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The Effect of Intravascular Lithotripsy on Calcific Coronary Plaques during Coronary Intervention

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Abstract
Background: Coronary Because calcification makes stent failure more likely and hinders device distribution, expansion, and apposition, it is a significant predictor of major adverse cardiac events (MACE) during percutaneous coronary intervention (PCI). The more popular methods, such as percutaneous transluminal coronary angioplasty (PTCA) with non-compliant (NC) balloons, cutting-/scoring-balloons, and rotational/orbital atherectomy, have their limitations. Intravascular lithotripsy (IVL) is a relatively new method that can modify calcified coronary plaques. Despite applying high pressure, NC balloon dilatation is often unable to provide the required force for rupturing calcifications. Because calcified lesions are generally eccentric, balloon dilatation often disrupts or dissects healthy intima or fibrous plaques instead of modifying calcified regions inside the artery. Even though they can debulk the lesion more intensively than NC balloons, cutting and scoring balloons still have the same restriction. The most effective methods for modifying calcified plaques before IVL, such as rotational or orbital atherectomy, have their limitations owing to guidewire bias. This bias can cause inhomogeneous ablation, which leaves large areas of the calcified plaques unmodified, especially in eccentric lesions. Optimal lesion modification strategies, such as intravascular ligation (IVL), rotational atherectomy (RA), or orbital atherectomy (OCT), may only be determined with the use of intravascular ultrasonography (IVUS) or optical coherence tomography (OCT). Review objective: There is mounting evidence that intravenous ligation (IVL) should be the first line of defense against newly formed, highly calcified coronary arteries, and this review paper addresses that evidence. stenting.

Keywords: Intravascular Lithotripsy; Calcific Coronary Plaques; Coronary Intervention.

1. Introduction

Calcified In coronary artery disease, coronary lesions are often seen. The frequency of individuals with heavily calcified lesions is continuously rising due to the effects of advancing age and comorbidities. The degree of calcification has a substantial impact on survival rates, rates of myocardial infarction, and the success of target lesion revascularization, according to studies **[1].**

Calcified lesions are notoriously hard to dilate using traditional angioplasty techniques because they are often round, refractory, and nondistensible. Prior to stent placement, it is highly advised to prepare the lesion using high-pressure dilatation, scoring/cutting balloons, or rotating atherectomy (RA) devices. Dissection, perforation, and blockage of the vessels make the aforementioned approaches difficult. The substantial risk of restenosis and stent thrombosis makes stent insertion impossible when a lesion cannot be fully dilated [6].

The new method of lesion preparation using intravascular lithotripsy (IVL) is effective for heavily calcified plaques in peripheral and coronary arteries. A lithotripsy procedure involves the vaporization of fluid to form an expanding bubble, which then interacts with arterial calcification via the generation of sonic pressure waves. Based on the evidence that is now available, intravenous ligation (IVL) is a very effective and safe method for increasing vascular compliance prior to stent insertion. Enhanced operator training and the IVL's 2017 CE certification have led to its increased usage in more complicated clinical settings [22].

The intravascular lithotripsy procedure uses high-pressure ultrasonic energy to allow percutaneous coronary intervention into lesions that have significant calcification. As more people take it and it becomes widely accessible throughout the globe, the latest supplement for calcium modification is proving to be promising [50].

De novo stenoses involving heavily calcified coronary arteries were the focus of this analysis, which sought to evaluate the safety and efficacy of intravenous ligation (IVL) in an Egyptian population.

2. Coronary artery calcification

The practice of using coronary artery calcium as a surrogate measure of coronary atherosclerosis dates back to the 1940s, when cardiologists would wear big red goggles to keep their eyes from being too light while they examined patients using fluoroscopy **[17].**

Updates in imaging technology, particularly high-speed multislice computed tomography (CT) scans, have made it possible to objectively evaluate the density and extent of coronary calcification, which was previously determined using the Agatston et al. approach. According to Hsieh and Flohr (2021), the coronary calcium score is a commonly used tool for predicting the likelihood of a future acute coronary event.

