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CASE REPORT

Intravascular Laser Lithotripsy - A Novel Modality for the Management of Severely Calcified Coronary Lesions: A Literature Review and Clinical Case Report

Kh.G. Fozilov[1], B.A. Yuldashov[2], B.R. Atamuratov[3], A.A. Yuldashov[4*], D.D. Sokhibov[5]

[1]*Director, Republican Specialized Scientific and Practical Medical Center of Cardiology, Tashkent 100052, Uzbekistan.*
[2]*Head, Department of Interventional Cardiology, Republican Specialized Scientific and Practical Medical Center of Cardiology, Tashkent 100052, Uzbekistan.*
[3]*Interventional Cardiologist, Republican Specialized Scientific and Practical Medical Center of Cardiology, Tashkent 100052, Uzbekistan.*
[4]*Interventional Cardiologist and PhD Researcher, Department of Interventional Cardiology, Republican Specialized Scientific and Practical Medical Center of Cardiology, Tashkent 100052, Uzbekistan.*
[5]*Interventional Cardiologist and PhD Researcher, Department of Interventional Cardiology, Republican Specialized Scientific and Practical Medical Center of Cardiology, Tashkent 100052, Uzbekistan.*

Corresponding Author: *A.A. Yuldashov, Email: doctor.yuldashov@icloud.com*

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Abstract

Objective: To present a clinical case of successful application of intravascular laser lithotripsy (IVL) in a patient with circular calcification of the left anterior descending artery (LAD).

Materials and methods: A case of a 53-year-old man with severe coronary calcification who underwent percutaneous coronary intervention using the FastWave IVL system is described.

Results: In a patient with severe circumferential calcification of the left anterior descending artery, intravascular laser lithotripsy (IVL) resulted in significant fragmentation of calcium deposits, as confirmed by intravascular ultrasound. The procedure resulted in effective artery dilation and successful implantation of three stents with adequate expansion (95–98%) and tight adherence to the vessel wall. There were no periprocedural complications. The total procedure duration was 120 minutes, with a radiation dose of 4658 Gy cm^2 and a contrast agent volume of 250 ml. Morphological changes recorded by IVUS before and after the procedure indicate a significant increase in the minimum lumen area (up to 10.79 mm^2 in the proximal segment) and a decrease in the degree of stenosis to <20%.

Conclusions: This clinical case demonstrates the high efficacy and safety of intravascular laser lithotripsy in the treatment of severe circumferential coronary calcification. IVL allowed for adequate modification of the calcified plaque and provided optimal conditions for stenting without complications. This method can be considered a preferred alternative to rotational atherectomy in patients with complex anatomical lesions and a high risk of complications. These data highlight the potential of IVL as a new tool in the interventional cardiologist's arsenal for improving clinical outcomes in complex forms of coronary artery disease.

Annotation: Coronary calcification is a significant challenge in interventional cardiology, complicating stent delivery and deployment and increasing the risk of complications during percutaneous coronary interventions (PCI). Traditional methods of calcified plaque modification, such as rotational atherectomy and cutting balloons, have limitations, including the risk of distal embolization and incomplete stent deployment [13]. Intravascular laser lithotripsy (IVL) is an innovative treatment for calcified lesions. The method uses shock waves to selectively destroy calcium deposits with minimal soft tissue damage [8]. The procedure ensured effective calcium destruction, optimal stent deployment, and the absence of periprocedural complications [5]. The results highlight the clinical significance of IVL as a safe and effective method capable of improving PCI outcomes in patients with calcified lesions [1]. This experience demonstrates the potential of IVL to change the standard of care for complex coronary lesions, providing cardiologists with a new tool to improve procedural success and patient prognosis.

Keywords: Coronary calcification, Laser intravascular lithotripsy, Percutaneous coronary intervention, Stenting, Plaque modification, Clinical case, Anterior descending artery.

Introduction

Pathophysiology of coronary calcification

Coronary artery calcification is characterized by the deposition of calcium hydroxyapatite crystals in the intimal and medial layers of the coronary artery walls, which is part of the atherosclerotic process [4]. This process is caused by inflammation, lipid accumulation, and apoptosis of vascular smooth muscle cells, leading to the formation of hard, inelastic plaques [8]. Risk factors include older age, diabetes mellitus, chronic kidney disease, and dyslipidemia, which enhance vascular calcification [13]. Calcified plaques reduce arterial compliance, making interventional procedures more difficult [5].

