Intravascular lithotripsy: An established frontier for calcific plaque modification.

[1]Stuti Shah, [2]Shlok Patel, [3]Saumya Joshi, [4]Karan Shah, [5]Janushee Modi, [6]Megh Patel, [7]Anshum Patel, [8]Harita Devalia, [9]Ashwati Konat, [10]Dr. Kamal Sharma*

[1,3,4,5,6]Department of Internal Medicine, B.J Medical College, Ahmedabad, Gujarat, India

[2]Department of Orthopedic Surgery, B.J Medical College, Ahmedabad, Gujarat, India

[7]Department of Neurology, AMC MET medical college, Ahmedabad, Gujarat, India

[8]Department of Internal Medicine, AMC MET medical college, Ahmedabad, Gujarat, India

[9]Department of Zoology, Biomedical Technology and Human Genetics, Gujarat University, Ahmedabad, IND.

[10]Department of Interventional Cardiology, U N Mehta Institute of Cardiology and Research Centre,

Corresponding Author: Dr. Kamal Sharma

Abstract:

Background: Coronary artery calcification is often found in patients with severe coronary artery disease. It is often regarded as one of the difficult frontiers to conquer in coronary stenting. Higher the coronary artery calcium score, the more challenging it is to modify the plaque prior to Percutaneous Coronary Intervention (PCI). Intravascular lithotripsy (IVL) is an evolving technology that utilizes acoustic shockwaves to create calcium fractures specifically disrupting both shallow and deep deposits of calcium in the intima and the media of coronary arteries.

Methods: Online databases such as PubMed and Google Scholar were explored, and all relevant publications were analyzed. Keywords utilized during our search were intravascular lithotripsy, shockwaves, coronary lithotripsy, calcified atheromatous plaques and coronary artery calcification. All the gathered information has been scoured to summarize the pre-clinical and clinical data on IVL and to provide a bird’s eye view on the prospects of this novel technique in trans catheter coronary intervention.

Results: Studies indicate that IVL causes better stent placement and expansion when used prior to PCI. IVL demonstrated high procedural success rates (93-97%) and favorable clinical outcomes, with low rates of major adverse cardiovascular events. Comparisons with alternative modalities highlighted IVL's superiority in managing severely calcified lesions, with fewer vascular complications and a shorter learning curve. IVL also causes an improvement in vessel compliance with minimal soft-tissue loss, thereby making successful PCI of calcified plaques more efficacious and simpler achieving higher clinical success, better acute lumen gain and lesser residual stenosis with IVL.

Conclusion: IVL is helpful in the preparation of calcified plaques for PCI. The success rate of drug eluting stent placement in IVL assisted PCI can approach 100% with excellent safety.

Keywords: Intravascular lithotripsy, shockwave lithotripsy, calcified atheromatous plaques, coronary artery lithotripsy, coronary artery calcification

1. Introduction:

Vascular calcification is a common phenomenon and occurs due to injury, repair, or inflammation. This pathological deposition of calcium is found in almost all patients with coronary artery disease[1]. Vascular calcification is more prevalent in the aged population and those with diabetes mellitus, hypertension, end-stage renal disease, dyslipidemia etc. This makes it of great significance given its association with major adverse cardiovascular events and increased cardiovascular risk[1-3].

The presence of calcified coronary plaque negatively impacts coronary intervention outcomes. It hinders with stent crossing, disrupts drug polymer from surface, alters drug delivery and elution kinetics, and affects stent deployment and expansion [4,5]. Calcification also increases the risk of early vascular complications such as dissection, perforation, or infarction; it also increases chances of late complications like re-stenosis, stent fracture, or distal embolization[6,7]. Successful percutaneous coronary intervention (PCI) needs to debulk or reduce coronary artery calcification to circumvent these issues.

Various other procedures have been tried out in the past including cutting or scoring balloon dilatation, excimer Laser, orbital atherectomy, rotational atherectomy etc. But these devices have borderline influence in improving the clinical outcomes. Traditional techniques like balloon dilation have failed due to non-compliance of the lesion to the balloon or difficult and bulky delivery systems with debulking devices and higher complications[8,9]. Even with the newer techniques like orbital or rotational atherectomy, there is a steep learning curve with a need for skilled team, training, and equipment[8]. These devices have been successful in cases of minor or superficial calcification but have decreased success for the deeper and eccentric calcifications[10].

Intravascular lithotripsy (IVL) is a newer technique developed to modify calcification in coronary artery disease. The technology is derived from extracorporeal lithotripsy which has been used for renal stones for many decades now[6,9,11]. Although extracorporeal lithotripsy uses focal, high energy urological lithotripsy, IVL uses acoustic energy specifically suitable for its vascular applications[11]. IVL works on sonic waves that deliver circumferential, pulsatile, and unfocused energy, which travels from the balloon-based catheter to the surrounding tissue. These waves selectively fracture the calcified plaque, which increases the vessel compliance and permits effective lesion preparation at low inflation pressures[5,9,10,12,13]. These microfractures modify the calcified plaque uniformly and thus, also penetrate deeper layers of calcification[14]. IVL has significantly improved stent expansion and delivery in severely calcified plaques[7,9]. According to various case reports, it has been shown that IVL has a short learning curve which makes it easy for cardiologists to use as it needs no additional acumen practically beyond that needed with any balloon catheter [9].

