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The Use of Rotational Atherectomy in the Treatment of Coronary Artery Disease – A Review of Efficacy, Safety, and Clinical Indications

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Abstract
Coronary artery disease is a leading cause of death worldwide, and percutaneous coronary intervention (PCI) is a common treatment. The presence of calcified plaques often makes the procedure difficult, as they limit vessel expansion and proper stent placement. To improve outcomes, several plaque modification techniques have been developed. One of the most widely used is rotational atherectomy (RA). This method employs a diamond-coated burr that rotates at high speed, selectively removing hard, calcified tissue while sparing the softer vessel wall. RA is mainly used as a supportive technique to prepare the lesion and enable effective balloon angioplasty and stent implantation.

Aim of the study: The purpose of this review is to present the current state of knowledge regarding rotational atherectomy, including its mechanism of action, clinical indications, efficacy, and potential complications. Additionally, the article reviews the role of this technique in contemporary guidelines and compares it with other available methods of calcification modification.

Material and methods: A comprehensive literature review on rotational atherectomy was conducted, covering publications from 2000 to 2024. Databases such as PubMed, Scopus, and Web of Science were searched using keywords including “rotational atherectomy,” “coronary artery disease,” “calcified lesions,” “PCI,” and “atherosclerosis treatment.” Clinical trials, meta-analyses, systematic reviews, and current cardiology society guidelines were included in the analysis.

Conclusions: Rotational atherectomy represents an effective and safe adjunct to percutaneous treatment of calcified coronary lesions. Despite emerging competing technologies, its long-standing clinical experience and proven efficacy secure its continued role in the management of advanced coronary artery disease. Further research, especially comparative studies among plaque modification techniques, is needed to optimize therapeutic strategies and improve patient outcomes.

Keywords: rotational atherectomy, percutaneous coronary intervention, coronary artery disease

Glossary of Abbreviations: RA - rotational atherectomy, OA - orbital atherectomy, ELCA - excimer laser coronary atherectomy, OCT - optical coherence tomography, CAD - coronary artery disease, PCI - percutaneous coronary intervention, IVUS - intravascular ultrasound, CTO - chronic total occlusion, MACE - major adverse cardiac events.

Introduction

Coronary artery disease (CAD) is one of the main causes of illness and death worldwide. It results from atherosclerotic plaque narrowing or blocking the coronary arteries, which limits blood flow to the heart and can cause angina, myocardial infarction, or heart failure. Major risk factors include high blood pressure, high cholesterol, diabetes, smoking, and genetic predisposition (Libby & Theroux, 2005). The standard treatment is percutaneous coronary intervention (PCI), usually involving balloon angioplasty and stent placement. In recent years, atherectomy has become more important, especially in heavily calcified lesions that hinder vessel expansion and stent delivery. By mechanically modifying or removing calcifications, atherectomy improves procedural success and long-term vessel patency (Sakakura et al., 2021).

Background and mechanism of action

Rotational atherectomy is the oldest and best-studied method for treating calcified coronary lesions. It was first described in 1987 by David Auth, who showed its effectiveness in reducing atherosclerotic plaque in experimental models. With an aging population and the growing burden of risk factors such as hypertension, sedentary lifestyle, and obesity, coronary lesions have become increasingly complex in patients undergoing percutaneous coronary intervention (PCI). As a result, the use of rotational atherectomy has expanded and is currently performed in about 1–3% of PCI procedures in Europe and the United States (Barbato et al., 2015).

Rotational atherectomy works by using a small, diamond-coated burr (usually 1.25-1.5 mm) that rotates at very high speeds of 140,000-180,000 revolutions per minute. This allows it to selectively ablate hard, calcified plaques while preserving the more elastic, healthy parts of the vessel wall (Barbato et al. 2017; Gupta et al. 2019). The burr is driven by an air-powered turbine and advanced along a special guidewire, with either radial or femoral artery access depending on the burr size and operator preference. During ablation, the calcified material is broken down into very small particles (<5 μm), which are then washed away through the bloodstream (Dobrzycki et al. 2018). A special flushing solution is continuously delivered through the system. This cooling mixture, containing verapamil, nitrates, and heparin in saline, protects the turbine, reduces spasm, and helps clear debris from the coronary circulation (Barbato et al. 2015).

