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Original Article

The application of rotational atherectomy in PCI for patients with complex coronary artery calcified lesions

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Abstract: Objective: To evaluate the safety and efficacy of rotational atherectomy (RA) in the treatment of complex coronary calcified lesions and to identify factors associated with patient prognosis. Methods: A retrospective study was conducted on 200 patients who underwent RA at Hunan Provincial People's Hospital between January 2022 and March 2024. Baseline demographics, angiographic, procedural, and laboratory variables were collected. Major adverse cardiovascular events (MACE) after discharge were recorded through scheduled clinic visits and telephone follow-up (median, 12 months). All patients received standardized RA, intracoronary imaging guidance, and 12-month dual antiplatelet therapy. Pre- and post-procedural parameters were compared using paired tests, and multivariable logistic regression was performed to identify independent predictors of adverse outcomes. Results: RA significantly increased the minimum lumen area (2.31 mm^2 *vs.* 5.80 mm^2, $P<0.001$) and minimum lumen diameter (1.61 mm *vs.* 2.50 mm, $P<0.001$). Among the 181 patients completing follow-up, 43 (23.8%) developed heart failure, and 19 (10.5%) died. Multivariate analysis identified hypertension (OR=3.201, $P=0.005$) and diabetes mellitus (DM, OR=1.915, $P=0.038$) as independent risk factors for poor prognosis. In patients with both hypertension and DM, older age (OR=1.069, $P=0.046$), left main coronary artery lesion (OR=4.270, $P=0.013$), and maximum burr diameter (OR=292.231, $P=0.006$) were strongly associated with adverse outcomes. Conclusion: RA effectively improves luminal dimensions in complex coronary calcified lesions. Concomitant hypertension and DM are independent risk factors for poor prognosis after RA. Among patients with both conditions, advanced age, left main coronary artery lesion, and larger maximum burr diameter may predict worse clinical outcomes.

Keywords: Rotational atherectomy, calcified coronary lesions, minimum lumen diameter, procedural complications, short-term outcomes

Introduction

Percutaneous coronary intervention (PCI) utilizes cardiac catheterization techniques to dilate narrowed or occluded coronary arteries, thereby improving myocardial blood perfusion. However, the high prevalence of coronary artery calcification in patients with coronary heart disease substantially increases the complexity of PCI. Calcified lesions form rigid, bone-like deposits on arterial walls, reducing vascular elasticity. Consequently, balloon catheters frequently fail to adequately pass or expand stenotic segments during PCI, increasing procedural risks. Severe calcification contributes to higher rates of stent restenosis and intraoperative complications, potentially leading to procedural failure or even mortality [1, 2].

Rotational atherectomy (RA) has been introduced to facilitate PCI in patients severe coronary calcified lesions, aiming to improve procedural success [3]. Based on the principle of "differential cutting", RA selectively ablates heavily calcified plaque, enlarges the vascular lumen, and facilitates subsequent device delivery [4]. Nevertheless, RA is technically demanding and carries risks of complications such as coronary no-reflow, vessel perforation, dissection, and myocardial infarction [5]. Furthermore,

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long-term patient outcomes following RA are influenced by multiple factors including age, sex, comorbidities (e.g., hypertension, diabetes mellitus [DM], and hyperlipidemia), and lesion complexity [6].

Despite its clinical importance, evidence regarding the impact of RA on procedural success and long-term outcomes in patients with complex coronary calcified lesions undergoing PCI remain limited. Previous studies have been constrained by small sample sizes and relatively short follow-up periods. Therefore, this study retrospectively analyzed the clinical data and follow-up data of 200 patients with complex coronary calcified lesions who underwent RA at Hunan Provincial People's Hospital. The study aimed to comprehensively evaluate the safety and efficacy of RA in this patient population and to identify prognostic factors associated with adverse clinical outcomes.

Materials and methods

Study population

This single-center retrospective study included 200 patients with complex coronary calcified lesions who underwent PCI with adjunctive RA at Hunan Provincial People's Hospital between January 2022 and March 2024. Complex coronary lesions were defined according to established criteria and included: left main ostial lesions, bifurcation lesions (branch vessel diameter >2.0 mm, including left main distal bifurcations), chronic total occlusions, long lesions (>30 mm), tortuous/angulated segments, and severely calcified lesions [7, 8].

