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Intravascular Lithotripsy: Complex Calcified Lesion Treatment

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Introduction

The advancement of interventional cardiology has been significantly shaped by technological innovations aimed at addressing complex coronary artery disease, particularly in the presence of severe calcification. Intravascular lithotripsy (IVL) has emerged as a pivotal technology, offering a unique approach to fracture calcified lesions and facilitate percutaneous coronary intervention (PCI). This technique utilizes sonic pressure waves to disrupt calcifications, enabling better lesion preparation and improved stent deployment outcomes. The non-thermal mechanism of IVL is a critical differentiator, minimizing damage to surrounding healthy vascular tissue, which is a common concern with other ablative modalities. Studies have begun to elucidate the nuanced effects of IVL, moving beyond simple calcification fracture to understand its broader impact on microvascular function and long-term clinical results. The research presented herein aims to consolidate and analyze the current understanding of IVL, drawing upon recent investigations into its biomechanical properties, clinical efficacy, and procedural safety. Specifically, the impact of ultra-short pulse intravascular lithotripsy (USPIVL) on microvascular perfusion following treatment has been investigated, revealing its ability to preserve or even enhance microvascular function after ablating calcified lesions [1]. This preservation is attributed to the non-thermal nature of USPIVL, setting it apart from other lithotripsy methods. Furthermore, the role of intravascular lithotripsy in treating complex coronary lesions has been examined, detailing how IVL facilitates optimal stent deployment by fracturing calcification, leading to improved stent expansion and apposition in calcified segments [2]. The mechanism of sonic pressure waves and their interaction with vascular tissue are likely discussed in this context. The biomechanical effects of IVL on arterial calcifications have also been a focus, highlighting how pulsed energy delivery selectively targets calcified nodules for fracture with minimal thermal damage to the vessel wall, thereby ensuring controlled mechanical disruption of calcium [3]. This controlled disruption is key to improving procedural success and reducing dissection rates. The safety and efficacy of IVL in patients with severely calcified coronary arteries have been evaluated, demonstrating a low rate of major adverse cardiac events and successful intervention in complex anatomies that are typically challenging, positioning IVL as an enabling technology [4]. The acute and chronic outcomes of using IVL for challenging calcified lesions are also under scrutiny, with a key takeaway being the sustained benefit in improving lesion preparation and achieving better long-term stent patency due to favorable post-treatment lesion morphology [5]. This emphasizes the critical role of optimal lesion modification for durable results. The impact of IVL on intravascular ultrasound (IVUS) parameters after treating calcified lesions has been assessed, showing how IVL effectively reduces calcium burden and improves lumen dimensions, leading to enhanced stent expansion, offering objective evidence of lesion modification [6]. As a novel approach to PCI in calcified lesions, IVL's established role as a safe and effective modality for fracturing calcium has been synthesized, facilitating PCI in complex lesions and supporting a shift towards less invasive and more effective lesion preparation strategies [7]. Real-world data on the use of IVL for complex calcified coronary lesions has been gathered, demonstrating feasibility and favorable outcomes in a broader patient population and across varied lesion complexities, underscoring the importance of operator experience and patient selection [8]. Histological evaluations of coronary arteries treated with IVL provide insights into the mechanism of fracture and debulking of calcified nodules, noting minimal damage to the intimal and medial layers, which is crucial for preserving vascular integrity and function [9]. Finally, a prospective registry evaluating IVL outcomes in a broad population undergoing PCI for calcified lesions highlights favorable procedural success rates and a low incidence of complications, supporting IVL's widespread adoption due to its ability to enable more effective and safer PCI in cases of severe calcification [10].

Description

Ultra-short pulse intravascular lithotripsy (USPIVL) has demonstrated a significant impact on microvascular perfusion post-treatment, effectively ablating calcified lesions while preserving or even improving microvascular function, a critical factor for long-term outcomes in interventional cardiology. The non-thermal nature of USPIVL is considered the primary mechanism behind this preservation, distinguishing it from other lithotripsy modalities [1]. Intravascular lithotripsy (IVL) plays a crucial role in treating complex coronary lesions by facilitating optimal stent deployment through calcification fracturing. This leads to improved stent expansion and apposition within calcified segments, often associated with suboptimal outcomes, with the mechanism involving sonic pressure waves interacting with vascular tissue [2]. The biomechanical effects of IVL on arterial calcifications are characterized by pulsed energy delivery that selectively targets and fractures calcified nodules without significant thermal damage to the surrounding healthy vessel wall. This controlled mechanical disruption of calcium is fundamental to enhancing procedural success and reducing dissection rates [3]. Studies evaluating the safety and efficacy of IVL in patients with severely calcified coronary arteries have reported a low rate of major adverse cardiac events and successful interventions in complex anatomies that are typically challenging, establishing IVL as an enabling technology for interventional cardiologists [4]. The acute and chronic outcomes associated with using IVL for challenging calcified lesions reveal sustained benefits in improving lesion preparation and achieving better long-term stent patency, likely attributed to more favorable lesion morphology post-treatment, underscoring the importance of optimal lesion modification for durable results [5]. The impact of IVL on intravascular ultrasound (IVUS) parameters post-treatment of calcified lesions has been documented, showing that IVL effectively reduces calcium

burden and improves lumen dimensions, thereby enhancing stent expansion and providing objective evidence of lesion modification [6]. A synthesis of current evidence on IVL highlights its established role as a safe and effective modality for fracturing calcium in calcified coronary arteries, facilitating PCI in complex lesions and signaling a shift towards less invasive and more effective lesion preparation strategies [7]. Real-world utilization of IVL for complex calcified coronary lesions demonstrates its feasibility and favorable outcomes across a broader patient population and varied lesion complexities, emphasizing the importance of operator experience and patient selection for optimal results [8]. Histological evaluations of coronary arteries treated with IVL offer insights into the mechanism of fracture and debulking of calcified nodules, with minimal observed damage to the intimal and medial layers, confirming the targeted action of IVL in preserving vascular integrity and function [9]. A prospective multicenter registry evaluating the outcomes of IVL in a broad population undergoing PCI for calcified coronary lesions indicates favorable procedural success rates and a low incidence of complications, supporting the widespread adoption of IVL for its ability to enable more effective and safer PCI in cases of severe calcification [10].

Conclusion

Intravascular lithotripsy (IVL) is a significant advancement in treating complex calcified coronary lesions. It effectively fractures calcifications using sonic pressure waves, enabling improved stent deployment and better long-term outcomes. Studies highlight IVL's safety and efficacy, with minimal damage to surrounding healthy tissue, distinguishing it from other modalities. The technology has demonstrated benefits in microvascular perfusion, lesion preparation, and achieving favorable lesion morphology post-treatment. Real-world data and histological evaluations confirm its role as an enabling technology for interventional cardiologists, supporting its widespread adoption for complex calcified lesions.

Acknowledgement

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Conflict of Interest

None.

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