8.5%)	
Type C	233 (90.3%)	140 (91.5%)	
Chronic total occlusion	35 (13.6%)	20 (13.1%)	0.887
Total lesion length (mm)	41.5 (26.8-61.6)	37.1 (23.8-59.8)	0.358
Total lesion numbers (N)	2.0 (2.0-3.0)	2.0 (2.0-3.0)	0.347
Rotablation main vessel/side branch			0.545
Main vessel only	221 (85.7%)	136 (88.9%)	
Main + side branch	23 (8.9%)	12 (7.8%)	
Side branch only	14 (5.4%)	5 (3.3%)	
Maximal burr size			0.152
1.25 mm (N, %)	50 (19.4%)	21 (13.7%)	
1.5 mm (N, %)	152 (58.9%)	87 (56.9%)	
1.75 mm (N, %)	53 (20.5%)	41 (26.8%)	
2.0 mm (N, %)	2 (0.8%)	4 (2.6%)	
2.25 mm (N, %)	1 (0.4%)	0	
Rotablation completed	254 (99.1%)	151 (95.9%)	0.842
Stents (N, %)	244 (94.6%)	138 (90.2%)	< 0.001
BMS (N, %)	37 (14.3%)	53 (34.6%)	
DES (N, %)	195 (75.6%)	85 (55.6%)	
DEB (N, %)	1 (0.4%)	0	
BMS + DES (N, %)	1 (0.4%)	0	
Stent numbers	2.0 (1.0-2.0)	2.0 (1.0-2.0)	0.894
Stent size (mm)	2.8 (2.5-3.0)	28 (2.6-3.0)	0.185
Total stent length (mm)	51.0 (30.0-70.3)	44.0 (30.0-70.0)	0.429
Syntax score baseline	28.8 (19.0-38.3)	32.0 (21.0-41.8)	0.066
Syntax score post-PCI	5.0 (0.0-14.0)	5.0 (0.0-14.0)	0.717
Syntax score gain	20.0 (12.0-28.6)	23.0 (15.0-31.0)	0.029
Total fluoro time (min)	41.0 (28.1-59.3)	46.0 (32.8-60.4)	0.250
Total contrast dose (ml)	180.0 (150.0-250.0)	180.0 (150.0-230.0)	0.894
Total procedure time (min)	150.0 (117.3-190.0)	150.0 (120.0-195.0)	0.621
Hemodynamic support, (N, %)	30 (11.6%)	33 (21.6%)	0.007
IABP/ECMO	30/0	33/0	
Shock at beginning of procedure	4 (13.3%)	13 (39.4%)	0.038
Shock during procedure	2 (6.7%)	2 (6.1%)	
Shock due to complication	0	1 (3.0%)	
Ad hoc as part of CHIP	24 (80%)	17 (51.5%)	
Removed at end of procedure	11 (36.7%)	10 (30.3%)	0.606
Continued after procedure	19 (63.3%)	23 (69.7%)	
Use of IIb/IIIa inhibitors (N, %)	2 (0.8%)	7 (4.6%)	0.010
Thrombus in situ	1 (50%)	5 (71.4%)	1.000
Thrombus during procedure	1 (50%)	2 (28.6%)	

* Including isolated LM disease.

ACC, American College of Cardiology; AHA, American Heart Association; BMS, bare metal stent; CHIP, complex and high-risk indicated procedure; DEB, drug eluted balloon; DES, drug eluted stent; ECMO, extra-corporeal membranous oxygenation; IABP, intra-aortic balloon pumping; PCI, percutaneous coronary intervention.

