Structural Heart 6 (2022) 100023

Articles and Issues Available at ScienceDirect

Structural Heart

journal homepage: www.structuralheartjournal.org

Research Correspondence

Efficacy of a Novel Posterior Leaflet Repair Device to Treat Secondary Mitral Regurgitation Using an Ex Vivo Heart Model

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ARTICLE INFO

Article history:
Submitted 19 September 2021
Revised 22 November 2021
Accepted 14 January 2022
Available online 2 April 2022

Keywords:
Posterior leaflet repair
Secondardy mitral regurgitation
Valvular regurgitation

Mitral regurgitation is one of the most prevalent valvular disorders. It has numerous etiologies grouped as primary typically because of underlying degenerative leaflet disease, or secondary mitral regurgitation (SMR), most commonly because of geometrical distortion of the left ventricle (LV) impacting the functional integrity of the valvular apparatus.[1] Specifically for SMR, LV dilation and dysfunction lead to papillary muscle displacement, annular dilation, and apical tethering of the leaflets with restricted mobility, predominantly affecting the posterior leaflet.

Beyond pharmacological therapy targeted to improve LV function, mitral valve (MV) interventional options in SMR are limited, with a lack of robust data to support isolated MV surgery. Only recently has the U.S. Food and Drug Administration approved MitraClip (Abbott) therapy for treating SMR based on randomized trials proving the concept that reducing MR can reduce mortality and hospital admissions in patients with heart failure.[2,3] These exciting new data have led to the development of multiple transcatheter MV technologies to treat SMR with innovative devices. In this study, we report on an innovative device that targets correcting the tethered leaflet in SMR.

The device (Mitria Medical, Cleveland, OH) studied is a braided Nitinol implant, where a portion of the device sits subannular between the posterior leaflet and LV free wall. The Mitria device is placed by puncturing the MV annulus at the desired implant location and then is delivered through known transcatheter techniques. It consists of a smaller bulb that sits supra-annular to anchor the device, while broad support to the leaflet and subvalvular apparatus is provided by the larger diameter bulb that sits subannular. As posterior leaflet motion can be restricted because of tethering from the displaced papillary muscles in SMR (Figure 1a), the Mitria device works by re-orienting the posterior leaflet and chordae tendineae anteriorly to improve coaptation (Figure 1b). By targeting manipulation of only the posterior mitral leaflet, the Mitria device preserves anterior leaflet motion, as well as other transcatheter options in the future. Although subvalvular techniques have been described in surgical repair for SMR, there is not a direct surgical predicate for the Mitria device approach, and therefore, we explored the potential efficacy of this approach through an ex vivo model that was intended to simulate SMR.

The ex vivo left heart simulator (Figure 1c), which has been previously reported and used to explore the mechanism and treatment of MV dysfunction,[4,5] consists of a three-dimensional (3D printed) left heart chamber connected to a pulsatile pump to allow for circulation of a test fluid at 70 beats per minute under physiologic pressures. The simulator includes pressure transducers and flow probes to allow for continuous data collection during testing, and normal saline was used as the test fluid instead of a blood analog solution due to the latter's incompatibility with the electromagnetic flowmeters. Excised cadaver MVs are integrated into the 3D printed left heart chamber through a sewing plate that sits between the left atrial and left ventricular

Abbreviations: LV, left ventricle; MR, mitral regurgitation; MV, mitral valve; SMR, secondary mitral regurgitation.

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https://doi.org/10.1016/j.shj.2022.100023