Clinical consequences

Severe coronary calcification significantly complicates percutaneous coronary interventions (PCI), increasing the risk of stent failure, incomplete deployment, and malapposition [12]. These factors increase the likelihood of restenosis, stent thrombosis, and other adverse cardiovascular events [4]. Furthermore, calcification increases the duration of procedures and the need for additional instrumentation, which increases the risk of complications [13]. Effective modification of calcified plaques is critical for achieving optimal angiographic and clinical outcomes [1]. Therefore, the development of new treatments for calcified lesions remains a priority.

Relevance of the study

The development of new treatment methods for calcified lesions remains a priority in interventional cardiology due to the high prevalence of coronary calcification and its impact on patient prognosis [4]. Intravascular laser lithotripsy is a promising approach that can overcome the limitations of traditional methods, providing safe and effective calcium destruction [8]. The clinical significance of the problem is determined by the fact that the presence of calcified atherosclerotic lesions with a calcium index >400 units according to the Agatston scale is associated with a 10-year cardiovascular mortality rate of up to 33.8% [10]. The present study aims to demonstrate the clinical efficacy of IVL using a unique clinical case as an example and to analyze current literature data.

Literature review

Modern methods for the modification of calcified plaques

Treatment of severe coronary calcification requires specialized techniques for plaque preparation prior to stenting. Currently, three main approaches are used: intravascular lithotripsy, rotational atherectomy, and cutting balloons [4].

Intravascular lithotripsy

Intravascular lithotripsy (IVL) uses acoustic shock waves to selectively destroy calcium deposits. The mechanism of action of VL is based on the use of electrohydraulic emitters to create localized acoustic pressure waves (~50 atm, pulse duration ~5 microseconds), which selectively destroy calcified deposits while maintaining the integrity of soft tissues [9]. In the case of laser lithotripsy, shock waves are generated by a laser (2 J, 5 Hz) through the collapse of cavitation bubbles in a saline solution, reaching pressures of up to 200 atm. The method effectively affects superficial and deep calcium, creating microcracks (width 0.32 ± 0.18 mm, depth 0.47 ± 0.31 mm), which increases arterial compliance by 2.3 ± 0.6 atm /ml [8]. The Disrupt CAD III study showed that IVL provides a 92.4% success rate with minimal complication rates (MACE 7.8% at 30 days) [5]. The modern Shockwave system Coronary IVL includes C2 and C2+ generation catheters with balloon diameters from 2.5 to 4.0 mm, operating under an inflation pressure of 4 atm with the ability to deliver up to 80 pulses per catheter. Advantages of IVL include minimal risk of distal embolization, no need for special guidewires, and the ability to use in complex anatomical conditions such as bifurcations and ostial lesions [13]. The procedural success of IVL is 92.4–97% according to large clinical trials DISRUPT CAD I–IV [3]. Limitations include the high cost of the device and the need for further research on long-term outcomes [1].

Rotational atherectomy

Rotational atherectomy (RA) is based on the mechanical ablation of calcified plaques using a high-speed rotating bur coated with diamond particles [4]. The method is effective in concentric fibrocalcification, ensuring calcium removal and facilitating stent delivery [13].

The main indications for RA are severe superficial calcification, obstructive lesions, ostial locations, and small vessel lesions. However, the use of RA is associated with an increased risk of complications, including the slow-flow / no-reflow phenomenon (up to 15% of cases), distal embolization, and the need for specialized operator training [7]. However, RA is associated with a risk of distal embolization, slow blood flow, and bradycardia, sometimes requiring temporary pacing [5]. In addition, the method requires highly skilled operators and specialized equipment, which limits its availability [12].

Cutting balloons

Cutting balloons create controlled incisions in calcified plaque using microblades or wire elements located on the balloon surface [4]. According to a 2023 meta-analysis, cutting balloons are superior to scoring balloons in patency in calcified lesions (90.8% vs. 79.5%) with a comparable perforation rate (0.9% and less than 1%) [14]. Advantages include the relative simplicity of the technique, cost-effectiveness, and reduced need for high-pressure dilation [13]. However, the effectiveness of the method is limited in deep or circumferential calcification, which may result in insufficient arterial lumen growth [5]. In addition, there is a risk of vessel dissection when using cutting balloons.