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 2, 2024

In this review, we explore the potential, feasibility, and current understanding for IVL as a preferred modality for the plaque modification in a calcified coronary lesion during PCI.

2. Methodology:

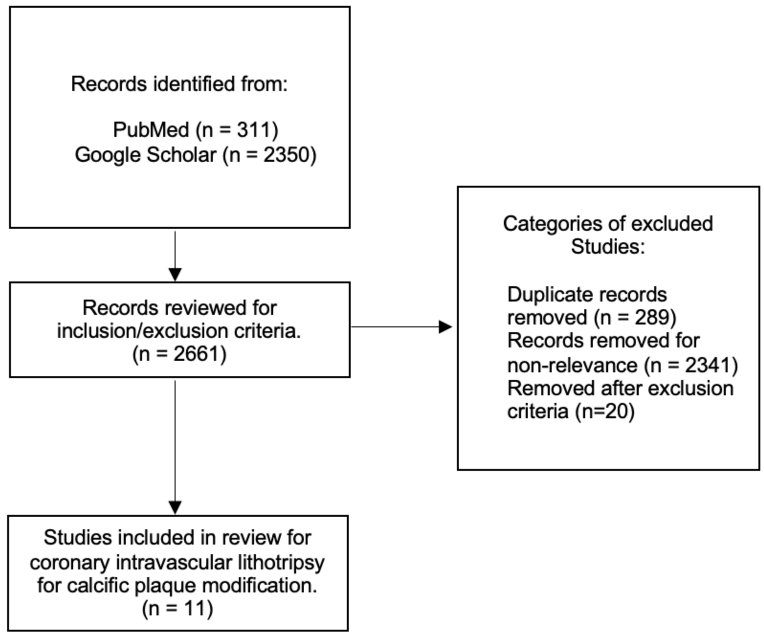
The electronic literature search was conducted in Online databases like PubMed and Google scholar in November of 2022to retrieve articles indexed from 2018 to 2022. All relevant open access publications were screened and analyzed by two independent reviewers. The search strategy employed a combination of Medical Subject Headings (MeSH) terms and keywords utilized during search included “intravascular lithotripsy”, “shockwaves”, “coronary lithotripsy”, “calcified atheromatous plaques” and “coronary artery calcification”.We extracted information about the sample size, demographics, risk factors, lesion and procedural characteristics, and safety and efficacy outcomes. Data extraction was completed manually to spreadsheet software (Excel; Microsoft Corporation, Redmond, WA). The investigators were not blinded to the journals or authors when extracting and analyzing the data. All the gathered information was compiled and summarized to produce a concise review of this novel technique. Our exclusion criteria were chosen to ensure that articles comprised were well-controlled and thoroughly valid. Articles identified through these methods were then selected based on the following inclusion criteria: (1) Studies focusing on intravascular lithotripsy for calcific plaque modification (2) Clinical trials, observational studies, and systematic reviews. (3)Articles published between 2018 and 2022.Our exclusion criteria were chosen to ensure that articles comprised were well-controlled and thoroughly valid. Articles meeting any of the following criteria were excluded: (1) Non-coronary intravascular lithotripsy studies (2)Incomplete/Animal/In-Vitro interventions (3) Articles included in non-peer-reviewed journal, not in English, published before a specific date and about theory rather than actual practice.

3. Results and Discussion

The initial electronic search produced 311 articles from PubMed and 2350 articles from Google Scholar. After removing duplicates and screening titles and abstracts, 20 studies were retained. Following the screening process, 11 articles were identified as potentially meeting inclusion criteria, leading to full-text assessments. Eventually, all 11 articles satisfied the predefined inclusion criteria and were incorporated into the review. Figure 1 includes detailed breakdown of search methodology.Intravascular lithotripsy procedures were consistently described across the included studies. Commonalities in the application of acoustic shockwaves for calcific plaque modification were identified, emphasizing the standardization of the intervention technique.

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 2, 2024

Figure 1. Flow diagram for reviewed studies.