Application

The main indication for rotational atherectomy is the treatment of heavily calcified coronary lesions that cannot be adequately dilated with balloons or crossed with standard catheters, which prevents proper stent implantation (Dobrzycki et al. 2018; Task Force et al. 2014). In contrast, its use in mildly or moderately calcified lesions shows little clinical benefit and may even raise complication risk (Tomey et al. 2014).

To guide clinical practice, Tomey et al. proposed an algorithm in which RA is reserved for severely calcified, de novo lesions in patients undergoing PCI. In cases of moderate calcification or uncertain angiographic findings, intravascular imaging (IVUS or OCT) is recommended to better assess calcium thickness and distribution and to select the optimal burr size (Tomey et al. 2014).

RA is also useful in complex interventions, such as ostial stenoses, bifurcation lesions, and chronic total occlusions (CTOs). Evidence supports its safety and efficacy in these scenarios, offering interventional cardiologists an additional option when dealing with challenging coronary disease (Abdelaziz et al. 2024; Allali et al. 2020; Tsai et al. 2022).

Table 1 Indications for use of rotational atherectomy (Dobrzycki et al. 2018)

Classic indications	Calcified or fibrous strictures that cannot be effectively balloon dilated Lesions that cannot be ballooned
Additional indications	Significant calcifications visible on angiography, intravascular ultrasound (IVUS), and/or optical coherence tomography (OCT), particularly when there is a risk of balloon angioplasty failure or unsuccessful stent deployment. Heavily calcified lesions located at bifurcation sites, including the distal left main coronary artery. Revascularization in chronic total occlusion (CTO) following successful lesion crossing.

Table 2 Contraindications for use of rotational atherectomy (Dobrzycki et al. 2018)

Absolute contraindications	Relative contraindications
Lesions in saphenous vein grafts Thrombus Angiographic signs of vessel dissection	Severe left ventricular dysfunction (ejection fraction < 30%) Advanced three-vessel coronary artery disease Significant stenosis of the left main coronary artery without adequate collateral circulation Lesions longer than 25 mm Lesions with angulation > 45° in tortuous segments

Disadvantages and risks of complications

Although rotational atherectomy plays an important role in managing calcified coronary lesions, it is associated with notable limitations and risks. The most frequent complications are vessel perforation (~1.5%) and the slow-flow/no-reflow phenomenon (1.2-2.6%) (Tomey et al. 2014; Kawamoto et al. 2016; Protty et al. 2021). A rare but severe problem is burr entrapment, which can sometimes require surgery. Because the procedure is technically demanding, inadequate technique may increase complication rates (Morita et al. 2023). RA is also linked to longer procedure times and greater contrast use, which is especially risky in patients with renal dysfunction. Predictors of contrast-induced kidney injury include high SYNTAX score, reduced left ventricular ejection fraction (<35%), and low baseline GFR (<45 ml/min). Intra-procedural risks include a high contrast-to-GFR ratio and periprocedural myocardial infarction (Mankerious et al. 2023).

Important contraindications are thrombus-containing lesions, saphenous vein graft disease, and angiographic signs of vessel dissection (Dobrzycki et al. 2018). Furthermore, the high cost of devices and the need for specialized training can limit access in many hospitals (Gupta et al. 2019).

Results

Technical and procedural efficacy

Several large registries and clinical trials have investigated the outcomes of rotational atherectomy (RA) followed by drug-eluting stent (DES) implantation.

The ROTATE registry (985 patients, 1176 lesions) reported high procedural efficacy, with optimal stent expansion in 90.6% and TIMI 3 flow in 99.1%. More than 90% of procedures were free of complications. The most frequent adverse event was vessel dissection (7%), while slow-flow/no-reflow (1.1%) and perforation (1.0%) were rare. In-hospital MACE occurred mainly due to periprocedural MI (7.3%), and overall mortality was 0.6% (Kawamoto et al. 2016).