Comparative analysis of methods

Table 1 presents three methods for modifying calcified lesions: intravascular lithotripsy (IVL), rotational atherectomy (RA), and cutting balloons. IVL demonstrates the highest clinical success rate—92.4% (according to the Disrupt CAD III study), primarily due to selective calcium destruction with minimal risk of distal embolization. The main limitations of this method remain its high cost and limited data on long-term efficacy.

Rotational atherectomy, with a clinical efficacy rate of 80–90%, has demonstrated high effectiveness for concentric calcification, but is associated with an increased risk of complications (slow flow, bradycardia) and requires specialized training. Cutting balloons have a success rate of 60–80%, are technically simple and affordable, but are of little use for deep and circumferential calcification.

Comparative Effectiveness of Treatment Methods

The results of the large randomized ROLLER COASTR-EPIC22 trial demonstrated non - inferiority of IVL compared to rotational atherectomy in the primary endpoint of minimal stent area (5.4 ± 1.8 mm^2 and 5.5 ± 2.1 mm^2, $p < 0.001$ for " non- inferiority") with a significantly better safety profile [2]. The 30-day MACE rate was 1.8% in the VS L group versus 5.3% in the RA group (p = 0.12).

Michigan BMC2 real-world clinical practice registry showed a progressive increase in the use of IVL from 0.04% in January 2021 to 4.28% in June 2022, with IVL surpassing rotational atherectomy in terms of frequency of use by February 2022 [6]. In-hospital MACE was 2.57% for VSL versus 4.10% for atherectomy, with comparable procedural success (89.4% vs. 89.1%, p=0.88).

Sagris meta-analysis et al., which included 38 studies with 2977 patients, confirmed the high efficacy of IVL with a clinical success of 93% (95% CI: 91%-95%) and procedural success of 97% (95% CI (confidence interval): 95%-98%) [11]. The incidence of hospital MACE was 8% (95% CI: 6%-11%) with a minimum mortality of 2% (95% CI: 1%-3%).

IVL demonstrates advantages in safety and versatility, especially in complex lesions such as bifurcations and osteal stenoses [8]. Rotational atherectomy remains preferred for concentric calcifications but requires high skill [12]. Cutting balloons are suitable for simple lesions but their efficacy is lower in severe calcifications [13].

Prospects and Limitations

Clinical trials such as TECTONIC (2025) continue to investigate L-IVL to confirm its role in improving coronary outcomes [1]. However, the high cost of the device and the need for long-term data remain limitations [5]. Future research should focus on cost optimization and the development of protocols for integrating L-IVL into clinical practice [8].

Clinical Case

Complaints and anamnesis

A 53-year-old patient, a smoker with a family history of cardiovascular disease, was hospitalized with complaints of chest pain occurring during physical activity (walking 500-600 meters). His medical history included an acute myocardial infarction of the inferior wall of the left ventricle in 2024, followed by stenting of the right coronary artery (RCA) in 2025.

On admission, he experienced chest pain during physical exertion with a limitation of 500–600 meters, corresponding to functional class II angina. Vital signs included blood pressure of 140/85 mmHg and heart rate of 85 bpm, which corresponds to compensated hemodynamic status.

Coronary angiography

Invasive coronary angiography revealed critical stenosis (up to 85%) in the proximal and mid-LAD segments and severe calcification. A previously implanted stent in the RCA is patent, with no signs of restenosis.

The Fig. 1 show angiographic projections of the left and right coronary arteries. Projection A shows the right coronary artery (RCA) with preserved patency of the previously implanted stent, without signs of restenosis. Projections B–D depict the left coronary artery in caudal and cranial angulation. Critical stenoses of up to 85%, as well as pronounced circumferential calcification, were detected in the proximal and middle segments of the anterior

Table 1: Comparative characteristics of methods for modifying calcified plaques

Method	*Mechanism of action*	*Advantages*	*Restrictions*	*Clinical success*
VSL	Laser shock waves	Selective destruction of calcium, low risk of embolization	High cost, limited long-term data	92.4% (Disrupt CAD III) [5]
RA	Mechanical ablation	Efficacy in concentric calcification	Risk of embolization, complexity of the procedure	80–90% [13]
Cutting cylinders	Controlled cuts	Simplicity, accessibility	Limited efficacy in deep calcification	60–80% [4]

