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Letter

RESEARCH LETTER

Intravascular Lithotripsy on Concentric, Eccentric, and Extrastent Calcium

Insights From a Bench Test Model

Intravascular lithotripsy (IVL) has emerged as an important weapon for treatment of severe calcified coronary artery disease (1). A coronary IVL balloon uses electrical energy to initiate expanding and collapsing bubbles that generate circumferential sonic pressure to selectively fracture calcium within the arterial wall. Although IVL effectively creates fractures in concentric calcium plaque, its efficacy on eccentric calcium, extrastent calcium, and calcium in bifurcation are less well studied. Using a bench test model, we aimed to evaluate the performance of an IVL balloon in eccentric, extrastent, and bifurcation calcified plaque.

The ex vivo vessel model was created by a polyjet 3-dimensional printer (J750 Digital Anatomy, Stratasys) with the material set as compliant blood vessels. Calcium models made of gypsum (outer diameter: 4.7 mm; inner diameter: 2.3 mm; length: 4 mm) were inserted manually into the vessel model (outer diameter: 8 mm; inner diameter: 4 mm) to simulate various anatomical situations. A 3.0-/12-mm IVL balloon (Shockwave Medical) was inflated to 4 atm, and IVL was delivered at 10 pulses per cycle. **Figures 1A to 1C** demonstrate the effect of IVL on the 180° eccentric and 360° concentric calcium models (Video 1). There were visible fractures (red arrowheads and asterisks) on concentric and eccentric calcium at 1 (**Figures 1Ai to 1Aiv**) and 4 cycles of IVL (**Figures 1Bi to 1Biv**), respectively. However, we could not see any fracture in 90° eccentric calcium even after 8 cycles of IVL (**Figures 1Ci to 1Civ**). In **Figures 1D and 1E**, an extrastent calcium model was made by deploying a 2.75/19 mm stent (Coroflex, B Braun) inside the vessel model (Video 2). After 1 cycle of IVL, we did not see any fractures in the concentric calcium (**Figure 1Di to 1Div**). After 8 cycles of IVL, we saw fractures in the concentric calcium and 1 fracture in the 180° eccentric calcium (**Figure 1Ei to 1Eiv**). **Figure 1F to 1H** shows the calcium bifurcation model (Video 3). IVL effectively produced fractures in concentric calcium after 1 cycle of IVL (**Figures 1Fi to 1Fiv**). Nevertheless, for 180° eccentric calcium opposite or proximal to the side branch ostium, we did not find any fracture even after 8 cycles of IVL (**Figures 1G and 1Hi to 1Hiv**).

In summary, IVL is effective for concentric calcium because we could almost always see transgypsum fractures upon the first few pulses we delivered, even around bifurcation. IVL efficacy generally reduces when the calcium arc is smaller or outside a metallic stent frame. Nevertheless, this bench test model could not fully mimic an in vivo situation. First, coronary calcified plaques are composed of various degrees of calcium, lipid, and fibrous tissue. They can exist in different forms (eg, superficial, deep, or nodular calcium). Concentric and eccentric calcium can have variable thickness along the arc, and they coexist with atherosclerotic plaques in a random manner. Moreover, we did not assess the effect of IVL on gypsum under a microscope; possible microcracks might have improved vessel compliance in vivo. Therefore, clinical research is needed to understand the effect of IVL on different calcium morphologies.

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

REFERENCE

1. Hill JM, Kereiakes DJ, Shlofmitz RA, et al. Intravascular lithotripsy for treatment of severely calcified coronary artery disease. *J Am Coll Cardiol*. 2020;76(22):2635-2646.

APPENDIX For supplemental videos, please see the online version of this paper.