In a real-world study, Cuenza et al. (2017) analyzed 81 patients undergoing RA before DES implantation. Angiographic success was achieved in 92.6%, and clinical success (angiographic success without 30-day major events) in 87.6%. Complications were infrequent (3.7%, including dissection, no-reflow, and burr entrapment). In-hospital MACE occurred in 7.4% (Cuenza et al. 2017).

The randomized ROTAXUS trial (240 patients) compared RA + DES with DES alone. Angiographic success was similar in both groups (96.7%), but procedural success was higher with RA (92.5% vs. 83.3%). In the conventional stenting group, stent delivery failure necessitated conversion to RA in 15 cases. RA was discontinued in 5 patients, mostly due to protocol deviations (Abdel-Wahab et al. 2013).

The Korea-ROCK registry (540 patients, 583 lesions) confirmed high technical (96.4%) and procedural (86.1%) success. In-hospital MACE occurred in 9.7%, predominantly periprocedural MI (7.9%). Vessel dissection (6.0%) and perforation (1.9%) were the most notable complications, with 11 in-hospital deaths (Lee et al. 2021).

Finally, the J2T ROTA registry (1090 patients with ≥70% stenosis) showed technical success in 96.2%. In-hospital complications included death (3.0%), MI (2.1%), tamponade (0.9%), major bleeding (1.6%), and the need for intra-aortic balloon pump support (2.7%). Emergency surgery was required in 0.6% of patients (Okai et al. 2018).

Clinical outcomes and long-term follow-up

Long-term data from clinical studies and registries confirm that rotational atherectomy (RA) provides acceptable safety and efficacy, though outcomes are strongly influenced by baseline patient risk.

The ROTATE registry reported in-hospital MACE in 8.3%, rising to 16.0% at one year and 24.9% at two years. Target vessel revascularization (TVR) was the most frequent adverse event (13.5% at one year; 19.8% at two years). All-cause mortality reached 5.0% and 9.5% at one and two years, respectively. Dialysis emerged as an independent predictor of adverse outcomes (Kawamoto et al. 2016).

In the Cuenza cohort, median follow-up was 12.2 months, with cumulative MACE of 13.5% and a 75% event-free survival at 34 months. Predictors of MACE included previous acute coronary syndrome, impaired left ventricular function, higher SYNTAX score, and elevated inflammatory indices (Cuenza et al. 2017).

A 2024 meta-analysis of 5,494 patients with chronic total occlusions showed no significant differences between RA + DES and standard angioplasty + DES regarding MACE (15.9% vs. 15.5%), mortality, myocardial infarction, or repeat revascularization (Abdelaziz et al. 2024).

The ROTAXUS trial follow-up (9 months) demonstrated comparable outcomes between RA and standard PCI, with similar mortality (~5%), restenosis (~11%), TVR (~12%), and MACE (24.2% vs. 28.3%). Despite initially greater lumen gain, late stent narrowing was more pronounced in the RA group (Abdel-Wahab et al. 2013).

In the Korea-ROCK registry, median follow-up of 1.5 years revealed 8.4% all-cause mortality and 16.0% TVF. Predictors of mortality included ACS at presentation, older age, chronic kidney disease, prior stroke, and intravascular imaging use (Lee et al. 2021).

The long-term J2T ROTA registry (median 3.8 years) documented high event rates, with all-cause mortality at 24.2% and MACE at 45.5%. TVR was required in 21.4%, and cardiac death occurred in 10.9%. The adverse outcomes reflected both the prolonged observation period and the high-risk population (mean age 70 years, diabetes 60%, dialysis 27.7%). Independent predictors of poor outcomes included advanced age, diabetes, chronic kidney disease, and reduced left ventricular ejection fraction (Okai et al. 2018).

Discussion

Rotational atherectomy (RA) remains one of the key techniques for modifying heavily calcified atherosclerotic plaques in the context of percutaneous coronary interventions (PCI). Numerous studies presented in this review confirm its high procedural and clinical efficacy in the treatment of lesions resistant to conventional angioplasty methods, particularly in high-risk patient populations.