Table 2: Patient demographic and clinical characteristics

Indicator	*Meaning*
Demographic data	
Age	53 years old
Floor	Male
Risk factors	
Smoking	Active smoker
Hereditary burden	For cardiovascular diseases
Medical history	
Previous MI	Acute MI of the inferior wall of the left ventricle (2024)
Previous interventions	stenting (2025)
Current complaints	Retrosternal pain during exertion
Functional class of angina	II FC (pain when walking 500-600 m)
Physical data	
Blood pressure	140/85 mmHg
Heart rate	85 beats/min

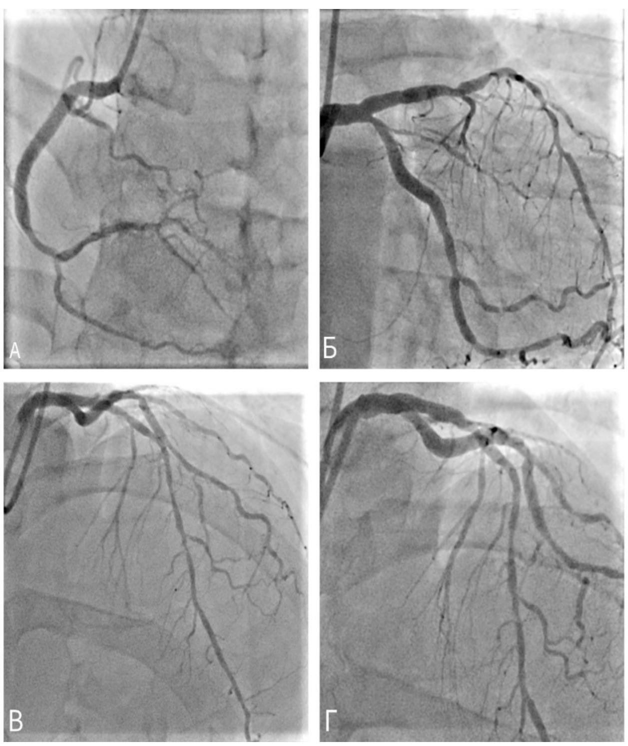

Fig. 1: Invasive coronary angiography. A. Right coronary artery. B. Left coronary artery in caudal annulation. B-D. Left coronary artery in cranial annulation.

descending artery (LAD). These data served as the basis for choosing the lesion modification strategy before stenting.

Interdisciplinary discussion

After discussion with the heart team, the patient was offered two treatment options: surgical revascularization (CABG) or percutaneous intervention on the LAD. Based on the patient's preference and the anatomical characteristics of the lesion, a decision was made to perform PCI with intravascular laser lithotripsy.

The course of the intervention

Right radial artery puncture, placement of a 6 Fr introducer sheath. A guide catheter was inserted into the ostium of the left coronary artery (LMCA). An ASAHI Sion Blue guidewire was advanced into the distal LAD.

Intravascular verification

An intravascular ultrasound was performed, which revealed 360-degree circular calcification with nodular components in the proximal and middle segments of the LAD.

Fig. 2 A and B demonstrate the presence of 360-degree circumferential calcification in the mid and proximal segments of the LAD. Areas of deep and nodular calcification are visualized. Images C–D present quantitative ultrasound parameters: minimum lumen area, thickness, and extent of calcium deposits. IVUS data confirmed severe wall rigidity and demonstrated the need for pre-modification with lithotripsy to achieve adequate stent deployment.

Lithotripsy

Lithotripsy was performed using a Sola balloon catheter (3.0×24 mm; FastWave Medical Inc., USA) at a pressure of 4–6 atm with the delivery of 320 shock pulses in 8 zones. Repeated IVUS demonstrated significant fragmentation of calcium deposits.