Coronary calcification pathophysiology

Under the microscope image: Special calcium stains, including von Kossa and Alizarine red, are the most effective in detecting microcalcification, the first kind of CAC, in lesions that have pathological intimal thickening and a size between 0.5 and 15 μm (Figure 1A). Early microcalcification inside the lipid pool may be seen by light microscopy and is believed to come from SMC apoptosis **[32].**

Matrix vesicles with diameters ranging from 100 to 700 nm can only be seen using electron microscopy when they undergo first calcification. Microcalcification involves both SMC apoptosis and matrix vesicles produced by macrophages . According to Wang et al. **[46],** apoptotic macrophages create a more noticeable appearance of bigger puncta, whereas SMC apoptosis results in small microcalcifications.

Detailed image: Nanometer foci in inflammatory atheroma, which may be seen at histology but cannot be seen on clinical CT scans due to their spatial resolution of around 0.5 mm, eventually develop into macroscopic vascular calcification that is observed on clinical CT scans [33].

The necrotic center of the atheroma is the first site of calcification. Macrophages and smooth muscle cells (SMCs) that are dead or dying produce extracellular vesicles. Initiation of calcification is supported by these vesicles. You can no longer regulate the concentration of phosphate and calcium in a certain area. As an example, phosphate may be produced from the breakdown of bigger molecules by enzymes like alkaline phosphatase and adenosine triphosphatase, as well as reactive oxygen species. At last, by actions that mimic osteo/chondrogenic conversion, the local concentration of free calcium and phosphate in autophagosomes reaches a level where calcium phosphate crystals may be seen under electron microscopy **[42].**

The two main kinds of vascular calcification are intimal calcification, which occurs within the vascular intimal layer, and medial calcification, which occurs within the vascular medial layer. Patients with peripheral vascular disease are more likely to have medial calcification, which mostly impacts the lower extremity peripheral arteries and causes them to lose their flexibility. Dialysis length, parathyroid hormone anomalies, hypercalcemia, hyperphosphatemia, renal failure, and arterial medial calcification development have all been linked. Meanwhile, coronary arteries most often exhibit intimal calcification. Based on the research conducted by Kim and Guzman in 2023, coronary intimal calcification will be the primary topic of this study.

Coronary calcification risk factors

Biological characteristics: Atherosclerosis develops at different rates in men and women. The preventive effects of estrogens in the years leading up to menopause may explain why the illness manifests 10–15 years later in women **[44].** One sub-study of the Women's Health Initiative found that 1,064 women between the ages of 50 and 59 who were randomly assigned to estrogen treatment or a placebo had a much lower mean CAC score (83.1) than the placebo group (123.1; $p = 0.02$)[32].

There is a great deal of ethnic heterogeneity, and this variance may impact the level of CAC, which in turn helps explain why there are significant variations in clinical results. A total of 6,814 participants from different racial and ethnic backgrounds were evaluated for coronary calcification in the MESA (Multi-Ethnic investigation of Atherosclerosis) investigation. Participants ranged in age from 45 to 84 years and did not have a history of clinical cardiovascular disease. In these four ethnic groups, the percentage of men with coronary calcification (Agatston score >0) was 70.4%, 52.1%, 56.5%, and 59.2% ($p < 0.001$), while in females it was 44.6%, 36.5%, 34.9%, and 41.9% ($p < 0.001$), according to [7].

An independent risk factor for unfavorable outcomes, CAC is greater in diabetes individuals and corresponds with total plaque load. Another risk factor for chronic acute kidney injury (CAC) is chronic renal illness, which may occur in conjunction with diabetes [48].

From a clinical standpoint

The use of CAC as an indicator of plaque instability: CAC has a substantial correlation with negative outcomes in every population that has been investigated so far, and it serves as a superior predictor of future events compared to all the risk factors or risk equations that have been developed up to this point.

In general, it seems that unstable plaque is predicted by patchy calcification, while total plaque load is correlated with heavy calcification. Spotty calcification was linked to more plaque volume progression than non-calcified plaques, according to serial intravascular ultrasonography (IVUS) investigations; severely calcified plaques, on the other hand, were shown to be resistant to change in plaque volume. According to a study by Kolozsváry et al. (2017), individuals who presented with acute coronary syndrome (ACS) or were predicted to develop ACS in the near future were more likely to have spotty calcification as detected by CT angiography, especially when the plaques had positive remodeling and poor attenuation.