The technical success of RA, defined as achieving TIMI grade 3 flow and less than 30% residual stenosis, was consistently high across all analyzed studies - ranging from 90.6% in the ROTATE registry, through 92.6% in the analysis by Cuenza et al., to 96.2% in the J2T ROTA registry. These favorable outcomes underscore the role of RA as an effective technique for vessel preparation prior to implantation of drug-eluting stents (DES).

At the same time, attention must be paid to the safety profile of this procedure. Although the majority of interventions were performed without significant intraprocedural complications (ROTATE registry: >90% without complications), the most frequently reported adverse event was vessel dissection (up to 7%) and slow- or no-reflow phenomenon (1–2%). Rarely, vessel perforation (1.0–1.9%) or entrapment of the rotational burr requiring surgical intervention occurred. In-hospital mortality rates ranged from 0.6% (ROTATE) to 3.0% (J2T ROTA), which, considering the complexity of lesions and patient risk profiles, can be regarded as acceptable.

Long-term clinical outcome analyses further support the appropriateness of RA in carefully selected patient populations. Rates of major adverse cardiovascular events (MACE) varied between 13.5% (Cuenza et al.) and 24.9% (ROTATE) over two years. In the J2T ROTA study, with nearly four years of follow-up, MACE occurred in 45.5% of patients, which may be attributed to the high-risk profile and advanced age of this cohort. Key predictors of adverse events after RA included advanced age, diabetes mellitus, chronic kidney disease, reduced left ventricular ejection fraction, and prior episodes of acute coronary syndromes.

Data from a meta-analysis by Abdelaziz et al. (2024), including over 5,400 patients, indicate that RA does not increase the incidence of MACE, mortality, myocardial infarction, or the need for repeat revascularization compared to conventional angioplasty in chronic total occlusions (CTO), thereby further strengthening the position of this technique in the contemporary treatment strategy for complex coronary lesions.

Conclusions

1. Rotational atherectomy is an effective and safe adjunctive method for percutaneous treatment of heavily calcified coronary lesions, particularly in anatomically challenging cases such as chronic total occlusions (CTO), bifurcations, and ostial stenoses.
2. The technical and procedural success rates of RA are high, exceeding 90% across all major clinical studies, which translates into improved stent deployment efficacy and a reduced risk of suboptimal stent expansion.

3. The safety profile of RA is acceptable, although it requires operator expertise and appropriate patient selection. The most common complications include vessel dissection, perforation, and slow-flow phenomenon.
4. Long-term clinical outcomes are competitive compared to conventional angioplasty, with current data showing no increase in the risk of major adverse cardiovascular events (MACE), mortality, or restenosis following RA.
5. Proper patient selection and the use of intravascular imaging modalities (IVUS/OCT) should be integral to the decision-making process regarding RA, aiming to minimize complication risks and optimize clinical results.
6. Further comparative studies with extended follow-up are needed, including assessments of RA against other calcium modification techniques (such as orbital atherectomy and ELCA), to develop individualized therapeutic strategies for patients with calcified coronary lesions.

Disclosure:

Author's contribution:

Author's contribution: Conceptualization: Piotr Jóźwiak, Maria Wysieńska; Methodology: Adam Rybak, Weronika Biaduń, Kinga Rogowska; Software: Adam Rybak, Aleksandra Romanowska, Paweł Arkadiusz Malmur, Maria Wysieńska; Check: Piotr Jóźwiak, Weronika Biaduń; Formal analysis: Adam Rybak, Kinga Rogowska; Investigation: Maria Wysieńska, Paweł Arkadiusz Malmur, Aleksandra Romanowska, Piotr Jóźwiak; Resources: Maria Wysieńska; Data curation: Piotr Jóźwiak, Maria Wysieńska; Writing - rough preparation: Piotr Jóźwiak, Maria Wysieńska, Adam Rybak; Writing - review and editing: Kinga Rogowska, Weronika Biaduń, Aleksandra Romanowska; Visualization: Paweł Arkadiusz Malmur, Kinga Rogowska; Supervision: Maria Wysieńska; Project administration: Adam Rybak, Piotr Jóźwiak, Aleksandra Romanowska, Weronika Biaduń.

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