Table 3. In-procedure complications and acute CIN of rotational atherectomy for patients < 80 years old and ≥ 80 years old

Variables	Age < 80 (N = 258)	Age ≥ 80 (N = 153)	p value
Transient slow/no flow (N, %)	25 (9.6%)	10 (6.5%)	0.268
Wire transection (N, %)	0	1 (0.7%)	-
Vessel perforation (N, %)	2 (0.8%)	3 (1.96%)	0.366
Access site hematoma (N, %)	4 (1.6%)	6 (3.9%)	0.183
Acute pulmonary edema (N, %)	8 (3.1%)	6 (3.9%)	0.657
Profound/refractory shock (N, %)	31 (12.0%)	19 (25.0%)	0.904
Ventricular arrhythmia (N, %)	5 (1.9%)	4 (2.6%)	0.732
Emergent CABG (N, %)	0	0	-
Immediate death related to procedure (N, %)	0	0	-
Acute CIN (N, %)	14 (5.4%)	7 (4.6%)	0.279

CABG, coronary artery bypass grafting; CIN, contrast-induced nephropathy.

Table 4. Clinical outcomes of rotational atherectomy for patients < 80 years old vs. ≥ 80 years old

Variables	Age < 80 (N = 258)	Age ≥ 80(N = 153)	p value
In-hospital			
MACE (N, %)	9 (3.5%)	22 (14.4%)	< 0.001
CV MACE (N, %)	5 (1.9%)	17 (11.1%)	< 0.001
All-cause mortality (N, %)	7 (2.7%)	20 (13.1%)	< 0.001
CV death (N, %)	3 (1.2%)	14 (9.2%)	< 0.001
Non-fatal MI (N, %)	1 (0.4%)	2 (1.3%)	0.558
Fatal MI (N, %)	0	2 (1.3%)	0.138
Stent thrombosis	0	1 (0.7%)	0.372
Stroke (N, %)	0	1 (0.7%)	0.372
TLR (N, %)	0	0	NS
TVR (N, %)	2 (0.8%)	1 (0.7%)	1.000
One month			
MACE (N, %)	17 (6.6%)	24 (15.7%)	0.003
CV MACE (N, %)	12 (4.7%)	18 (11.8%)	0.007
All-cause mortality (N, %)	12 (4.7%)	21(13.7%)	0.001
CV death (N, %)	7 (2.7%)	14 (9.2%)	0.004
Non-fatal MI (N, %)	1 (0.4%)	2 (1.3%)	0.558
Fatal MI (N, %)	0	2 (1.3%)	0.137
Stent thrombosis	2 (0.8%)	1 (0.7%)	1.000
Stroke (N, %)	1 (0.4%)	1 (0.7%)	1.000
TLR (N, %)	2 (0.8%)	1 (0.7%)	1.000
TVR (N, %)	4 (1.6%)	2 (1.3%)	1.000
One-year			
MACE (N, %)	75 (29.1%)	56 (36.6%)	0.099
CV MACE	57 (22.1%)	35 (22.9%)	0.816
All-cause mortality (N, %)	39 (15.1%)	44 (28.8%)	0.001
CV death (N, %)	13 (5.0%)	20 (13.1%)	0.003
Non-fatal MI (N, %)	8 (3.1%)	5 (3.3%)	0.907
Fatal MI (N, %)	4 (1.6%)	4 (2.6%)	0.474
Stent thrombosis	3 (1.2%)	1 (0.7%)	1.000
Stroke (N, %)	3 (1.2%)	1 (0.7%)	1.000
TLR (N, %)	37 (14.3%)	11 (7.2%)	0.032
TVR (N, %)	43 (16.7%)	14 (9.2%)	0.037

CV, cardiovascular; MACE, major adverse cardiovascular events; MI, myocardial infarction; TLR, target lesion revascularization; TVR, target vessel revascularization.

tion, ICM/shock, multi-vessel disease, age ≥ 80 years and serum creatinine were all independent predictive factors for MACEs in this cohort (Table 5), whereas PAD was a borderline predictor for MACEs. On the other hand, hypertension history was a significant negative predictor for MACE.

In terms of all-cause mortality, the Cox regression model showed that age ≥ 80 years, PAD, ACS presentation, ICM/shock, multivessel disease and serum creatinine were all independent predictors of all-cause mortality in the patients (Table 5). Interestingly, hypertension history remained a negative predictor in multivariate analysis.