Inclusion criteria: patients who met indications for RA [9], including: 1) angiographically confirmed severe calcification, 2) lesions resistant to balloon crossing or stent delivery, or 3) lesions that failed to achieve adequate expansion after balloon dilation. Exclusion criteria: 1) severe heart failure precluding procedural tolerance; 2) active infections or significant coagulation disorders; or 3) hemodynamic instability before the procedure.

The study complied with the Declaration of Helsinki and other relevant ethical principles. Approval was obtained from the Clinical Research and Application Ethics Committee of Hunan Provincial People's Hospital (Approval No.: 2024-397).

Research methods

Data collection and follow-up: Patient demographic and clinical data, including age, sex and medical history (e.g., DM, hypertension, dyslipidemia), were collected. Heart failure diagnosis was defined as hospitalization for heart failure symptoms concurrent with electrocardiographic changes, chest X-ray abnormalities, elevated B-type natriuretic peptide (BNP) level, and a left ventricular ejection fraction (LVEF) ≤50%.

Pre-procedural data included minimum lumen area (MLA), minimum lumen diameter (MLD), left ventricular size (LV size), serum creatinine (Cr), uric acid (UA), LVEF (%), platelet count (PLT), and hemoglobin (HGB) levels. Intraoperative parameters comprised burr size, number of stents implanted, total contrast volume, and procedure-related complications (e.g., no-reflow, thrombosis, malignant arrhythmias, hypotension, dissection, cardiac arrest, acute left heart failure). Postoperative assessment (performed on day 1) included in-stent MLA and MLD, LV size, LVEF, Cr, UA, PLT, HGB, and in-hospital adverse events (myocardial infarction, all-cause mortality).

Post-discharge follow-up was conducted via outpatient visits and telephone interviews to monitor major adverse cardiovascular events (MACE), including myocardial infarction, repeat revascularization, heart failure, rehospitalization, stroke, and Bleeding Academic Research Consortium (BARC) type 2-5 bleeding. Follow-up began one month after the procedure and continued through September 2024, with a median duration of 12 months (range: 1-16 months). Scheduled assessments were conducted at 1, 3, 6, and 12 months, and every 6 months thereafter. Unscheduled evaluations were arranged for patients presenting with acute symptoms to promptly capture clinical changes.

Endpoint adjudication followed strict diagnostic criteria. Heart failure was defined as the presence of New York Heart Association (NYHA) class II or higher symptoms, BNP >350 pg/mL (>500 pg/mL for patients aged >70 years), and echocardiographic LVEF ≤50%; Myocardial infarction was defined base on the Third Universal Definition of Myocardial Infarction, requiring troponin elevation above the 99th percentile upper reference limit plus ischemic symptoms,

electrocardiographic changes, or imaging evidence; Repeat revascularization was determined by coronary angiography demonstrating ≥70% diameter stenosis of the target vessel, followed by PCI/coronary artery bypass grafting (CABG) intervention; All-cause mortality was verified via hospital records or family notification, with classification into cardiac or non-cardiac causes.

Follow-up data were collected through outpatient reviews (including complete blood count, blood biochemistry, echocardiography) and standardized telephone questionnaires. For patients initially lost to follow-up, supplementary data were retrieved from community health centers to maximize completeness. All endpoint events were independently reviewed by two associate chief physicians or above. Any discrepancies were resolved through departmental consensus discussions. Complete follow-up data were ultimately obtained for all 181 patients who complete follow-up.

Treatment method and surgical procedure: All patients underwent standardized PCI with adjunctive RA according to a uniform protocol. Pre-operatively, dual antiplatelet therapy consisting of aspirin 100 mg (J20130078) plus either clopidogrel 75 mg (H20056410) daily or ticagrelor 90 mg (H20193252) twice daily was administered for at least five days; loading doses were given to patients without prior preparation. Vascular access was obtained through either the radial or femoral artery under local anaesthesia, and a 6- or 7-French guiding catheter was positioned at the coronary ostium.

A dedicated 0.009-inch (0.23 mm) RotaWire™ (Boston Scientific) was advanced across the target lesion. Plaque modification was accomplished with the Rotablator™ system (Boston Scientific); burr size was selected to achieve a burr-to-artery ratio of 0.5-0.6, based on preprocedural intravascular ultrasound (IVUS) or optical coherence tomography (OCT) measurements, or on angiographic vessel diameter. Ablation was performed at rotational speeds of 140 000-180 000 rpm, with individual runs limited to 15-20 seconds and separated by 30-60 seconds to allow saline flushing and ischemia monitoring. A minimum of three runs were executed per lesion. Systemic anticoagulation was maintained with an intravenous heparin bolus of 80-100 U/kg (H61020229), maintaining an activated clotting time greater than 300 seconds.