The total calcification level in whole heart radiographs was categorized by MORI et al. as follows: none (0%), mild (<5%), moderate (>5% to ≤ 20%), and severe (>20%), identical to the scoring pattern for coronary calcium. Figure 1 shows the stratification of major plaque types per patient according to the extent of calcification observed by radiography; the selection process was based on the cause of death [32].

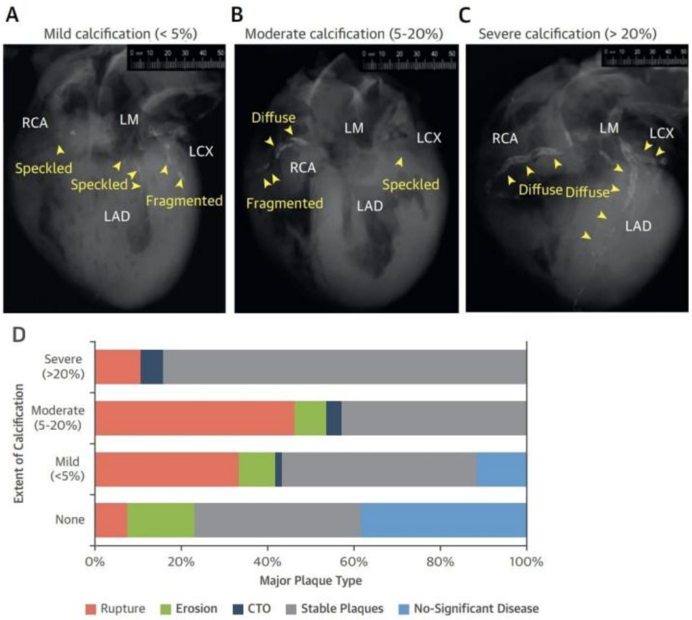

Fig. (1) Extent of Calcification by Plaque Type (Yahagi et al., 2017)

An integral part of coronary artery disease (CAD) and an indicator of total disease load is coronary artery calcium (CAC). In terms of predicting future risk of coronary artery disease (CAD), early diagnosis of CAC in younger people has substantial prognostic implications (Carr et al., 2017).

However, The reliability of predicting which patients would experience certain events and when they will occur was shown to be low on a per-patient basis. A higher calcium score is associated with fibrocalcific plaque and repaired plaque rupture, both of which are more common in elderly individuals. It is possible for some of these plaques to be stable, while others might undergo significant narrowing without thrombosis and eventually evolve into a calcified nodule that causes thrombosis. According to Yağar [47], it is not easy to use calcium as a patient-specific risk predictor for future occurrences.

Assessment and Measurement

Intravascular ultrasound (IVUS) and optical coherence tomography (OCT) are two methods that Nakano et al. [34] noted as useful for evaluating CAC.

Signal-poor dropout with acute borderline is an OCT symptom that may be used to identify sheets of calcification. The signal-poor sections of lipid or necrotic core have diffuse or poorly defined boundaries, whereas the signal-poor regions of calcium are well demarcated. This makes OCT-detected calcium and these other types of cores difficult to distinguish. There is little data on various calcification patterns, however this technique seems to mostly detect sheet calcification [39].

Heterogeneous signal with high attenuation, likely caused by fibrin interposed between nodules, is characteristic of nodular calcification, as noted by Ijichi et al., which is visually distinct from sheet calcification. Ijichi et al. [24] noted that the lumen surface takes on an uneven appearance when the nodule protrudes, a condition known as calcified nodule.