3.1 Intricacies of IVL:

Percutaneous coronary intervention (PCI) to revascularize the coronary vessels with extensively calcified lesions may be associated with stent under-expansion, thrombosis, mal-apposition, stent fracture and re-stenosis of the vessel.[6] Therefore, it is pivotal to modify these calcified lesions for utilizing adjunctive therapies like Intravascular Lithotripsy (IVL) for vessel preparation prior to stent deployment. [9]

Intravascular Lithotripsy (IVL) involves essentially the same principles as those of extracorporeal shockwave lithotripsy (used in the treatment of nephrolithiasis) i.e., conversion of electrical energy into high-amplitude sonic pressure waves. [15, 16] The lithotripsy emitters present inside the integrated balloon create bubbles by vaporizing the fluid medium, which expand and collapse the balloon creating the pressure waves. These waves are transmitted to the arterial wall creating fractures in the calcium present in the intima and the media.[9] The peak positive pressure transmitted to the vessel wall is approximately 5 MPa (~50 atm) and negative pressure of about 0.3 MPa or 3 atm. Hence, the fundamental mechanism of calcium fracture is this compression produced by the positive peak of the shockwave, while the negligibly low negative pressure prevents tissue damage produced by the tensile stress.[4] These calcium fractures ease the stent expansion and delivery by enhancing the compliance of the vessel wall, and concurrently help in stable deployment and trackability in situ thereby preventing device embolization.[17] These fractures are multi planar and circumferential, unlike the ‘uniplanar troughs’ that can occur with rotational atherectomy.[6] Studies have shown IVL to be efficacious for concentric lesions, however limited benefits are seen with eccentric lesions with smaller calcium arc, or when calcium is outside the metallic stent frame, in cases where IVL is used for stent restenosis.[18]

The Shockwave C^2 Coronary IVL system consists of the IVL generator, connector cable, and a single use IVL catheter. The catheter has multiple lithotripsy emitters enclosed in an integrated balloon that can be delivered over a 0.014 guidewire. The balloon has a fixed length of 12 mm (if the length of the lesion surpasses 12 mm, then the pulses are delivered again after repositioning the balloon), and the diameter ranges from 2.5-4 mm. The diameter of the selected balloon should have 1:1 ratio with the diameter of the target vessel.[9] If the integrated balloon cannot be delivered to the lesion, guide catheter extension or pre-dilation using a balloon can be utilized to ease the delivery.[6] After delivery, it is inflated up to 4 atm, which is followed by delivery of 10 sequential pulses. The pressure is then increased to 6 atm, and then the balloon deflated to prevent tissue ischemia.[19] The IVL catheter has a capacity to deliver pulses at the rate of 1 per second up to a maximum of 80 pulses.[9] In case there is an inability to achieve adequate vessel preparation, another IVL catheter can be used.[6]

There are several advantages to this catheter design: the fluid medium enclosed within the balloon dissipates heat generated by the lithotripsy emitters, the balloon curtails any tissue deformation along with providing stability and support, and most importantly, it provides an efficient medium to transmit the pressure waves.[4] Furthermore, the interventional cardiologists are familiar with the balloon-based design making IVL easier to use.[9]

3.2 Comparison with alternate modalities:

In the peripheral vasculature, calcifications can be primarily of two types- Intimal (coral reef) and medial (Monckeberg’s sclerosis). These impair the vessel wall’s compliance and elasticity. It has been proven that calcium plaque hinders antiproliferative drug penetration and distribution. Calcium plaque also makes it difficult for stent expansion and apposition and hence its deployment.[20] Available devices for plaque modification can be classified into two main categories: First group, comprises balloon dependent devices that are- non-compliant (NC) balloon, ultrahigh-pressure balloon (OPN), and cutting/scoring catheters, i.e., devices that perform by exerting pressure on the internal side of the lesion. Second group consists of atherectomy- dependent devices-1) rotational, 2) laser and 3) orbital, that emphasize on pulverizing and getting rid of atherosclerotic plaque. Although the latter devices have a high success rate of over 90%, all of them have some limitations.[21] However, deep calcium deposits are seldom affected by these “debulking” devices.[20]

Owing to their tolerance to high inflation pressures, NC balloons are the first opted alternative in mild to moderate calcified stenosis; after deployment and inflation of the balloon, it applies a substantial amount of pressure on a confined portion of targeted coronary vessel. Another variation of balloon dependent devices is cutting balloons, which increase the vessel compliance by making several distinct incisions in the atherosclerotic coronary segment using an elaborate system of microsurgical blades attached to its exterior, which are tailor-made for this purpose, leading the luminal calcium to crack. Another participant of the balloon-dependent category is scoring balloons which have scoring elements encircling it. Such a design reduces the balloon slippage risk all the while exerting considerable amount of force over a circumscribed area.[1] Despite such qualities, these balloons are not immune from limitations. Non-Compliant (NC) balloons with very-high-rated burst-pressure have poor crossability.[22] Even the high pressure rated NC balloons are often lacking the required force for plaque disruption. Dissection or disruption of fibrous plaque or healthy intima adds on to the list of limitations, which by high amount of pressure is implied by the balloon dilatation on lesions which are largely eccentric in nature. Cutting and scoring balloons also face the same limitation.[14]