Intracoronary imaging (IVUS or OCT) was performed both before and after RA to evaluate calcific modification and quantify lumen dimensions. After plaque modification, balloon angioplasty with semi- or non-compliant balloons was undertaken to facilitate stent delivery. Drug-eluting stents were subsequently implanted under angiographic and IVUS guidance, aiming for optimal expansion - defined as an IVUS-derived minimum stent area >5.0 mm^2 with complete apposition.

Intracoronary nitroglycerin (100-200 μg; H370-21445) was administered before and after imaging runs. Glycoprotein IIb/IIIa inhibitors or vasopressors were used at the operator's discretion in response to procedural complications. Standard dual antiplatelet therapy was maintained for at least 12 months after the procedure.

Statistical analysis

Statistical analysis was performed using SPSS software. Demographic characteristics, preoperative conditions, and intraoperative parameters were summarized using descriptive statistics, presented as mean ± standard deviation (SD) or median (interquartile range [IQR]). Continuous variables were compared between groups using independent samples t-tests or Wilcoxon rank-sum tests, as appropriate. Categorical variables, expressed as frequencies and percentages, were analyzed using chi-square tests or Fisher's exact tests. Comparisons of pre- and post-operative parameters were conducted using paired t-tests or Wilcoxon signed-rank tests.

To identify potential risk factors for adverse outcomes, univariate analyses were first performed. Variables with $P<0.05$ in the univariate analysis were subjected to collinearity diagnostics before inclusion in binary logistic regression models. Multicollinearity was assessed using the variance inflation factor (VIF), with VIF >10 indicating severe collinearity; When significant collinearity was detected, stepwise regression was employed to address it. Following collinearity adjustment, eligible variables were entered into a binary logistic regression model using stepwise selection to determine independent risk factors of adverse outcomes. All sta-

Table 1. Clinical characteristics (n=181)

Characteristics	Values
Sex [n (%)]	
Male	109 (60.2)
Female	72 (39.8)
Age [M (P_{25}-P_{75}), years]	70.00 (61.00-74.00)
Hypertension [n (%)]	141 (77.9)
Diabetes mellitus [n (%)]	94 (51.9)
Previous PCI/CABG [n (%)]	43 (23.8)
Surgical approach [n (%)]	
emoral artery	15 (8.3)
Radial artery	166 (91.7)
Left main coronary artery lesion [n (%)]	89 (49.2)
Preoperative TIMI flow [n (%)]	
0	30 (16.6)
1	3 (1.7)
2	16 (8.8)
3	132 (72.9)
IABP/ECMO implantation [n (%)]	76 (42.0)
Maximum burr diameter [M (P_{25}-P_{75}), mm]	1.50 (1.50-1.50)
Number of rotational atherectomy runs [M (P_{25}-P_{75}), n]	6 (4-7)
Total rotational atherectomy time [M (P_{25}-P_{75}), s]	124.0 (78-174)
Number of stents implanted [M (P_{25}-P_{75}), n]	2.00 (2.00-3.00)
Contrast volume used [M (P_{25}-P_{75}), mL]	160.00 (110.00-210.00)
Hospital stay duration [M (P_{25}-P_{75}), d]	9.00 (7.00-13.00)
Complications [n (%)]	11 (6.1)

PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting; TIMI, thrombolysis in myocardial infarction; IABP, intra-aortic balloon pump; ECMO, extracorporeal membrane oxygenation.

tistical test were two-tailed, and a *P*-value <0.05 was considered statistically significant.

Results

Clinical characteristics of patients

A total of 200 patients were initially enrolled, with 19 lost to follow-up, resulting in 181 cases included in the final analysis (**Table 1**). Baseline characteristics revealed a median age of 70 (61-74) years and a male predominance (60.2%, 109/181). Hypertension was present in 141 patients (77.9%) and DM in 94 (51.9%); 43 patients (23.8%) had a prior history of PCI or CABG. Procedurally, the trans-radial approach was used in 166 patients (91.7%), and left main coronary artery disease was observed in 89 (49.2%). Pre-procedural TIMI flow grade 3 was documented in 132 patients (72.9%).