DISCUSSION

Our results showed that RA is feasible and can achieve a very high success rate in high-risk octogenarians with complex anatomies, and with equal safety and no increase in procedural complications, despite a lower systemic blood pressure, more cardiogenic shock and a greater need for hemodynamic support. In addition, our results showed that the octogenarians who required RA were associated with increased all-cause/CV death through one year, as well as higher MACEs/CV MACEs during the first month. ACS presentation, ICM/shock, multi-vessel disease, age ≥ 80 years, and serum creatinine were all independent predictive factors of MACEs in this cohort, whereas PAD was a borderline predictor. However, hypertension history was a significant negative predictor of MACEs. We also found that age ≥ 80 years, PAD, ACS presentation, ICM/shock, multivessel disease and serum creatinine were all independent predictors for all-cause mortality, whereas hypertension history again remained

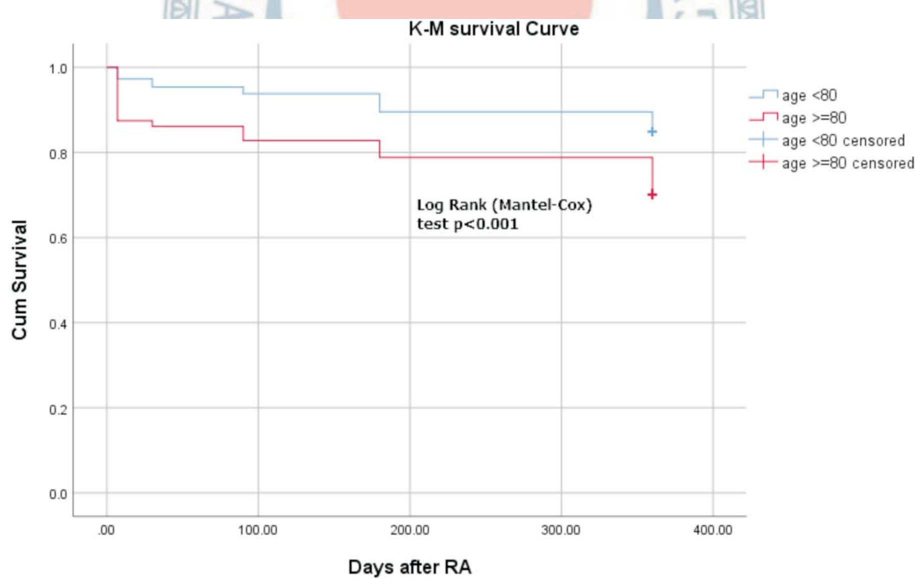

Figure 1. *Kaplan-Meier survival curve for total major adverse cardiovascular event (MACE), showing that cumulative MACE was significantly higher in the octogenarian group at one year which was contributed by more total and cardiovascular (CV) deaths through the first year.*

Table 5. Cox regression analyses for MACE and all-cause mortality of all patients

Variables	MACE			All cause mortality		
	OR	95% CI	p value	OR	95% CI	p value
Age ≥ 80	1.52	1.07-2.17	0.021	2.09	1.34-3.27	0.001
PAD	1.61	1.00-2.60	0.050	2.14	1.23-3.72	0.007
ACS	2.67	1.67-4.26	< 0.001	3.84	2.13-6.92	< 0.001
MVD, DVD vs. SVD	2.33	1.21-4.48	0.011	3.36	1.28-8.79	0.014
TVD vs. SVD	2.81	1.49-5.31	0.001	3.41	1.32-8.80	0.011
Creatinine	1.11	1.05-1.17	< 0.001	1.08	1.00-1.16	0.049
Ischemic CM/shock	3.04	1.91-4.83	< 0.001	4.47	2.61-7.68	< 0.001
Hypertension	0.62	0.44-0.90	0.011	0.50	0.32-0.78	0.002

ACS, acute coronary syndrome; DM, diabetes mellitus; DVD, double vessel disease; Ischemic CM, ischemic cardiomyopathy; MACE, major adverse cardiovascular event; MVD, multi-vessel disease; OR, odds ratio; PAD, peripheral arterial disease; SVD, single vessel disease; TVD, three vessel disease; 95% CI, 95% confidence interval.

a negative predictor of all-cause mortality.