Atherectomy modifies lesion structure and increases vessel compliance by plaque-debulking and causes splinters in calcium sediments.[1]Efficacy of IVL is superior compared to conventional devices i.e. Rotational and orbital atherectomy, for preparing the lesion before undergoing stent delivery.[23,24] Despite the high efficacy of fore mentioned tools, their use remains limited owing to the perplexity and aggressive nature of the devices, and steep learning curve.[23] Vascular complications such as dislodgement of atheroemboli continues to be a significant challenge for rotational atherectomy.[4] Against this, IVL being catheter-balloon based therapy, is easy to use with a shorter learning curve.[25] In terms of incidence of no-reflow, IVL takes precedence over atherectomy, as it does not generate plaque ablation, making no- flow a highly improbable situation. In the context of Left Main Stenosis (LM) no-flow is a severe adverse event and can be a possibility with the use of atherectomy based devices.[24,25] Another advantage of IVL over others is that the wire can be maintained in the side branch, which is particularly useful in Left Main Stenosis (LM) where there may be large amounts of subtended myocardium supplied by the two branches.[26] Risk of unique complication with Rotational atherectomy and orbital atherectomy is that burr entrapment or device dislodgement may occur.[22]

3.3 Safety and Efficacy Data:

According to the analysis of serial Disrupt CAD trials done by Liang B et al., [27] the number of patients under observation was 628 with an average age of 71.8 years. It was observed that the application of intravascular lithotripsy had procedural success of 93.0%, angiographic success of 97.5%, and 100% success in stent delivery in calcified lesions, thus showing favorable efficacy. Procedural success was stipulated as the potential of IVL to decrease the stenosis of the vessel by 50% with no indication of MACE in the hospital itself. Achievement of angiographic parameters has been explained as the ability to expedite successful delivery of stents with the aim of achieving residual stenosis less than 50% and no sign of consequential angiographic impediments. Among the 628 patients, 568 were relieved from MACE while they were in the hospital. The remaining patients were free from MACE within 6 months. The percentage of 30 days MACE was also found to be significantly less.

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 2, 2024

The tolerance of the patients to IVL prior to implantation of stent was good. The procedural success was found to be significantly high with an average success rate of 93.8 %. Hence, based on the above-mentioned facts, IVL proves to be safe and efficacious as the criteria for safety and efficacy were satisfied.[27]

According to another study by Rola P et al., [16,26] the safety and efficiency of S-IVL was evaluated in patients with severely calcified Left main stenosis. The primary endpoints considered were related to successful execution of IVL clinically and the consequences related to safety. Favorable clinical outcome was explained as successful placement of the stent and it's positioning along with preserved thrombolysis as the procedure culminates. Safety end results were stipulated based on following factors: perforation of coronary vessels, defects in reflow, new formation of thrombus, ventricular arrhythmias, vessel closure, aberrations in placing of stent, inappropriate expansion, failure to surpass the lesion, and malfunctions. MACCE were described as events related to myocardial infarction, cerebrovascular abnormalities, hemorrhagic episodes, requirement for recurrent revascularization, or death of the patient. Due to the bulkiness of the device, body lesions were noted to be caused while installing IVL. The study concludes that the use of S-IVL is safe and efficient as all the patients achieved favorable clinical outcomes with a mean post-surgery stenosis of 6%. There was no sign of any cardiac complications. 2 cases of MACCE were reported within 30 days of follow up.[16]

According to a study conducted by Blachutzik F et al.,[14] observation of safety and efficacy of IVL was done in two groups of people categorized under Disrupt CAD I and Disrupt CAD II. Disrupt CAD I, which consisted of 60 people, was a pre-market study of the evaluation of safety and efficacy of IVL whereas CAD II, which consisted of 120 people, was a post market study of evaluation of the same. The primary endpoint considered for the Disrupt CAD I study was patients being free from Major adverse cardiac events (MACE) within 30 days of undergoing the procedure of IVL. MACE here was described as incidence of cardiac death, MI or revascularization of the target vessel in the patients after undergoing IVL. For Disrupt CAD II, the primary endpoint was considered as the patient being free from MACE in the hospital itself. The outcome of these 2 groups was evaluated and discussed, suggesting facts regarding the high safety and efficacy of IVL. Clinical success of the procedure was defined as less than 50% of post residual stenosis with no evidence of MACE in hospital and this was met in 93.3% of the patients. Moreover, 98.9% patients achieved angiographic success, which was explained as successful stent delivery in the patient with less than 50% of residual stenosis and no sign of major angiographic complications. There were no signs of perforations, abrupt closures, slow flow, or no flow event observed in the patients of both the study groups. The rate of flow limiting dissections was low. Within 30 days, the percentage of patients facing MACE was 14.7% in total and divided as 8.7% in patients having eccentric lesions and 6.0% in patients having concentric lesions. The data mentioned above proves that IVL treatment provides consistent outcomes and very high rates of procedural and angiographic success and low incidence of vascular complications.[14]