Fig. 3 A– C demonstrate calcified areas prior to lithotripsy, characterized by continuous circumferential calcification without signs of fragmentation. Images B–D were obtained after 320 shock pulses were delivered using the FastWave

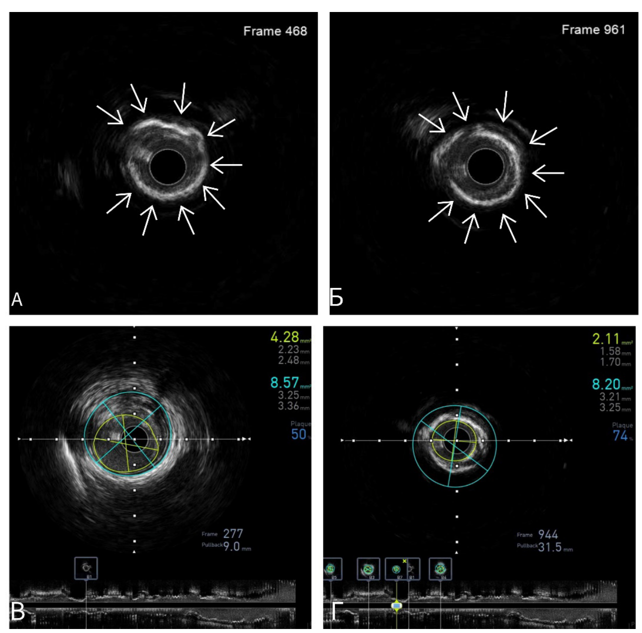

Fig. 2: Intravascular ultrasound examination of the LAD. A. Circular calcium in the middle segment. B. Circular calcium in the proximal segment. C-D. Digital indicators of the affected area.

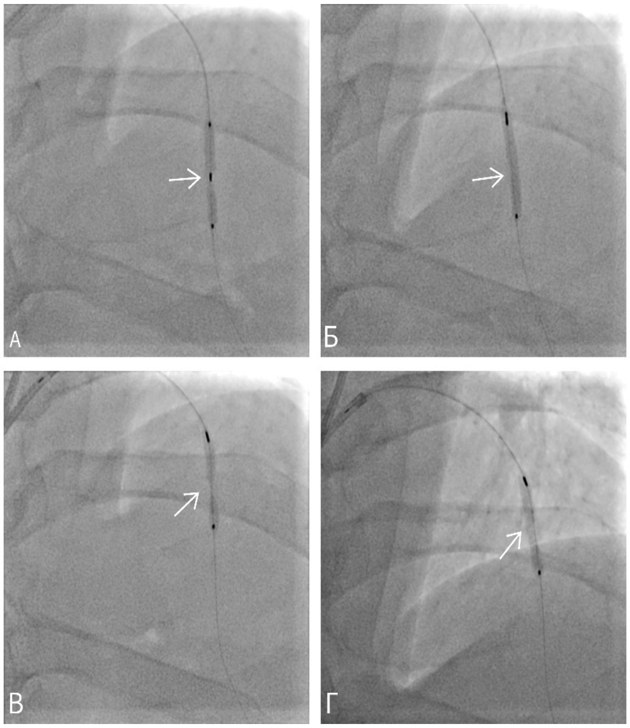

Fig. 3: Intravascular lithotripsy. A-B. Calcified areas before lithotripsy. B-D. Calcified areas after lithotripsy.

Sola balloon catheter: multiple cracks, fragmentation lines, and disruption of the calcium integrity are visualized. The effect of lithotripsy was confirmed in all treatment areas, resulting in increased vascular wall compliance.

A control intravascular ultrasound examination showed effective destruction of the integrity of the circular calcified areas of the lesion.

The total duration of the percutaneous procedure was 120 minutes, with a fluoroscopy duration of 28.3 minutes, a radiation dose of 4658 Gy cm^2, and a contrast agent volume of 250 ml. Lithotripsy was performed using a FastWave Medical Sola balloon catheter. Sola 3.0×24 mm, in 8 zones, with the delivery of 320 shock pulses at a pressure of 4–6 atm, with a total exposure time of 12 minutes.

Predilation was performed with a 3.0×30 mm balloon under a pressure of 16–18 atm, and postdilation was performed using 3.5×15 mm and 4.0×8 mm balloons at pressures up to 24 atm. The absence of complications confirms the technical safety and controllability of the procedure.

Intravascular ultrasound imaging revealed significant positive changes in vessel morphology. In the proximal segment of the LAD, the minimum lumen area increased from 3.3 mm^2 to 10.79 mm^2 after stenting, while the degree of stenosis decreased from 72% to 18%. Calcification remained circumferential (360°), but cracks and fragmentation were observed after lithotripsy, indicating successful plaque modification.