PCI in the very elderly is challenging due to the patient's age, multiple co-morbidities [diabetes mellitus and chronic renal disease (CKD)], ACS and complex anatomies.[3] These factors were also found in our patient cohort, and only 19.6% of the octogenarians had stable angina, and most others had either ACS, ICM or cardiogenic shock. Not surprisingly, 9.2% of the octogenarians had cardiogenic shock. Furthermore, 78.4% of the octogenarians had MVD, and 12.4% were diagnosed with PAD. The median left ventricle ejection fraction (LVEF) was only 45.0%. Despite having a lower rate of diabetes than the non-octogenarians, diabetes was still present in 42.5% of our patients, and 75.2% had hypertension. The total Syntax score was also high, reaching 32.0 at baseline, showing the complexity of the coronary lesions and the challenges faced in PCI. All of these features illustrate the very high-risk profiles of our octogenarians who required RA in the cath lab for heavily calcified lesions.

In recent years, CHIPs have gained a lot of attention due to the challenges faced during PCI and the presence of multiple co-morbidities. CHIPs often refer to very elderly patients with frailty, renal insufficiency and many other co-morbidities.[20-22] Heavy coronary calcification is more common in the very elderly and an important component of CHIPs.[4] RA is frequently used to treat device-uncrossable or device-undilatable calcified lesions in order to achieve optimal revascularization.[9] RA is an advanced technique used in PCI, but even when performed by experienced interventionists, it is still associated with different complications at varying rates, particularly when it comes to diffuse heavy calcifications with acute bends, side-branch lesions and patients with left ventricle (LV) dysfunction. Once complications occur, the very elderly are more vulnerable to their consequences. Whether extreme old age plays an important role in the outcomes of PCI with RA remains an interesting and as yet unresolved question. The Euro4C study analyzed the contemporary use and outcomes of RA in European patients, and found that the predictors for MACEs at one year were female gender, renal failure, ACS at admission, depressed LV function and significant LM disease.[23] Januszek et al. reported that age > 75 years was not significantly associated with MACEs in patients diagnosed with heavily calcified lesions who were treated with RA.[24] Orbital atherectomy is another tool used to treat severely calcified coronary lesions, with the merits of providing a less slow or no flow phenomenon.[25] In the study by Lee et al., being more than 75 years of age was also not associated with adverse clinical events.[26] Although RA in octogenarians has been reported in the literature, most studies have had limitations including limited patient numbers,[14,15] being limited to only ACS, simpler lesions or single artery disease,[16] only part of the treated lesions were heavily calcified,[17] or the study was not performed in a contemporary manner with PCI with RA for heavily calcified lesion modification. Even though RA has been used in octogenarians since early in the history of PCI,[5,18] the procedures then were performed in the BMS era when RA was used mostly for the debulking of atherosclerotic plaque rather than the modification of heavily calcified lesions.[9] Therefore, at that time, severe coronary calcification accounted for only a minority of the lesions treated with RA,[5] or the severity of calcification was not clearly stated in those studies.[18] Also, the treated lesion length was short in those studies.[5,18] Furthermore, most of the patients had single-vessel disease, and most of the RA-treated vessels were the left anterior descending artery. Even though simpler lesions were treated in those studies compared to ours, the procedural success rate in those early studies was not very high, and the CABG rate cannot be overlooked.

The use of RA for the modification of heavily calcified lesions in the very elderly in the DES era was only reported once.[17] Despite a 100% success rate for RA and a low complication rate, heavy calcification accounted for only 47.9% of their patients. Furthermore, ACS presentation, diabetes and CKD were seen in only 53.5%, 33.8% and 5.6% of their patients, respectively. No RA vessels, lesion length, lesion complexity or Syntax scores were addressed in that study. In comparison, all of our RA procedures were conducted for the modification of heavily calcified coronary lesions as in contemporary practice, and the baseline Syntax score was as high as 32.0 with 91.5% AHA/ACC type C lesions. Furthermore, 21% of the RA procedures were performed for MVD and 11.1% for side branches. The total lesion length (37.1 mm) was also longer than reported in previous studies. Nevertheless, RA was completed in 95.9% of the cases despite hemodynamic support being used during the procedure in 21.6% of our patients. Despite these high-risk and highly complex anatomic features, our study showed that periprocedural complications and risk of acute CIN were not increased in the very elderly. The gain in Syntax score was even higher in our octogenarians. The good results and low complication rate for RA in octogenarians at our cath lab could be due to our experience, including a high-volume medical center, experienced operators and a long history in the use of RA for the treatment of complex lesions.[10-12] To the best of our knowledge, our series is the largest yet in real-world practice to investigate the feasibility, efficacy and safety of RA in very high-risk octogenarian patients with complex coronary anatomies.