According to study by Saito S et al., [17], 64 patients were involved with mean age being 74 years. Observation was that 93.8% met the primary safety endpoint and 93.8% achieved procedural success. Primary safety endpoint was defined as no signs of MACEupto 30 days

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 2, 2024

after the procedure and procedural success was taken as successful placement of stent to target vessel with residual stenosis less than 50% and no signs of MACE in the hospital itself. The description of MACE was given as any incidence of cardiac death, Myocardial Infarction, or revascularization of the target vessel. The primary safety and efficacy endpoints were non inferior to the IVL control group, 93.8% in the IVL group and 91.2% in the control group. There were 0 cardiac deaths reported, 0 incidence of target vessel revascularization or Q- wave MI. Procedural success in the IVL group (93.8%) was also noninferior to the control group (91.6%). There were 0 cases of failure of placement of stent during the procedure or residual restenosis in-stent greater than or equal to 50%. According to the data, IVL was proved to be highly efficacious and safe compared to the control group and the primary safety and efficacy endpoints were successfully fulfilled.[17]

Multiple studies were tabulated to gain deeper insight into working, characteristics, and success rate of IVL along with a better understanding of the study structures. Table 1 shows comparison between various studies of IVL for their baseline demographics. Table 2 shows procedural details with lesion anatomy description. Table 3 highlights the safety and efficacy data of various IVL studies.

Even with all the great success stories of IVL, it does have some noteworthy drawbacks which cannot be overlooked. As reported by Chugh Y et al., one of the most common adverse events reported is device malfunction. In their study, they saw it in 13 out of 23 patients I.e., 56.5% of the patients. One of the most common modes of device failure seen in IVL is dislodgement of catheter or partial balloon. It was seen in 12 out of 20 people i.e., 60% of the patients observed. Balloon rupture was observed in 3 out of 20 patients (15%).[28]

Keeping all these complications in mind, we must not forget that the chances of occurrence of these complications is infrequent in all the other studies and is often related to high complexity of peripheral and coronary lesions. Hence, sincere monitoring and surveillance of IVL is highly advised.[28]

In this current study we analyzed 4 studies for average calculations including Disrupt CAD, Aksoy A et al., Wiens EJ et al, Mastranjelo A et al. [15,19,24,27,29] There were a total of 840 patients with an average age of 72 years. A vast majority of the participants (77%) were males. Various comorbidities were found in most participants with most having hypertension (84.5%), hyperlipidemia (82%) and less commonly diabetes (38%). Smoking was a risk factor with over a half of participants with significant history. Many patients had a prior myocardial infarction (27.4%). Around 10% of patients had a prior stroke or CABG.

Table 1 includes baseline demographics of included studies.

Table 1: Baseline demographics

	Disrupt CAD (I+II+III+IV) [15,27]	**A. Aksoy 2019 et al.** [19]	**Wiens EJ et al** [24]	**Mastranjelo A et al** [29]	**TOTAL**	**MEAN/ percentage**

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 2, 2024

Number of patients	628	57	50	105	840	210
Demographics						
a) Age (in years)	71.8 ±8.9	75.9(±9.9)	71.5 (66.3-77.5)	71.4±7.6		72.01
b) Males, n(%)	484 (77.1%)	42(73.7%)	32 (64%)	89 (84.8%)	647 (77.02%)	72.02%
Risk factors						
a) Diabetes, n(%)	241 (38.4%)	20(35.1)	28 (56%)	29 (27.6)	318 (38%)	38%
b) Hypertension, n(%)	539 (85.8%)	52(91.2)	41 (82%)	78 (74.3)	710 (84.5%)	84.5%
c) Hyperlipidemia, Hypercholesterolemia, n(%)	531 (84.6%)	37(64.9)	41 (82%)	79 (75.2)	688 (82%)	82%
d) Smoking, n(%)	357 (56.8%)	18(31.6)	23 (46%)	52 (49.5)	450 (53.6%)	53.6%
e) History of MI, n(%)	137 (21.8%)	30(52.6)	30 (60%)	33 (31.4)	230 (27.4%)	27.4%
f) History of stroke, n(%)	54 (8.6%)	13(22.9)	6 (12%)	5 (4.8)	78 (9.3%)	9.3%
g) Prior PCI, n(%)	-	31(54.4)	27 (54%)	52 (49.5)	-	-
h) Prior CABG, n(%)	60 (9.6%)	7(12.3)	7 (14%)	17 (16.2)	91 (10.8%)	10.8%
i) Chronic kidney disease, n(%)	157 (25.1%)	20(35.1)	-	26 (24.8)	-	-