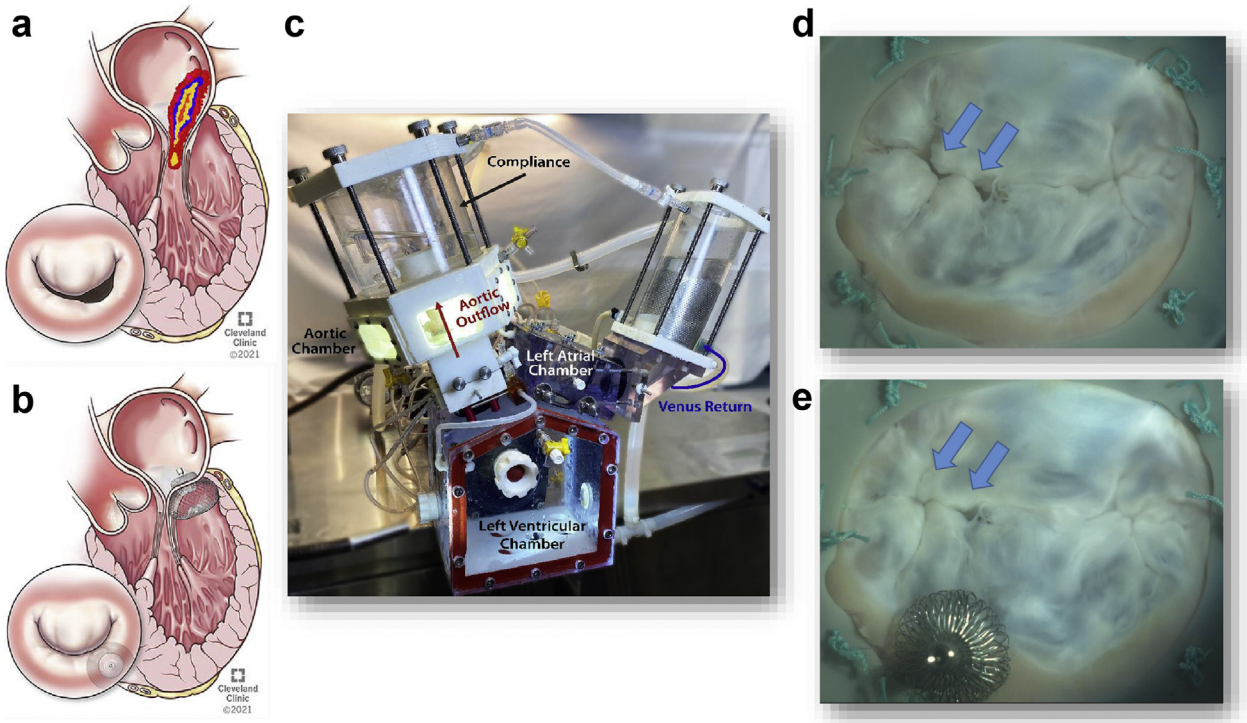

Figure 1. (a) Posterior leaflet motion is restricted due to tethering from the displaced papillary muscles resulting in regurgitation; (b) Mitria device re-orients the chordae tendineae and posterior leaflet anteriorly to improve coaptation; (c) the left heart simulator setup used for the ex vivo testing; (d) baseline example from one of the valves tested where a lateral regurgitant jet becomes evident (arrows); and (e) after placement of the Mitria device in the valve from (d), there is subsequent improvement in coaptation (arrows). Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2022. All Rights Reserved.

chambers. In our testing, the MV annulus, leaflets, chordae tendineae, papillary muscles, posterior LV wall, and surrounding left atrial tissue were excised from 4 normal porcine hearts. The MV annulus was sutured into the simulator, and the papillary muscles were mounted onto adjustable holders that resided in the ventricular chamber of the left heart simulator. The posterior LV wall was also preserved, as the Mitria device sits between the LV wall and posterior leaflet. At baseline, SMR was simulated by forcefully dilating the annulus and displacing the papillary muscle holders until the leaflets became tethered (Figure 1d). The primary regurgitant jet was centrolateral in 2 models and centromedial in the other 2 models. The Mitria device was delivered through the posterior annulus in the region of regurgitation (Figure 1e) for each model. The left heart simulator ran for approximately 5 minutes before data acquisition, and then 10 cardiac cycles of data were collected and averaged for the baseline condition and the repair condition (i.e., after device implantation) using the pressure transducers and flow probes. The ex vivo model was intended to simulate physiologic pressures and flows and thus provide results that are likely to be representative of hemodynamic data.

All 4 MVs tested showed improvement in regurgitation and other relevant hemodynamic data after the placement of the Mitria device. The mean regurgitant fraction decreased from 42.41% at baseline to 15.69% after repair (63% reduction), with a corresponding increase of the mean effective stroke volume from 46.34 to 55.55 mL (20% increase). Also, the mean arterial pressure and mitral cardiac output for all 4 simulations increased from 66.41 mm Hg and 3.24 L/min at baseline to 80.22 mm Hg and 3.89 L/min after device placement (21% and 20% increase), respectively.

Using this innovative ex vivo model, we demonstrate the efficacy of a novel device to reduce MR in an objective and quantitative manner.

Ethics Statement

The research reported in this Correspondence has adhered to the relevant ethical guidelines.

Funding

The authors have no funding to report.

Disclosure Statement

SRK, TJH, and JLM are named inventors on licensed patents concerning the Mitria Medical device. SCH provides consulting for Mitria Medical.

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