Echo dense (hyperechoic) plaque, which is brighter than the surrounding reference tissue, is the appearance of calcium on intravascular ultrasound. But the acoustic shadow that the calcified plaque casts limits it. The results showed that intravascular ultrasound (IVUS) failed to identify calcium in 14.8 percent of plaques with histopathologic calcium in an in vitro investigation of coronary artery explants from humans. This was caused by microcalcific deposits and deep calcium that was concealed by huge necrotic cores, which dampened the echo. One other thing that IVUS may find is nodular calcification. According to Saito et al. [40], intravascular ultrasound (IVUS) examination can measure the radial (arc) and longitudinal (length) extent, but not the thickness (depth).

The gold standard for noninvasive CAC detection is computed tomography (CT). In order to forecast the relative risk of cardiovascular events in both symptomatic and asymptomatic individuals, calcium scoring, specifically the Agatston score, has been used. By adding together the overall calcified area and the highest density of calcification (>130 Hounsfield units [HU]), the Agatston score provides a comprehensive assessment of all calcified lesions. Despite the adoption of other scoring techniques, the Agatston score remains the most regarded due to its simplicity [8].

One way to stratify risk for future coronary events is to look at the step-wise method in which CAC and cardiovascular events are linked. Both total and cancer-specific death rates are lower in populations with lower CAC scores. Accordingly, international standards advocate for CAC evaluation to enhance clinical risk prediction in suitably chosen asymptomatic patients, particularly those with a moderate Framingham Risk Score ranging from 5% to 20% [20].

Pharmaceutical Approach

In their study, Puri et al. used intravascular ultrasound (IVUS) to measure plaque volume and calcification in patients who were doing high-intensity statin treatment (HIST), low-intensity statin therapy (LIST), or no statin therapy at all. The researchers observed that all study groups had significantly higher calcium indices from baseline. This could be related to statin therapy, as indicated by statistically significant increases ($p = 0.03$ for LIST vs. no-statin; $p = 0.007$ for HIST vs. no-statin; $p = 0.18$ for HIST vs. LIST; median for HIST, +0.044; low-intensity statin therapy (LIST), +0.038; and no-statin, +0.020; $p < 0.001$ for all).

Taking statins increases the likelihood of calcium advancement, according to another research by Banach et al. However, when looking at how statin treatments affected coronary calcium load, several CT investigations found contradictory results. Hypotheses that might account for these contradictory findings include variations in patient demographics, agent concentration, and research length [5].

Methods for modifying calcium

It is now more easier to use percutaneous coronary intervention (PCI) to treat subgroups of high-risk patients with coronary artery disease that is physically complicated. One of the biggest problems with PCI complications is coronary artery calcification, which persists even if interventional procedures have become better [45].

Over 90% of men and 67% of women have CAC beyond the age of 70, indicating that the prevalence of the condition varies with gender. Calcium coronary disease must be better understood and treated as patients over the age of 75 account for almost one third of all percutaneous coronary intervention (PCI) treatments [30].

To enhance technical results in percutaneous coronary intervention (PCI) with severely calcific CAD, the following supplementary technologies are available:

imaging inside the corona

Both short-term and long-term clinical results may be enhanced by using intracoronary imaging to guide percutaneous coronary intervention (PCI). When it comes to percutaneous coronary intervention (PCI), both intravascular ultrasound (IVUS) and optical coherence tomography (OCT) help immensely with understanding the morphology of coronary lesions and facilitating better procedure planning. When it comes to identifying, pinpointing, and measuring coronary calcification, IVUS (Figure 2) and, in particular, OCT, are priceless [31]. Image 2: Intravascular ultrasound showing arterial calcification. In the upper right quadrant, there is a hyperechoic patch of calcium (red arrow), and in the region next to this, there is hypoechoic ultrasound drop out (blue arrow). This is because ultrasound waves cannot pass through calcium. This is seen in the HD-IVUS (60 MHz) picture. B, a high-definition intravascular ultrasonography (HD-IVUS) picture demonstrating full ultrasound drop-out and a 360-degree arc of hyperechoic calcification [31].

Compared to intravascular ultrasound (IVUS), optical coherence tomography (OCT) provides a more accurate assessment of calcium thickness because it can see calcified plaque without artifacts [41].