Table 2 represents the data related to procedural details with lesion anatomy was observed as well as analyzed from the studies of Disrupt CAD, A. Aksoy et al, Mastrangelo A et al., [15,19,27,29] and the following conclusions were drawn. With an average number of patients considered for evaluation being 263.3, it was observed that the most affected vessel was left anterior descending artery, affecting 150 patients on an average. The 2ndmost affected vessel was found to be the right coronary artery followed by the left main artery with the average

number of patients affected being 74.67 and 9.67 respectively. Circumflex artery was least affected. Radial artery is the most frequently used artery used as a vascular access for carrying out the procedure. Out of an average 263.3 patients, radial artery is used as a medium of vascular access in 128.67 patients. Femoral artery is also used in 76 patients for the same. The average lesion length is observed to be 22.89 mm. Most of the patients are affected by severe calcification of the vessels. An average of 250 patients out of 263 have been diagnosed to have severe calcification in the vessels. While carrying out the procedure, the mean contrast volume used was 190 ml.

Table 2: Procedural details with lesion anatomy description

	Disrupt CAD (I+II+III+IV)[15, 27]	**A. Aksoy 2019 et al.[19]**	**Mastranjelo A et al[29]**	**TOTAL**	**MEAN**
Number of patients	628	57	105	790	263.3
Lesion and Procedural characteristics					
a) Target vessel					
i) Left main artery, n(%)	9 (1.4%)	9(15.8%)	11 (10%)	29 (3.67%)	9.67
ii) Left anterior descending artery, n(%)	368 (58.6%)	26(45.6%)	56 (50.9%)	450 (57%)	150
iii) Circumflex artery, n(%)	75 (11.9%)	-	14 (12.7%)	-	-
iv) Right coronary artery, n(%)	176 (28%)	19(33.3%)	29 (26.4%)	224 (28.35%)	74.67
b) Vascular access					
i) Radial artery, n(%)	281 (62.7%)	19 (33.3%)	86 (78.2%)	386 (49%)	128.67
ii) Femoral artery, n(%)	160 (36.4%)	38 (66.7%)	30 (27.2%)	228 (29%)	76
iii) Brachial artery	3 (0.7%)	-	-	-	-
iv) Ulnar artery	1 (0.2%)	-	-	-	-
c) Lesion length (mm)	24.4 ± 11.5	10.8±9.45	20.46 ± 15.99		22.89
d) Lesion characteristics					
i) Eccentric	-	34(59.7%)	82 (74.6%)	-	-
ii) Concentric	-	23 (40.3%)	28 (25.5%)	-	-
e) Lesion calcification					
i) Moderate	-	10 (17.5%)	16 (14.5%)	-	-
ii) Severe	609 (97.0%)	47 (82.5%)	94 (85.5%)	750 (95%)	250

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 2, 2024

f) Contrast volume (ml)	179.8 ± 77.3	165±63	265 ± 130		190
g) Procedure time (min)	57.0 (41.5-83.0)	-	-	-	-
h) Fluoroscopy time (min)	-	27.34±18.95	24.08 ± 13.99	-	-
i) Number of pulses applied	74.7 ± 42.7	66±27	64 ± 21		-
j) IVL pressure (atm)	6.0 ± 0.5	29.2±7.8	19 ± 4		-
k) No. of stents	1.3 ± 0.5	1.3	-	-	-
l) Pre-dilatation	299 (47.6%)	-	70 (63.6%)	-	-
m) Post-dilatation	588 (94.1%)	19(33.3%)	11 (10%)	618 (78.2%)	206

Table 3 demonstrates the safety and efficacy data in 795 patients. IVL has had a very high procedural (93%), angiographic (97%) success rate and stent delivery was successful in almost all patients (98%). Despite these high successes, there were few instances of Major adverse cardiovascular events in around 75 patients. Balloon burst occurred in 12 patients. Other adverse events like perforation, arrhythmia or severe complication were found in less than 0.5% patients, thus proving the highly efficacious nature of intravascular lithotripsy. [15,19,27,29]

Table 3: Safety and efficacy outcomes

	Disrupt CAD [I+II+III+IV][15,27]	**Aksoy A et al.** [19]	**Mastrangelo A et al.** [29]	**TOTAL**	**MEAN**
No. of patients/lesions	628	57	110	795	265
Procedural success	584 (93.0%)	47(82.5%)	107 (97.3%)	738 (93%)	246
Angiographic success	612 (97.5%)	47(82.5%)	110 (100%)	769 (97%)	256.33
Stent delivery	625 (99.5%)	47(82.5%)	107 (97.3%)	779 (98%)	259.67
MACE					
In Hospital	40 (7%)	0	35 (33.4%)	75 (10.2%)	25

EARLY (<30 DAYS)	54 (9.5%)	-	0	-	-
LATE (>30 DAYS)	5 (8.3%)	-	14 (13.3%)	-	-
Failure of IVL	-	7 (12.3%)	5 (4.6%)	-	-
Balloon Burst	0 (0%)	7 (12.3%)	5 (4.6%)	12 (1.5%)	4
Perforation	0 (0%)	0 (0%)	1 (0.9%)	1 (0.12%)	0.33
Arrhythmia	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0
Severe complications	0 (0%)	0 (0%)	4 (3.6%)	4 (0.5%)	1.33

4. Conclusion:

IVL has emerged as the novel plaque modification technique for calcified lesions with small learning curves and with good clinical efficacy and safety data. Further long-term data in randomized control trials with other plaque modification techniques are needed to compare its safety and efficacy in intermediate and long term.