RA was performed with a median maximum burr diameter of 1.50 mm (1.50-1.50), a median of 6 runs (4-7), and a total ablation time of 124 s (78-174). Drug-eluting stent implantation required a median of 2 stents (2-3), and contrast volume was 160 mL (110-210). Mechanical circulatory support with intra-aortic balloon pump (IABP) or extracorporeal membrane oxygenation (ECMO) was needed in 76 patients (42.0%). The post-procedural length of stay was 9 days (7-13), with major complications occurring in 11 patients (6.1%).

Comparison of vascular parameters before and after procedure

Post-RA MLA demonstrated significant increase from preoperative 2.31 mm^2 (2.00-2.65) to 5.80 mm^2 (4.80-6.81) (*P*<0.001; **Figure 1A**). MLD similarly improved from 1.61 mm (1.50-1.70) to 2.50 mm (2.31-2.70) (*P*<0.001; **Figure 1B**), confirming effective calcium modification.

No significant difference was observed in LV size (48.00 mm [IQR, 44.00-53.00] vs. 50.52 mm [IQR, 50.52-50.52]; P>0.05; **Figure**

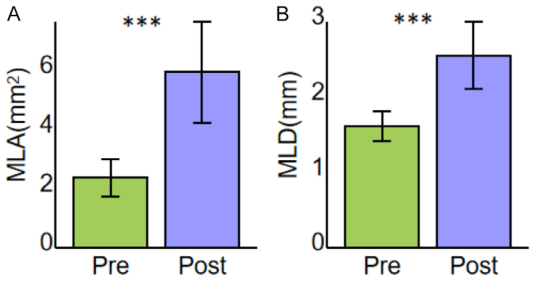

Figure 1. Changes in minimum lumen area (MLA) (A) and diameter (MLD) (B) before and after PCI procedure. Note: ***P<0.001.

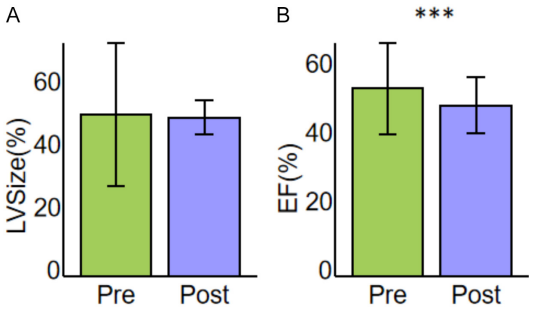

Figure 2. Changes in left ventricular size (LV Size) (A) and ejection fraction (EF%) (B) before and after PCI procedure. Note: ***P<0.001.

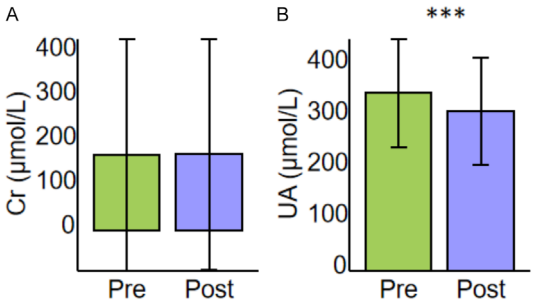

Figure 3. Changes in creatinine (Cr) (A) and uric acid (UA) (B) before and after PCI procedure. Note: ***P<0.001.

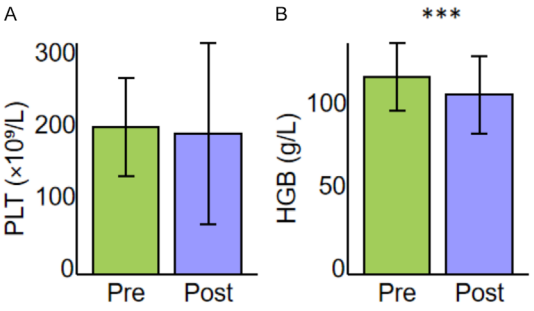

Figure 4. Changes in platelet count (PLT) (A) and hemoglobin (HGB) (B) before and after PCI procedure. Note: ***P<0.001.

2A). However, EF decreased significantly from 58.00% (IQR, 45.00-65.00) to 49.70% (IQR, 49.70-49.70; P<0.001; **Figure 2B**).

Serum Cr showed no significant difference, with preoperative levels of 74.00 μmol/L (61.00-104.00) versus postoperative levels of 78.00 μmol/L (64.00-129.00) (P>0.05; **Figure 3A**). UA decreased notably from preoperative 339.00 μmol/L (283.00-408.00) to postoperative 309.00 μmol/L (258.00-341.00) (P<0.001, **Figure 3B**).