There is a higher chance of stent under-expansion and a negative impact on PCI outcomes linked with severe and widespread lesion calcification. When the existence and severity of lesion calcification are uncertain, optical coherence tomography (OCT) or intravascular ultrasound (IVUS) should be performed, according to the 2019 intracoronary imaging consensus recommendations of the European Society of Cardiology. Certain imaging characteristics, especially when using OCT's superior spatial resolution, have been recognized as signs of stent under-expansion. A lesion length more than 5 mm, a calcium arc of 180° or more, and a calcium thickness of 0.5 mm or more are the criteria. According to Räber et al. (2018), if there are big pools of calcium (≥180°) and no calcium fractures after the first lesion preparation, it may be necessary to increase the intensity of the preparation.

Methods for modifying calcium

There are two main types of CAC modification techniques: those that use balloons and those that use atherectomy.

methods use balloons:

Balloons that do not comply: Traditional balloon angioplasty (BA) using semi-compliant or noncompliant (NCB) balloons is often successful in treating coronary lesions. The use of NCBs for pre-dilation of lesions often adequately prepares them for stent implantation, allowing for the achievement of an optimal minimum stent area. Nevertheless, when dealing with concentrically calcified lesions, even when NCBs are applied at high pressures, there is still a chance of uneven balloon expansion. Specifically, the calcified portion of the lesion may not expand as much as the rest of the lesion, giving it a characteristic dog-bone look. This symptom might lead to perforation, balloon rupture, or artery dissection, all of which indicate a lack of sufficient lesion preparation [4]. Although conventional NCBs are capable of being inflated to pressures as high as 20–24 atm, they are vulnerable to damage when exposed to calcium, especially spiculated calcium, due to their one-layer construction.

Non-compliant, high-pressure balloons with two layers: The OPN balloon and other ultra high-pressure dual-layer devices have recently emerged, allowing enabling more uniform and low-profile application of very high pressures to lesions (Figure 12A) [15]. In a limited case series (n=8), Díaz et al. were the pioneers who tested the extremely high-pressure balloon at 40 atm. No dissections, perforations, or balloon rupture were seen in these instances of unexpandable stents, in-stent restenosis, or plaque preparation prior to stent implantation [14].

One kind of balloon is the cutting balloon (CB), which contains three or four microsurgical blades linked longitudinally across its surface. Another kind is the scoring balloon. By applying a concentrated force at relatively modest balloon inflation pressures, the device is able to make shallow cuts in the hardened atherosclerotic plaque. This reveals the inner, more elastic tissue of the artery, which may lead to better stent expansion and increased vascular compliance (Figure 3). As stated by Okura et al. in 2002,.

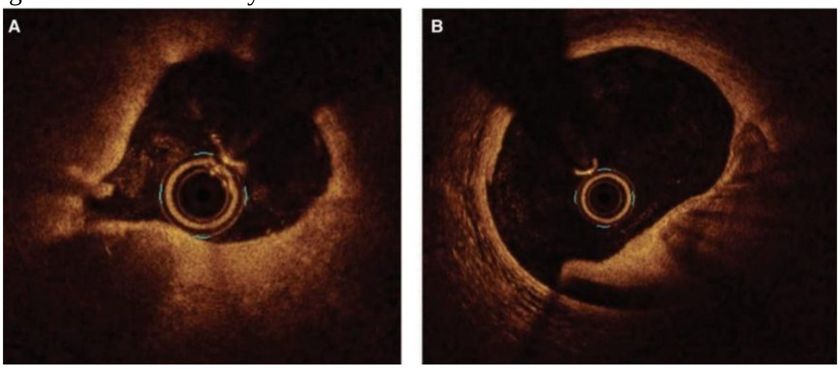

Fig. (2) Optical coherence tomography scans during balloon cutting. In the first place, prior to PVCI OCT scan shows a deep calcific nodule (0.90 mm) in the bottom left quadrant that is pressing on the vascular lumen. There is a 3.51 mm2 minimum luminal area in this section. Okura et al. (2002) found that an OCT picture taken just after a 1:1 sized cutting balloon enhanced the minimum luminal area to 7.52 mm2. The image also showed evidence of vascular preparation, with balloon-associated dissection visible at 7 and 9 o'clock.