References:

1. Kaul A, Dhalla PS, Bapatla A, Khalid R, Garcia J, Armenta-Quiroga AS, et al. Current treatment modalities for calcified coronary artery disease: A review article comparing novel intravascular lithotripsy and traditional rotational atherectomy. Cureus. 2020;12(10):e10922. Available from: http://dx.doi.org/10.7759/cureus.10922

2. Dean J, Kereiakes JM, Hill RA, Shlofmitz AJ, Klein RF, Riley MJ, et al. Intravascular Lithotripsy for Treatment of Severely Calcified Coronary Lesions: 1-Year Results From the Disrupt CAD III Study. Journal of the Society for Cardiovascular Angiography & Interventions. 2022;1(1).

3. Honton B, Monsegu J. Best practice in intravascular lithotripsy. IntervCardiol. 2022;17. Available from: http://dx.doi.org/10.15420/icr.2021.14

4. Kereiakes DJ, Virmani R, Hokama JY, Illindala U, Mena-Hurtado C, Holden A, et al. Principles of intravascular lithotripsy for calcific plaque modification. JACC Cardiovasc Interv. 2021;14(12):1275–92. Available from: http://dx.doi.org/10.1016/j.jcin.2021.03.036

5. Brinton TJ, Ali ZA, Hill JM, Meredith IT, Maehara A, Illindala U, et al. Feasibility of shockwave coronary intravascular lithotripsy for the treatment of calcified coronary stenoses: First description. Circulation. 2019;139(6):834–6. Available from: http://dx.doi.org/10.1161/circulationaha.118.036531

6. Hill JM, Kereiakes DJ, Shlofmitz RA, Klein AJ, Riley RF, Price MJ, et al. Intravascular lithotripsy for treatment of severely calcified coronary artery disease. J Am Coll Cardiol. 2020;76(22):2635–46. Available from: http://dx.doi.org/10.1016/j.jacc.2020.09.603

7. Tepe G, Brodmann M, Werner M, Bachinsky W, Holden A, Zeller T, et al. Intravascular lithotripsy for peripheral artery calcification. JACC Cardiovasc Interv. 2021;14(12):1352–61. Available from: http://dx.doi.org/10.1016/j.jcin.2021.04.010

8. Ali ZA, Nef H, Escaned J, Werner N, Banning AP, Hill JM, et al. Safety and effectiveness of coronary intravascular lithotripsy for treatment of severely calcified coronary stenoses: The Disrupt CAD II study. Circ Cardiovasc Interv. 2019;12(10). Available from: http://dx.doi.org/10.1161/circinterventions.119.008434

9. Sinclair H, Fan L, Fahy E, Shahid F, Ratib K, Nolan J, et al. Intravascular imaging–guided intracoronary lithotripsy: First real-world experience. Health Sci Rep. 2021;4(3). Available from: http://dx.doi.org/10.1002/hsr2.307

10. Natalia M, Forero T, Daemen J. The coronary intravascular lithotripsy system. IntervCardiol. 2019;14(3):174–81. Available from: http://dx.doi.org/10.15420/icr.2019.18.r1

11. Dini CS, Tomberli B, Mattesini A, Ristalli F, Valente S, Stolcova M, et al. Intravascular lithotripsy for calcific coronary and peripheral artery stenoses. EuroIntervention. 2019;15(8):714–21. Available from: http://dx.doi.org/10.4244/eij-d-18-01056

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 2, 2024

12. Wilson SJ, Spratt JC, Hill J, Spence MS, Cosgrove C, Jones J, et al. Incidence of "shocktopics" and asynchronous cardiac pacing in patients undergoing coronary intravascular lithotripsy. EuroIntervention. 2020;15(16):1429–35. Available from: http://dx.doi.org/10.4244/eij-d-19-00484

13. Sattar Y, Almas T, Arshad J, Zghouzi M, Ullah W, Mir T, et al. Clinical and angiographic success and safety comparison of coronary intravascular lithotripsy: An updated meta-analysis. Int J Cardiol Heart Vasc. 2022;39(100975):100975. Available from: http://dx.doi.org/10.1016/j.ijcha.2022.100975

14. Blachutzik F, Honton B, Escaned J, Hill JM, Werner N, Banning AP, et al. Safety and effectiveness of coronary intravascular lithotripsy in eccentric calcified coronary lesions: a patient-level pooled analysis from the Disrupt CAD I and CAD II Studies. Clin Res Cardiol. 2021;110(2):228–36. Available from: http://dx.doi.org/10.1007/s00392-020-01737-3