PLT demonstrated no notable change, measuring 194.00×10⁹/L (158.00-249.00) preoperatively and 180.00×10⁹/L (141.00-221.00) postoperatively (P>0.05; **Figure 4A**). HGB declined notably, from 119.00 g/L (107.00-134.00) before the procedure to 110.00 g/L (97.00-122.00) after the procedure (P<0.001; **Figure 4B**).

Influencing factors of adverse outcomes

During follow-up, 19 patients were lost to follow-up. Among the remaining 181 patients, the following adverse events were observed: myocardial infarction in 11 cases (6.1%), repeat revascularization in 16 (8.8%), heart failure in 43 (23.8%), rehospitalization in 46 (25.4%), stroke in 1 (0.6%), BARC 2-5 bleeding in 7 (2.9%), and death in 19 (10.5%). The median time from procedure to death was 12 months (range: 1 day to 16 months).

Patients were stratified into favorable-outcome and adverse-outcome groups based on event occurrence. Univariate analyses of clinical characteristics, preoperative vascular parameters, and procedural factors are presented in **Table 2**. Significant intergroup differences (P<0.05) were identified for hypertension, DM, and preoperative serum Cr levels. Subsequent binary logistic regression analysis (**Table 3**) demonstrated that hypertension (OR=3.201, 95% CI: 1.409-7.270, P=0.005) and DM (OR=1.915, 95% CI: 1.037-3.536, P=0.038) were independent risk factors for adverse outcomes.

Predictors of adverse outcomes in patients with comorbid hypertension and DM

Among the 78 patients with both hypertension and DM, univariate analysis (**Table 4**) revealed

Table 2. Univariate analysis of adverse outcomes (n=181)

Characteristics	Favorable-outcome group (n=103)	Adverse-outcome group (n=78)	Z/χ^2	P
Sex [n (%)]			0.099	0.753
Male	61 (59.2%)	48 (61.5%)		
Female	42 (40.8%)	30 (38.5%)		
Age [M (P_{25}-P_{75}), years]	69.00 (63.00-74.00)	71.00 (59.00-75.00)	-0.636	0.717
Hypertension [n (%)]	72 (69.9%)	69 (88.5%)	8.880	0.003
Diabetes mellitus [n (%)]	46 (44.7%)	48 (61.5%)	5.065	0.024
Previous PCI/CABG [n (%)]	29 (28.2%)	14 (17.9%)	2.553	0.110
Surgical approach [n (%)]			0.699	0.403
Femoral artery	7 (6.8%)	8 (10.3%)		
Radial artery	96 (93.2%)	70 (89.7%)		
Left main coronary artery lesion [n (%)]	45 (43.7%)	44 (56.4%)	2.874	0.090
Preoperative TIMI flow [n (%)]			2.934	0.383
0	20 (19.4%)	10 (12.8%)		
1	3 (2.9%)	0 (0%)		
2	8 (7.8%)	8 (10.3%)		
3	72 (69.9%)	60 (76.9%)		
IABP/ECMO implantation [n (%)]	39 (37.9%)	37 (47.7%)	1.670	0.196
Maximum burr diameter [M (P_{25}-P_{75}), mm]	1.50 (1.50-1.50)	1.50 (1.50-1.50)	-1.009	0.313
Number of rotational atherectomy runs [M (P_{25}-P_{75}), n]	6 (4-8)	5.5 (3.8-7)	-0.808	0.419
Total rotational atherectomy time [M (P_{25}-P_{75}), s]	130 (81-178)	117 (74-163)	-1.165	0.244
Number of stents implanted [M (P_{25}-P_{75}), n]	2.00 (2.00-3.00)	3.00 (2.00-3.00)	-0.483	0.629
Contrast volume used [M (P_{25}-P_{75}), mL]	160 (120-210)	150 (110-210)	-1.144	0.253
Complications [n (%)]	3 (2.9%)	8 (10.3%)	3.006	0.083
Preoperative MLA [M (P_{25}-P_{75}), mm^2]	2.37 (2.00-2.70)	2.30 (2.00-2.51)	-1.293	0.196
Preoperative MLD [M (P_{25}-P_{75}), mm]	1.61 (1.50-1.70)	1.60 (1.50-1.70)	-1.164	0.245
Preoperative LV Size [M (P_{25}-P_{75}), mm]	49 (45-53)	47 (43.75-54.50)	-0.670	0.503
Preoperative Cr [M (P_{25}-P_{75}), μmol/L]	70 (59-91)	81 (65-141)	-2.510	0.012
Preoperative UA [M (P_{25}-P_{75}), μmol/L]	337 (283-408)	339 (277-413)	-0.448	0.654
Preoperative EF [M (P_{25}-P_{75}), %]	58 (47-65)	57 (41-66)	-0.337	0.736
Preoperative PLT [M (P_{25}-P_{75}), $\times 10^9$/L	204 (166-249)	179 (147-254)	-1.571	0.116
Preoperative HGB [M (P_{25}-P_{75}), g/L]	121 (109-134)	116 (102-136)	-1.557	0.119