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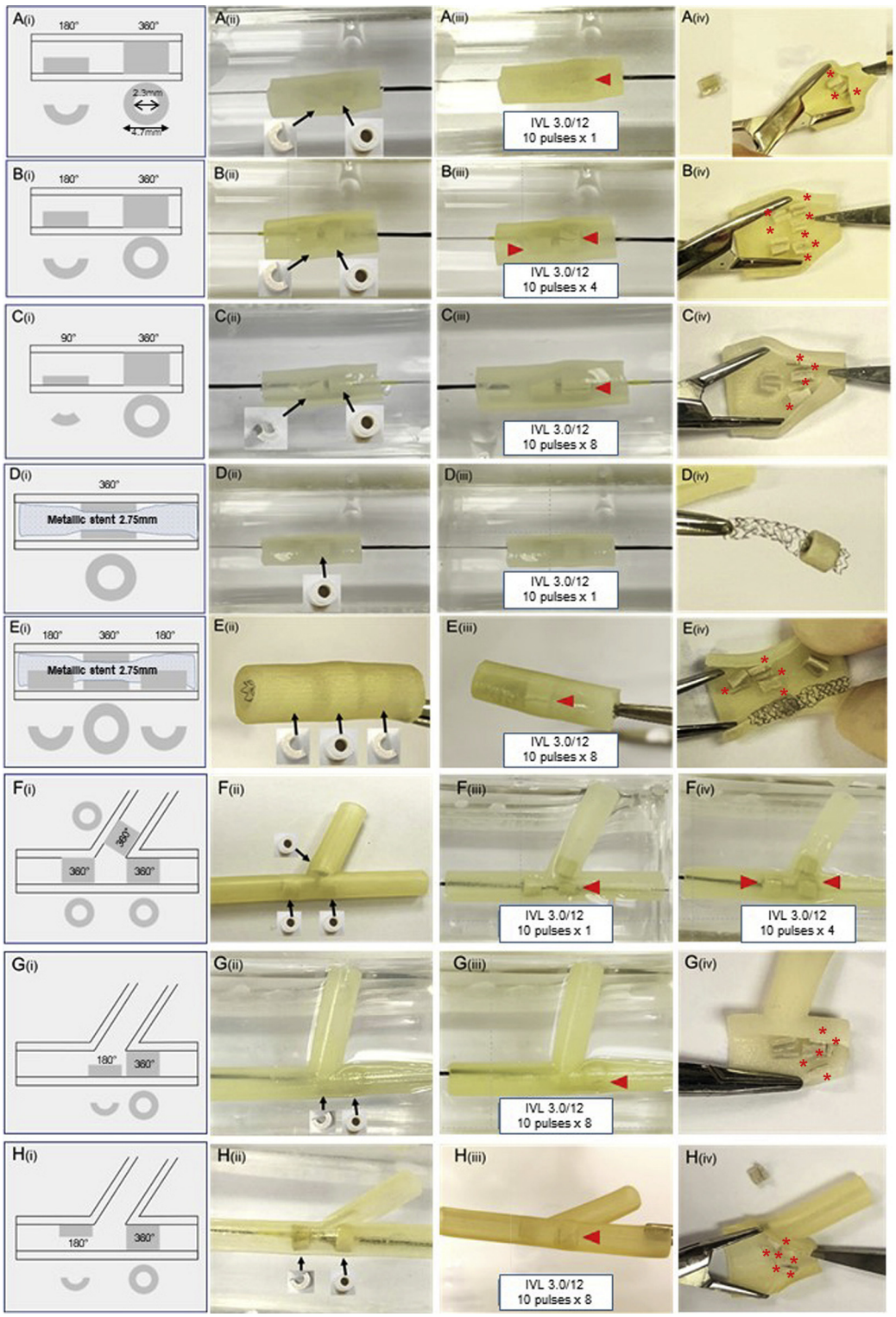
FIGURE 1 **Effect of IVL on Concentric, Eccentric, Extrastent and Bifurcation Calcium**



(A, B, C) Intravascular lithotripsy (IVL) on 90°/180° eccentric calcium and 360° concentric calcium. **(D and E)** Extra-stent calcium. **(F, G, H)** Bifurcation calcium. **Red arrowheads** denote the visible fractures on the gypsum after IVL. **Red asterisks** denote the number of visible fractures on the gypsum after careful dissection of the vessel model.