Table 3: Technical parameters of the procedure

Indicator	*Meaning*
Total procedure time	120 minutes
Fluoroscopy time	28.3 minutes
Dose area product (DAP)	4658 Gy cm^2
Volume of contrast agent	250 ml
Lithotripsy	
- Catheter type	FastWave Sola 3.0×24 mm
- Number of pulses	320
- Working pressure	4-6 atm
- Number of impact zones	8
- Exposure time	12 minutes
Predilation	
- High pressure cylinder	3.0×30 mm
- Maximum pressure	1 6 -18 atm
Post-dilation	
- Cylinder 1	3.5×15 mm (18-20 atm)
- Cylinder 2	4.0×8 mm (22 - 24 atm)
Complications	None

Similar improvements were noted in the mid-LAD segment: the lumen area increased from 1.97 mm^2 to 8.4 mm^2, and the degree of stenosis decreased from 80% to 17%. These data objectively confirm the effectiveness of lithotripsy and the creation of conditions for optimal stenting.

Three drug-eluting stents were implanted: 3.0 x 26 mm and 3.5 x 30 mm (twice). The minimum stent expansion area in the proximal segment was 10.79 mm^2, with 95% expansion and adequate wall adherence. In the second stent (middle segment), the area was 8.4 mm^2, with an expansion rate of 97%. For the distal stent, the area was 7.8 mm^2, with an expansion rate of 98%.

A high degree of stent expansion with adequate apposition confirms the effectiveness of the preceding lithotripsy and the validity of the chosen method. All values were determined using quantitative IVUS analysis.

In the Fig. 4 shown, arrows indicate areas of calcium deposit fragmentation in the arterial wall after intravascular lithotripsy. Multiple radial and longitudinal microcracks are clearly visible, indicating successful destruction of the calcified plaque. These changes provided conditions for optimal stent deployment and restoration of the arterial lumen. This result has important clinical significance, particularly in circumferential calcification, which was previously considered intractable.

Implantation of stents

After pre-dilation with a non-compliant balloon (3.0×30 mm; 16–18 atm), three DES were implanted one after the other: 3.0×26 mm, 3.5×30 mm, 3.5×30 mm

Table 4: Morphological results according to IVUS data

Parameter	*Before lithotripsy*	*After lithotripsy*	*After stenting*
Proximal segment of the LAD			
Minimum clearance area (mm^2)	3.3	4.04	10.79
Reference vessel diameter (mm)	4.02	4.02	4.02
Degree of stenosis (%)	72	66	18
Calcification			
- Length (degrees)	360°	360° (fragmented)	-
- Thickness (mm)	0.5	0.5 (with cracks)	-
- Depth (superficial/deep)	Deep	Deep with cracks	-
Middle segment of the LAD			
Minimum clearance area (mm^2)	1.97	2.8	8.4
Reference vessel diameter (mm)	3.6	3.6	3.6
Degree of stenosis (%)	80	74	17
Calcification			
Length (degrees)	360°	360° (fragmented)	-
Thickness (mm)	0.9	0.9 (with cracks)	-

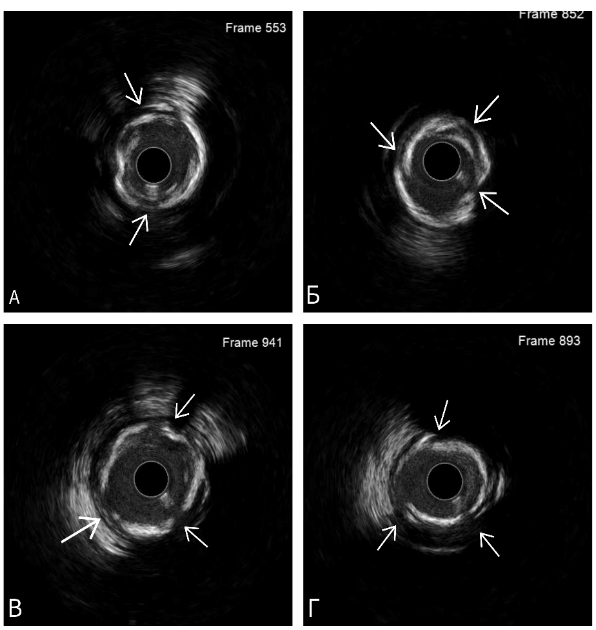

Fig. 4: IVUS after lithotripsy. Arrows indicate fragmentation of the calcified area.