MLA, minimum lumen area; MLD, minimum lumen diameter; LV Size, left ventricular size; Cr, creatinine; UA, uric acid; EF, ejection fraction; PLT, platelet count; HGB, hemoglobin.

Table 3. Multivariate analysis of adverse outcomes (n=181)

	Variables	B	SE	P	OR (95% CI)
Step1	Diabetes mellitus	0.683	0.316	0.031	1.979 (1.066-3.676)
	Hypertension	1.119	0.420	0.008	3.062 (1.343-6.979)
	Preoperative Cr	0.001	0.001	0.219	1.001 (1-1.002)
	Constant	-1.667	0.429	<0.001	0.189
Step2	Diabetes mellitus	0.650	0.313	0.038	1.915 (1.037-3.536)
	Hypertension	1.164	0.419	0.005	3.201 (1.409-7.270)
	Constant	-1.558	0.418	<0.001	0.211

notable differences between the favorable-outcome and adverse-outcome groups regarding age, left main coronary artery lesion, and maximum burr diameter (all $P<0.05$). Binary logistic regression analysis (**Table 5**) demonstrated that age (OR=1.069, 95% CI: 1.001-1.142, P=0.046), left main disease (OR=4.270, 95% CI: 1.359-13.416, $P=0.013$), and maximum

Table 4. Univariate analysis of adverse outcomes in patients with comorbid hypertension and diabetes mellitus (n=76)

Characteristic	Favorable-outcome group (n=34)	Adverse-outcome group (n=42)	Z/χ^2	P
Sex [n (%)]			0.946	0.331
Male	14 (41.2%)	22 (52.4%)		
Female	20 (58.8%)	20 (47.6%)		
Age [M (P_{25}-P_{75}), years]	69.00 (63.00-74.00)	71.00 (59.00-75.00)	-2.349	0.019
Previous PCI/CABG [n (%)]	10 (29.4%)	11 (26.2%)	0.098	0.755
Surgical approach [n (%)]			0	1.000
Femoral artery	4 (11.8%)	4 (9.5%)		
Radial artery	30 (88.2%)	38 (90.5%)		
Left main coronary artery lesion [n (%)]	9 (26.5%)	22 (52.4%)	5.223	0.022
Preoperative TIMI flow [n (%)]			3.377	0.311
0	8 (23.5%)	7 (16.7%)		
1	1 (2.9%)	0 (0%)		
2	2 (5.9%)	7 (16.7%)		
3	13 (67.6%)	28 (66.7%)		
IABP/ECMO implantation [n (%)]	11 (32.4%)	20 (47.6%)	1.813	0.178
Maximum burr diameter [M (P_{25}-P_{75}), mm]	1.50 (1.25-1.50)	1.50 (1.50-1.50)	-2.351	0.019
Number of rotational atherectomy runs [(P_{25}-P_{75}), n]	5 (4-7.3)	6 (3-7)	-0.032	0.975
Total rotational atherectomy time [(P_{25}-P_{75}), s]	139.5 (107.5-179.3)	128 (63.3-166.5)	-1.238	0.216
Number of stents implanted [M (P_{25}-P_{75}), n]	2.00 (2.00-3.00)	2.50 (2.00-3.00)	-0.060	0.952
Contrast volume used [M (P_{25}-P_{75}), mL]	160.00 (120.00-210.00)	130.00 (110.00-210.00)	-1.445	0.148
Complications [n (%)]	1 (2.9%)	5 (11.9%)	1.026	0.311
Preoperative MLA [M (P_{25}-P_{75}), mm^2]	2.37 (2.00-2.70)	2.27 (1.97-2.40)	-1.600	0.110
Preoperative MLD [M (P_{25}-P_{75}), mm]	1.62 (1.50-1.71)	1.58 (1.50-1.63)	-1.674	0.094
Preoperative LV Size [M (P_{25}-P_{75}), mm]	46.50 (42.00-52.00)	47.00 (44.00-51.47)	-0.345	0.730
Preoperative Cr [M (P_{25}-P_{75}), μmol/L]	73.50 (56.00-116.00)	80.00 (57.51-170.64)	-0.794	0.427
Preoperative UA [M (P_{25}-P_{75}), μmol/L]	322.50 (283.00-412.00)	337.45 (261.00-394.00)	-0.340	0.734
Preoperative EF [M (P_{25}-P_{75}), %]	58.00 (49.00-64.00)	57.00 (44.00-65.00)	-0.679	0.497
Preoperative PLT [M (P_{25}-P_{75}), $\times 10^9$/L]	205.50 (158.00-248.00)	184.50 (148.00-256.00)	-0.679	0.497
Preoperative HGB [M (P_{25}-P_{75}), g/L]	118.50 (106.00-132.00)	115.50 (102.00-130.00)	-0.909	0.363