Despite the very successful PCI rates with the use of RA, our octogenarian patients still showed an expected increase in total/CV deaths through one year, and higher MACEs/CV MACEs during the first month. These results were due to age and other conventional risk factors. In the Cox regression model, ACS presentation, ICM/shock, multi-vessel disease, age ≥ 80 years and serum creatinine were all independent predictive factors for MACEs throughout the study period. In terms of all-cause mortality after RA, age ≥ 80 years, PAD, ACS, ischemic CM/shock, multivessel disease and serum creatinine were all independent predictors in our cohort. Interestingly, hypertension history was a negative predictor for both MACEs and all-cause mortality in our population. Further, larger studies are warranted to confirm this finding.

Limitations

There are several limitations to the current study. First, the retrospective design is subject to all its inherent limitations. Second, the study population was heterogenous in clinical diagnoses and had varying clinical presentations. However, this study reflects real-world practice where heavily calcified complex lesions in very-high risk patients demand rotablation ad hoc or in a bail-out manner in order to achieve complete revascularization and good results. However, the large population allowed us to perform multivariate Cox regression analysis in order to explore the independent risk factors for MACEs and all-cause death. Third, the study population spanned a period of over 10 years, during which PCI devices, operation skills and experience all improved. However, both disease severity and lesion complexity surrounding PCI also increased during this period, resulting in a tradeoff. These changes which occurred over time were difficult to control in this study. However, the large patient cohort was meant to explore the feasibility, safety and efficacy of RA in very-high risk octogenarians in real-world practice. Lastly, we found that a hypertension history was a negative predictor for both MACEs and all-cause mortality in our population. This is an interesting finding and awaits confirmation through future additional studies with more patients.

CONCLUSION

RA is feasible and can be carried out with a very high completion rate in high-risk octogenarians with complex anatomies. Additionally, it can be performed with equal safety and no increase in procedural complications, despite more cardiogenic shock at baseline and a greater need for hemodynamic support during the procedure. Even though RA in octogenarians was associated with an increase in all-cause/CV deaths during the first year and increased MACEs/CV MACEs in the first month, these results were related to old age and other conventional risk factors.

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DECLARATION OF CONFLICTS OF INTEREST

All the authors declare no conflicts of interest.