Angiosculpt and Lacrosse NSE scoring balloons are semi-compliant and encased in a helical pattern of three or four rectangular struts made of nitinol [9].

In theory, the SB is an improved mechanical version of the CB that aims to make the procedure more deliverable by lowering mechanical stress to the vessel wall by concentrated force inflations. One possible advantage of scoring the arterial lumen over a typical CB is a decreased risk of coronary artery dissection without sacrificing the degree of luminal expansion [19].

The procedure known as intravascular lithotripsy (IVL)

The intravenous balloon catheter is the most recent development in CAC's balloon-based therapy arsenal. Using a common, reliable guidewire, the IVL balloon is enhanced. After positioning the balloon in the desired location, it is inflated to its nominal low pressure of 6 atm using up to 80 energy pulses per balloon, according to De Silva et al. [13].

The saline/contrast combination within the balloon is vaporized by the energy, which then produces high-amplitude ultrasonic pressure waves, which are the actual working mechanism. In both the inner and outer layers of the blood artery, the waves have a greater effect on calcium and other hard surfaces. This results in microfractures or circumferential fissures, which increase vascular compliance and change the shape of lesions (Figure 4), making it easier to expand devices like stents and balloons.

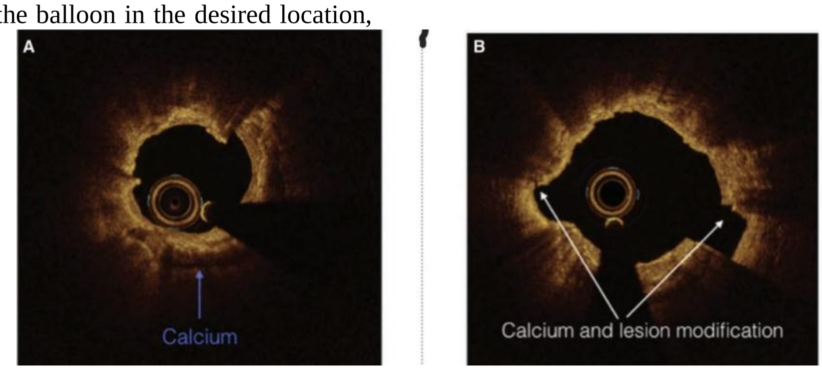

Fig. (3) OCT picture of intravascular lithotripsy. A, optical coherence tomography (OCT) scan of a 0.54 mm thick calcification arc spanning 180° (top right to bottom left quadrants). Microfractures may be seen in the optical coherence tomography (OCT) picture that follows intravascular lithotripsy (Ishihara et al., 2021).

According to Ali et al. (2017), low-pressure balloon-based techniques have the advantage of not mechanically traumatizing the vascular wall. This, in turn, reduces the risk of arterial problems and, perhaps, intimal damage, which are believed to occur after high-pressure BA.

This method was originally tested in a human experiment with intermediate to severely calcified coronary arteries in the Disrupt CAD (Shockwave Coronary Rx Lithoplasty Study in Coronary Artery Disease) (n=60). The device delivery success rate was 98.3%, and PCI was effective in treating the two patients who had coronary dissection. With a mean diameter stenosis of 73%, 78% of the lesions were concentric and heavily calcified. An ALG of 1.7±0.6 mm and a 6-month MACE of 8.5% were seen as a result of the IVL's usage. This included cardiac death (n=2 [3%]) and non-Q-wave MI (n=3 [5%]) (Brinton et al., 2018). The method effectively increases the minimum luminal area (4.16±1.86 vs 2.23±1.11 mm2; P<0.01), according to an OCT sub-group study (n=31) conducted by Ali et al. [2], without perforation or sluggish flow/no-reflow. These outcomes are achieved by ablation/atherectomy-based procedures. "The extraction of coronary atherectomy plaque"

Therapeutic Rotational Atherectomy (RA): RA involves inserting a specific 0.009-inch guidewire (Rotawire) into the coronary artery along with a diamond-encrusted elliptical burr. While avoiding softer elastic tissue, the burr spins at rates ranging from 140,000 to 220,000 rpm, abrading fibro-calcified, non-elastic tissue into microscopic particles (<10 µm). The smoother luminal surface, increased luminal diameter, and ease of balloon predilatation and stent installation are all results of lesion modification by debridement (Figure). The reticuloendothelial system removes lesion material as it moves downstream (Hansen et al., 1988).