Table 5. Multivariate analysis of adverse outcomes in patients with concomitant hypertension and diabetes (n=76)

Variables	B	SE	Wald	P	OR (95% CI)
Age	0.067	0.034	3.984	0.046	1.069 (1.001-1.142)
Left main disease	1.452	0.584	6.175	0.013	4.270 (1.359-13.416)
Maximum burr diameter	5.678	2.047	7.692	0.006	292.231 (5.287-16151.924)
Constant	13.451	4.068	10.936	0.001	0.000

burr diameter (OR=292.231, 95% CI: 5.287-16151.924, *P*=0.006) were significant predictors of adverse outcomes. Subgroup analysis of complications showed that 2 of 3 no-reflow events occurred in cases where burr diameter was ≥1.5 mm, suggesting a potential association between larger burr size and endothelial injury, warranting further validation. These findings indicate that, in patients with hypertension-DM comorbidity, age, left main coronary artery involvement, and burr diameter may cumulatively influence prognosis.

Discussion

With the advancements in imaging technologies such as IVUS and optical coherence tomography, the application of RA in complex

coronary calcified lesions has been increasingly explored [10, 11]. RA combined with IVUS-guided stent implantation has been shown to substantially reduce the incidence of MACE at 1-year follow-up [12]. Compared with these studies, our research - featuring an extended follow-up period (median, 12 months), further confirms the efficacy of RA in enlarging the lumen area and reducing MACE, particularly among patients with comorbid hypertension and DM.

RA has been shown to improve the success rate of interventions for calcified coronary lesions [10, 13]. In line with prior reports, our study demonstrated significant post-procedural improvements in MLA and MLD. Kobayashi *et al.* [14] reported similar vascular parameter improvements, with MLA increasing from 1.72 mm^2 to 2.61 mm^2 and MLD from 1.12 mm to 2.6 mm following RA. However, the clinical benefits of RA are not universal. Watanabe *et al.* [15] found no significant clinical advantage of RA over non-RA strategies for IVUS-detected calcified nodule lesions. In the acute phase, IVUS revealed no difference in lumen area gain between the two groups, suggesting that RA may be ineffective for the calcified nodule subtype - a key distinction from the population with complex heterogeneous lesions included in this study. Moreover, for calcified nodules identified by IVUS, routine application of RA did not reduce ischemia-driven target vessel revascularization rates. This discrepancy indicates that the efficacy of RA may be lesion-subtype dependent. RA can substantially improve mechanical parameters (MLA/MLD) in severe circumferential calcification through differential ablation. However, its effect on nodular calcification is limited, as nodules feature deeper calcium deposits and elastic recoil, educing ablation efficiency [16, 17]. Therefore, precise lesion screening via intravascular imaging is essential to optimize the efficacy of RA.

In prognostic research, while numerous previous studies have extensively investigated the impact of RA on calcified lesions, few have specifically focused on patients with the complex comorbidity of both hypertension and DM. In our analysis, the coexistence of hypertension and DM emerged as an independent risk factor for adverse outcomes. Several mechanisms may explain this association. Chronic hyperglycemia in DM accelerates vascular calcification by inducing osteogenic differentiation of vascular smooth muscle cells (VSMCs) [18, 19]. Hypertension, on the other hand, synergistically exacerbates the pathological changes through endothelial dysfunction and arterial remodeling [19]. Their combined effect may increase plaque stiffness and impair optimal stent expansion [18], rendering blood vessels more prone to restenosis after RA. Similarly, Gao *et al.* [20] confirmed that hypertension is an independent predictor of RA-related complications, which is consistent with our findings.