REFERENCES

1. Madhavan MV, Gersh BJ, Alexander KP, et al. Coronary artery dis-

ease in patients ≥ 80 years of age. *J Am Coll Cardiol* 2018;71: 2015-40.
2. Kassimis G, Karamasis GV, Katsikis A, et al. Should percutaneous coronary intervention be the standard treatment strategy for significant coronary artery disease in all octogenarians? *Curr Cardiol Rev* 2021;17:244-59.
3. Shanmugam VB, Harper R, Meredith I, et al. An overview of PCI in the very elderly. *J Geriatr Cardiol* 2015;12:174-84.
4. Arnson Y, Rozanski A, Gransar H, et al. Coronary artery calcium in the elderly: prevalence, severity, and association with all-cause mortality. *J Am Coll Cardiol* 2017;69:1553.
5. Henson KD, Popma JJ, Leon MB, et al. Comparison of results of rotational coronary atherectomy in three age groups (< 70, 70 to 79 and > or = 80 years). *Am J Cardiol* 1993;71:862-4.
6. Gravina Taddei CF, Weintraub WS, King S 3rd, et al. Early and intermediate outcomes after rotational atherectomy in octogenarian patients. *Am J Geriatr Cardiol* 1999;8:169-72.
7. Sandhu K. Percutaneous coronary intervention in the elderly. *Int J Cardiol* 2015;199:342-55.
8. Shanmugam VB. An overview of PCI in the very elderly. *J Geriatr Cardiol* 2015;12:174-84.
9. Gupta T, Weinreich M, Greenberg M, et al. Rotational atherectomy: a contemporary appraisal. *Interv Cardiol* 2019;14:182-9.
10. Mosseri M, Satler LF, Pichard AD, Waksman R. Impact of vessel calcification on outcomes after coronary stenting. *Cardiovasc Revasc Med* 2005;6:147-53.
11. Sharma SK, Tomey MI, Teirstein PS, et al. North American expert review of rotational atherectomy. *Circ Cardiovasc Interv* 2019; *12:e007448.*
12. Chen YW, Su CS, Chang WC, et al. Feasibility and clinical outcomes of rotational atherectomy for heavily-calcified side branches of complex coronary bifurcation lesions in the real-world practice of the drug-eluting stent era. *J Interv Cardiol* 2018;31: 486-95.
13. Chen YW, Chen YH, Su CS, et al. The characteristics and clinical outcomes of rotational atherectomy under intra-aortic balloon counterpulsation assistance for complex and very high-risk coronary interventions in contemporary practice: an eight-year experience from a tertiary center. *Acta Cardiol Sin* 2020;36:428-38.
14. Kassimis G, Papakonstantinou D, Tsounos I, Kanonidis I. "One-man" bailout technique for high-speed rotational atherectomy-assisted percutaneous coronary intervention in an octogenarian. *J Geriatr Cardiol* 2020;17:61-3.
15. Kassimis G, Theodoropoulos KC, Didagelos M, Ziakas A. Successful off-label use of rotational atherectomy in ST-segment elevation myocardial infarction: a case report. *Cardiovasc Revasc Med* 2022;40S:272-5.
16. Dahdouh Z, Roule V, Dugué AE, et al. Rotational atherectomy for left main coronary artery disease in octogenarians: transradial approach in a tertiary center and literature review. *J Interv Cardiol* 2013;26:173-82.
17. Sharma V, Abdul F, Haider ST, et al. Rotablation in the very elderly - safer than we think? *Cardiovasc Revasc Med* 2021;22:36-41.
18. Cohen BM, Blum MA, Weber VJ, et al. Rotational atherectomy in octogenarians: results and follow up. *Am J Geriatr Cardiol* 2000; 9:73-5.
19. Wang YH, Chen WJ, Chen YW, et al. Incidence and mechanisms of coronary perforations during rotational atherectomy in modern practice. *J Interv Cardiol* 2020;2020:1894389.
20. Myat A, Patel N, Tehrani S, et al. Percutaneous circulatory assist devices for high-risk coronary intervention. *JACC Cardiovasc Interv* 2015;8:229-44.
21. Chen J, Mohler ER 3rd, Xie D, et al. Risk factors for peripheral arterial disease among patients with chronic kidney disease. *Am J Cardiol* 2012;110:136-41.
22. Mallappallil M, Friedman EA, Delano BG, et al. Chronic kidney disease in the elderly: evaluation and management. *Clin Pract (Lond)* 2014;11:525-35.
23. Bouisset F, Barbato E, Reczuch K, et al. Clinical outcomes of PCI with rotational atherectomy: the European multicentre Euro4C registry. *EuroIntervention* 2020;16:e305-12.
24. Januszek R, Pawlik A, Staszczak B, et al. Age and gender differences in clinical outcomes of patients with heavy-calcified coronary artery lesions treated percutaneously with rotational atherectomy. *Adv Clin Exp Med* 2020;29:225-33.
25. Shlofmitz E, Shlofmitz R, Lee MS. Orbital atherectomy: a comprehensive review. *Interv Cardiol Clin* 2019;8:161-71.
26. Lee MS, Shlofmitz RA, Martinsen BJ, et al. Impact of age following treatment of severely calcified coronary lesions with the orbital atherectomy system: 3-year follow-up. *Cardiovasc Revasc Med* 2018;19:655-9.