Orbital Atherectomy (OA): This atheroablation technique gained FDA clearance in 2013, making it a relatively new development in the field. Utilized over a specialized 0.014" wire, this apparatus has a burr adorned with a diamond-coated crown that traverses the artery in an elliptical fashion. Absence of cutting action presumably decreases the probability of vessel perforation and creates smaller debris particles<2 µm, while the calcified lumen is abated by the crown's abrasive surface. Ablation also differs from RA in that it maintains a constant blood flow across the artery. These characteristics may lessen the chances of slow-flow/no reflow, lessen the severity of thermal damage, and eliminate the need for routinely using temporary pacing during OA. By adjusting the burr's speed, the operator may regulate the depth of the ablation by expanding the orbital diameter of the crown radially in response to increased centrifugal force. This improves the efficiency of the procedure by preventing the need to replace the burr several times. Because of the increased risk of vessel perforation caused by the elliptical mode of action, OA is not recommended for use in vessels with diameters less than 2.5 mm. Reddy et al. (2023) reported that the ORBIT studies evaluated the safety and effectiveness of OA.

Laser Thrombolysis: The Excimer Laser Coronary Atherectomy (ELCA) catheter uses short-wavelength, high-energy ultraviolet light pulses to cut carbon bonds in organic matter within the lesion. The resulting heat separates cellular debris, breaks the lesion into micro-particles, and allows for greater luminal expansion. A conventional 0.014" work-horse guidewire is used to guide the 0.9, 1.4, 1.7, or 2.0 mm ELCA catheter. Both the diameter of the vessel and the consistency of the plaque determine the catheter choice. Most typically, a 6F guide is used with a 0.9 mm catheter in vessels with a diameter greater than 2.0 mm. Historically, ELCA has mostly been used to prevent no-reflow in cases of intracoronary thrombus. The uneven supply of UV light energy in calcific lesions significantly enhances the risk of vascular dissection, however this generally happens simultaneously with major lesion change. As a result, the manufacturer cautions against using it in extensively calcified lesions. Evidence from case series is mounting that ELCA can be safely and effectively used in various situations involving fibro-calcific disease, such as chronic total occlusion recanalization, debulking native, vein graft disease, and in-stent restenosis with peri-stent calcium, even though there is a lack of data from large-scale trials [29].

The pros and cons of atherectomy and calcium modulation using balloons

Several technical and anatomical considerations, such as the lesion's location, the concentration of the calcium pool, the operator's experience and knowledge, and the availability of devices in the area, go into deciding which modification approach to utilize. The devices that may be utilized in the setting of different degrees of calcific illness are shown in Figure 13. Intracoronary imaging should be used to choose the best device for the specific lesion or artery, as it will help eliminate doubt and make the selection easier [41].

When dealing with balloon uncrossable lesions, the first line of defense is usually RA or OA to change the lesion's shape enough to deploy other devices. In many cases, nevertheless, lesion preparation prior to stent placement requires more than just one modification procedure. Imaging should be used systematically during procedures to assess the success of techniques, specifically with regard to ALG and calcium fractures. This helps to understand if the technique has adequately modified the lesion, which in turn determines if another device is needed and, if so, which device would be most beneficial.

Atherectomy and intravenous ligation combined as a complementary CAC modification

The use of intravenous ligation in conjunction with radial angiography (RA) or orbital angiography (OA) has been documented for the purpose of altering severely calcified coronary lesions in preparation for stent placement during percutaneous coronary intervention (PCI).

Exploratory MRI: Case studies and series have shown that a method that combines RA and IVL, sometimes called "rotatripsy," is effective in reducing CAC. In such circumstances, RA is often administered to debulk superficial CAC prior to the delivery of the IVL balloon to further prepare the lesion. Eight patients treated with OA in conjunction with the peripheral IVL system's off-label usage for CAC modification were the subjects of a single-center study published by Yarusi et al. in 2022.