Postdilation was performed using the POT technique with 3.5×15 mm and 4.0×8 mm balloon catheters at 16–18 atm.

Fig. 5 A–G illustrate the stages of implantation of three drug-eluting stents and post-dilation. A shows implantation of the distal stent. 3.0×26 mm stents, and in B–C, two 3.5×30 mm stents in the mid and proximal segments. Image G demonstrates post-dilation using a high-pressure balloon (3.75×10 mm) using the POT technique. At all stages, full stent deployment, absence of deformations, and good adhesion to the vessel wall are visualized, which correlates with the final IVUS data.

Table 5: Characteristics of implanted stents

Characteristics	*Meaning*
Stent 1 (proximal)	3.5 x 30 mm
- Minimum stent area (mm^2)	10.79
- Degree of disclosure (%)	9 5
- Adjacent to the wall	Adequate
Stent 2 (medium)	3.5×30 mm
- Minimum stent area (mm^2)	8.4
- Degree of disclosure (%)	97
- Adjacent to the wall	Adequate
Stent 3 (distal)	3.0× 26 mm
- Minimum stent area (mm^2)	7.8
- Degree of disclosure (%)	98
- Adjacent to the wall	Adequate

Discussion

This clinical case demonstrates the efficacy and safety of intravascular laser lithotripsy in a patient with severe circumferential calcification of the anterior descending artery. The results are consistent with those of the large, multicenter DISRUPT CAD study, which confirms the high efficacy of this method.

A unique feature of this case is the presence of 360-degree circumferential calcification with nodular components, which presents a technical challenge for traditional plaque modification methods. The use of laser lithotripsy enabled effective fragmentation of the calcified deposits, as confirmed by a follow-up IVUS study.

An important aspect is the absence of periprocedural complications, including distal embolization, dissection, or vessel perforation. This underscores the safety of the

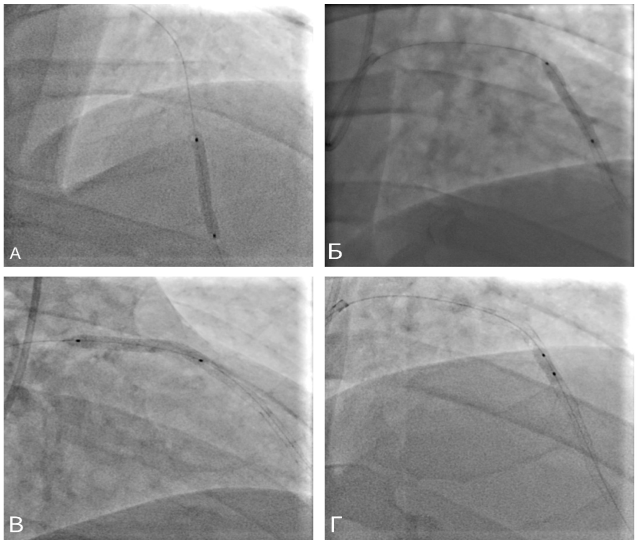

Fig. 5: Implantation of drug-eluting stents. A. DES 3.0*26 mm. B-C. DES 3.5 * 30 mm. D. Postdilation with a high-pressure balloon catheter 3.75*10 mm.

method compared to rotational atherectomy, which carries a significantly higher risk of such complications.

Successful implantation of three stents with optimal deployment and adherence, confirmed by final IVUS, indicates that pre-treatment of calcified plaque with laser lithotripsy provides conditions for high-quality revascularization.

The high cost of the device remains a limitation of the method, but cost-effectiveness may be justified by a reduction in the incidence of complications and improved long-term outcomes, which requires further study in randomized trials.

Conclusion

Intravascular laser lithotripsy (IVL) is an effective and safe method for modifying heavily calcified coronary lesions, providing optimal angiographic and intravascular stenting results under challenging anatomical conditions. This clinical case confirms the technical feasibility and high efficacy of this method, including significant calcium fragmentation, complete stent deployment, and the absence of periprocedural complications. IVL can be considered a preferred alternative to rotational atherectomy in patients with circumferential calcification and a high risk of complications, expanding the capabilities of modern interventional cardiology. Further prospective studies are needed to evaluate long-term clinical outcomes, cost-effectiveness, and define standardized indications for the use of this technology in routine practice.

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