15. Kereiakes DJ, Di Mario C, Riley RF, Fajadet J, Shlofmitz RA, Saito S, et al. Intravascular lithotripsy for treatment of calcified coronary lesions. JACC Cardiovasc Interv. 2021;14(12):1337–48. Available from: http://dx.doi.org/10.1016/j.jcin.2021.04.015

16. Rola P, Włodarczak A, Barycki M, Pęcherzewski M, Kulczycki JJ, Szudrowicz M, et al. Shockwave intravascular lithotripsy as a novel strategy for balloon undilatable heavily calcified chronic total occlusion lesions. Cardiol J. 2021; Available from: http://dx.doi.org/10.5603/cj.a2021.0112

17. Saito S, Yamazaki S, Takahashi A, Namiki A, Kawasaki T, Otsuji S, et al. Intravascular lithotripsy for vessel preparation in severely calcified coronary arteries prior to Stent placement ― primary outcomes from the Japanese disrupt CAD IV study. Circ J. 2021;85(6):826–33. Available from: http://dx.doi.org/10.1253/circj.cj-20-1174

18. Tam C-CF, Leung M-FM, Fang C. Intravascular lithotripsy on concentric, eccentric, and extrastent calcium. JACC Basic Transl Sci. 2021;6(11):885–6. Available from: http://dx.doi.org/10.1016/j.jacbts.2021.08.008

19. Aksoy A, Tiyerili V, Jansen N, Al Zaidi M, Thiessen M, Sedaghat A, et al. Propensity-score-matched comparison of safety, efficacy, and outcome of intravascular lithotripsy versus high-pressure PTCA in coronary calcified lesions. Int J Cardiol Heart Vasc. 2021;37(100900):100900. Available from: http://dx.doi.org/10.1016/j.ijcha.2021.100900

20. Misztal M, Trystuła M, Konieczyńska M, Musiał R, Legutko J, Pieniążek P. Intravascular lithotripsy with peripheral Shockwave catheter - a breakthrough in calcified carotid artery stenosis treatment. PostepyKardiolInterwencyjnej. 2020;16(4):491–4. Available from: http://dx.doi.org/10.5114/aic.2020.101778

22. Sakakura K. Lesion preparation for severely calcified coronary artery disease - intravascular lithotripsy as a new option. Circ J. 2021;85(6):834–6. Available from: http://dx.doi.org/10.1253/circj.CJ-20-1272

23. Généreux P. Intravascular lithotripsy for the treatment of calcified coronary artery disease: A simple and disruptive technology. J Am Coll Cardiol. 2020;76(22):2647–9. Available from: http://dx.doi.org/10.1016/j.jacc.2020.10.014

24. Wiens EJ, Sklar JC, Wei YH, Aleem Q, Minhas K. Real-world outcomes in treatment of highly calcified coronary lesions with intravascular shockwave lithotripsy. Indian Heart J. 2021;73(5):653–5. Available from: http://dx.doi.org/10.1016/j.ihj.2021.09.002

25. Lemesle G, Laine M, Bonello L. Reply: The challenge of researching pre-treatment omission with invasive strategy timing in NSTEACS. JACC Cardiovasc Interv. 2020;13(14):1726–7. Available from: http://dx.doi.org/10.1016/j.jcin.2020.06.002

26. Rola P, Włodarczak A, Kulczycki JJ, Barycki M, Furtan Ł, Pęcherzewski M, et al. Efficacy and safety of shockwave intravascular lithotripsy (S-IVL) in calcified unprotected left main percutaneous coronary intervention - short-term outcomes. PostepyKardiolInterwencyjnej. 2021;17(4):344–8. Available from: http://dx.doi.org/10.5114/aic.2021.112524

27. Liang B, Gu N. Evaluation of the safety and efficacy of coronary intravascular lithotripsy for treatment of severely calcified coronary stenoses: Evidence from the serial Disrupt CAD trials. Front Cardiovasc Med. 2021;8:724481. Available from: http://dx.doi.org/10.3389/fcvm.2021.724481

28. Chugh Y, Khatri JJ, Shishehbor MH, Banerjee S, Croce K, Alaswad K, et al. Adverse events with intravascular lithotripsy after peripheral and off-label coronary use: A report from the FDA MAUDE database. J Invasive Cardiol. 2021. Available from: https://pubmed.ncbi.nlm.nih.gov/34866049/

29. Mastrangelo A, Monizzi G, Galli S, Grancini L, Ferrari C, Olivares P, et al. Intravascular lithotripsy in calcified coronary lesions: A single-center experience in "real-world" patients. Front Cardiovasc Med. 2022;9:829117. Available from: http://dx.doi.org/10.3389/fcvm.2022.829117