Of particular note, in the hypertension-DM subgroup, age, left main coronary artery lesion, and maximum burr diameter were significantly associated with adverse outcomes. Age, a well-established risk factor for various cardiovascular diseases, contributes to progressive vascular stiffening and calcification, thereby increasing both intraprocedural risk during RA and long-term adverse events. Left main coronary artery disease, characterized by larger vessel diameters and critical myocardial territories, inherently increases procedural complexity and risk [6, 21]. RA procedures for such lesions may precipitate bradyarrhythmias and other conduction disturbances [6], necessitating exceptional procedural caution given the potentially catastrophic consequences of complications. The association between larger burr diameters and unfavorable outcomes aligns with existing literature: the burr-to-artery ratio is a key determinant of both post-procedural luminal dimensions and complication risk. Oversized burrs may produce vascular endothelial injury, coronary artery perforation, stent delivery failure, or restenosis [22, 23], as the mechanical stress may exceed vascular tolerance [24]. Therefore, comprehensive preoperative assessment of vessel anatomy is crucial for guiding the selection of RA indications and reducing the risk of MACE. The PREPARE-CALC trial by Abdel-Wahab *et al.* [25] specifically identified burr-to-artery ratios >0.6 as major predictors of procedural complications, including dissections and perforations. In this study, the rotational burr diameter of 1.5 mm corresponded to a mean burr-to-preprocedural MLD ratio of 0.93, indicating near-equivalent dimensions of the burr and baseline MLD. Such relatively large burrs may elevate endothelial injury risks and consequently worsen clinical outcomes [25, 26]. Current IVUS-guided protocols recommend ini-

tiating with smaller burrs and increasing size only as needed to achieve procedural targets [27]. The primary goal of RA should focus on modifying lesion characteristics to convert refractory calcified segments/nodules into expandable lesions rather than overemphasizing intravascular debulking. This strategy may potentially reduce complications and optimize patient prognosis. Collectively, while contemporary RA research predominantly emphasizes volumetric plaque reduction, our findings suggest that procedural endpoints should shift toward achieving lesion modifiability and expansibility to improve safety and outcomes. In addition, the confidence interval of this indicator is extremely wide in this study, which mainly reflects the scarcity of corresponding clinical events in this subgroup. We tend to interpret this result from a clinical perspective: a larger burr diameter is likely to serve as a proxy indicator for 'extremely severe calcified lesions' rather than an independent risk factor. In clinical practice, larger diameter burrs are only chosen for the hardest and most complex calcified lesions. Therefore, this significant statistical association is more likely to reveal the high risk inherent in such extremely complex lesions, suggesting that for such patients, even under high success rate elective surgery, their long-term prognosis is still not optimistic, and perioperative management and long-term follow-up need to be strengthened.

While providing valuable insights into the application of RA in PCI, this study has several limitations. Research indicates that bailout RA demonstrates superior outcomes compared to planned RA, suggesting its safe utilization as a rescue strategy when conventional methods fail to effectively treat lesions [28]. However, the lack of in-depth analysis regarding decision-making factors distinguishing planned from bailout RA restricts our comprehensive understanding of RA's efficacy as a salvage approach. Second, as a single-center study with a limited sample size, the generalizability of findings may be constrained, particularly the inability to accurately assess RA's relative advantages across different lesion types due to the absence of direct comparative analysis between RA and non-RA groups. Furthermore, although the study identified several prognostic factors in patients with comorbid hypertension and DM (e.g., advanced age, left main coronary artery involvement, and maximum burr diameter), the relatively small subgroup sample sizes may have compromised the robustness and statistical power of these findings. In addition, the present study did not conduct in-depth analysis of the potential impact of different burr diameters on outcomes, and the complication assessment lacked granularity. Especially in patients with hypertension and diabetes who received maximum burr diameter treatment, the number of events was small, leading to unstable OR estimates of some risk factors and a wide confidence interval. Future research should include large-scale, multicenter randomized controlled trials with extended follow-up periods to thoroughly investigate patient subgroups and technical factors, thereby enabling more comprehensive evaluation of RA's role and long-term efficacy in treating coronary calcified lesions.

Disclosure of conflict of interest

None.

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