Tools with demonstrated success for higher load of calcification include RA, OA, laser atherectomy, and, more recently, IVL. By stimulating fissures with ultrasonic pressure waves, IVL has provided a new way to overcome deeply buried calcium, allowing stent growth. Per Dash (2018). The IVL balloon catheter may have trouble passing through severely narrowed or extensively calcified lesions, however. Although a relatively high success rate was found in the DISRUPT-CAD III trial's cohort of patients, it is possible that the examined group had much smaller vascular diameter stenosis compared to a real-world population. According to recent guidelines, RA can help patients with fibrotic or heavily calcified lesions have a better procedural success. It can also be a good first step to take in case an IVL balloon doesn't cross [28]. The "RotaTripsy" technique, which involves RA followed by IVL, could potentially work together to treat both luminal and abluminal calcification in large coronary arteries. A case series combining RA with IVL was published not long ago (Buono et al., 2021), and the first publication of this combination was by Jurado-Roman et al., 2019. Nevertheless, IVL was not employed as an initial method but rather as a last resort in this case series. Patients having percutaneous coronary intervention (PCI) with calcified lesions still have an increased risk of major adverse cardiac events (MACEs), even if stent technology, medication, and PCI procedures have advanced. Because of its low risk of side effects and relative simplicity of administration, intravenous ligation (IVL) is quickly replacing traditional methods of treating highly calcified coronary lesions. But atherectomy is still a first-line treatment, especially when even low-profile balloons don't cross, as the DISRUPT CAD-II study's authors pointed out [3].

Also, atherectomy tools that help the IVL balloon catheter cross were not allowed in DISRUPT CAD III. Only 1.8% of patients in the DISRUPT III study were unable to pass the IVL balloon over the target lesions; however, this likely reflects selection bias [21].

Research has shown that there is a correlation between a larger burr-to-artery ratio and a higher risk of complications such as peri-procedural myocardial infarction and target-lesion revascularization. Consequently, aggressive strategies that use larger RA burr sizes (>0.70 burr-to-artery ratio) have not historically been more effective than less aggressive strategies with smaller burr sizes (≤0.70 burr-to-artery ratio). On top of that, 7-Fr and 8-Fr systems are needed for 2.0-mm and 2.15-mm burrs, respectively, and they have been linked to increased problems on their own. In a research by Guedeney et al., a 6-Fr guide system was used to effectively finish the surgery in most patients with a comparably bigger reference vessel size and a high degree of stenosis, using a much lower burr-to-artery ratio of 0.43 ± 0.05. The acknowledged limitations of PCI in patients with severe CAC are further highlighted by the observed fatality in this trial [16].

Orbital psycus: In our clinic, we follow the standard procedure for treating calcified stenoses: if the intravascular imaging catheter cannot pass the lesion due to moderate to strong angiographic calcification, which happened in 15 out of 24 instances (63%), upfront atherectomy is performed. When there isn't a lot of balloon-induced dissection, it's better to employ RA or OA upfront, although atherectomy may be used safely if the balloons don't inflate enough [10].

Several criteria determine whether RA or OA is the better option. To start, RA has a front-drilling function, which might be helpful when tiny balloons or microcatheters can't pass through calcified stenosis. Also, the 1.25-mm crown works in vessels with diameters between 2.5 and 4.0 mm, thus OA might be a better option for lengthy lesions or big veins. While RA may be limited by the size of the guiding catheter, OA may debulk calcium in vessels of varying diameters without increasing the burr size [43].

3. Conclusions:

In an all-comers cohort with substantially calcified coronary lesions, intravascular lithotripsy offers a viable method for lesion preparation with a high success rate, minimal procedural complications, and low incidence of major adverse cardiac events (MACEs). In cases when there is a significant amount of coronary calcium, coronary intravascular ligation (IVL) offers a novel, safe, and effective way to prepare the vessels for revascularization. We still don't know if IVL is better than the other approaches in this specific population. Improved IVL comparisons would aid in directing treatment choices for these individuals.

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