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Annulus tension of the prolapsed mitral valve corrected by edge-to-edge repair

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ABSTRACT

Background: Mitral valve (MV) performance after edge-to-edge repair (ETER) without ring annuloplasty is suboptimal. ETER efficacy needs to be evaluated from annulus tension (AT) of a prolapsed MV corrected by ETER to understand annular dilatation.

Methods: Ten porcine MVs were harvested and mounted on a MV closure test rig. The MV annulus tissue rested on top of a saddle-shaped plastic ring on which the annulus could slide freely. The annulus was held by strings in the periphery during MV closure under a hydrostatic trans-mitral pressure. String tensions were measured and further divided by string spacing to obtain AT. The MVs were then prolapsed by shifting split papillary muscles to simulate mono-leaflet prolapse due to elongation of chords, which insert into a single leaflet. Last, MV prolapse was corrected by ETER applied in the central leaflet region and AT was measured.

Results: AT in both anterior and posterior leaflet prolapse corrected by ETER was less than that of normal MVs. AT in the anterior leaflet prolapse corrected by ETER was less than that in the posterior leaflet prolapse corrected by ETER.

Conclusion: ETER does not restore the normal AT and therefore leads potential of annular dilatation. The anterior leaflet prolapse has a greater potential of annular dilatation than the posterior leaflet prolapse after ETER. Annuloplasty is recommended to maintain long-term ETER efficacy.

1. Introduction

Mitral valve (MV) prolapse is a typical disease of the MV caused by papillary muscle elongation, chordal elongation or rupture, or enlarged leaflets, and is responsible for mitral regurgitation. A repair technique known as edge-to-edge repair (ETER) has been used extensively to correct MV prolapse (Alfieri et al., 2001; Fucci et al., 1995). ETER is most commonly performed on the center of the main scallop of leaflets with ring annuloplasty, which is required to reshape the annulus and reduce the annular orifice (Alfieri et al., 2001). ETER performed without ring annuloplasty yields suboptimal midterm results when compared to ETER, performed with annuloplasty (Maisano et al., 2003; Timek et al., 2003). Annular dilatation may persist after ETER without annuloplasty. Therefore, the success of ETER largely depends on the use of ring annuloplasty and ETER is thus considered as a secondary procedure. It elicits a question: why does ETER not prevent the MV from annular dilatation in the long run? Therefore we investigated annulus tension (AT) in ETER using a novel system that is able to reveal the mechanism of annular dilatation (Bhattacharya and He, 2009; He and Bhattacharya, 2008; He and Bhattacharya, 2010).

We proposed a mechanism of annulus dilatation that mitral annulus dilatation is a consequence of imbalanced annulus mechanics between the centripetal mitral leaflet tension and centrifugal left ventricle myocardial force at annulus in systole. AT is defined as a leaflet tension force at the annulus per unit length of the annulus perimeter. The MV leaflets and left ventricular myocardium are in force equilibrium at the annulus during MV closure in the normal heart without initiation of annulus dilatation. This equilibrium implies that AT is equal to and thus interpreted as myocardial force in the normal MV-left ventricle system. Alteration in either one due to pathologies will break the equilibrium, which ultimately results in annulus geometry changes such as annulus dilatation. We found that AT decreases in MV bileaflet prolapse due to papillary muscle elongation and is thus lower than the normal left ventricular myocardial force (He and Bhattacharya, 2008). This imbalanced annular mechanics due to MV bi-leaflet prolapse causes annular dilatation even in the normal left ventricle according to the mechanism of annular dilatation. This mechanism has successfully explained some MV physiologies and pathologies on the MV annulus, especially in the normal left ventricle size (Bhattacharya and He, 2009; He and Bhattacharya, 2008; He and Bhattacharya,

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2010). In addition, clinical study reports annular dilatation without any pathology in a normal left ventricle, also called as "pure annular dilatation" (Glower et al., 2009). This pure annular dilatation could also be caused by imbalanced annular mechanics. Now we have a question about MV prolapse: can it be corrected by ETER without further annulus dilatation? Therefore, the objective of this research was to understand AT of a prolapsed MV corrected by ETER.

2. Methods

2.1. MV closure test rig and annulus tension measurement

We followed the same method for AT measurement as described in our earlier papers (Bhattacharya and He, 2009; He and Bhattacharya, 2010). A total of ten fresh porcine hearts were obtained from a local slaughterhouse and transported to the lab. The MVs of annulus size M36 measured in an Edwards ring sizer (Edwards LifeSciences LLC, Irvine, CA) were selected and dissected from porcine hearts. Each MV was mounted in a MV closure test rig, which was designed to measure the AT at a static trans-mitral pressure shown in Fig. 1. Each MV was mounted on the plastic ring glued on the annulus mounting board, with the MV annulus coinciding with the plastic ring. The ring had a saddle shape and a 5 mm saddle height as shown in Fig. 2, because the ratio of the saddle height to intercommissural diameter is usually 15% in a prolapsed MV (Grewal et al., 2010). The annulus ring was made according to M36 on an Edwards ring sizer, and the ring area and perimeter were 7.63 cm^2 and 122 mm, respectively. The commissural axis length was 35 mm, and the septal-lateral axis length was 30 mm. The annulus mounting board separated the atrium in the bottom chamber and left ventricle in the top chamber. The atrial chamber had an opening below the MV, which was connected through a plastic pipe to a lower reservoir. The left ventricle chamber was open to the air and contained saline in which the MV was immersed. The papillary muscles were sutured to two papillary muscle holders made of steel rods, the positions of which could be adjusted three-dimensionally. A static trans-mitral pressure was built up by the difference in the saline levels of the two reservoirs when the MV closed. Any leakage across the MV was measured in a measuring cylinder through a PVC hose in the downstream of the MV. When the MV closed under a trans-mitral pressure, the MV annulus tended to shrink towards the center of the MV orifice. Strings connected to MV annulus, prevented the MV

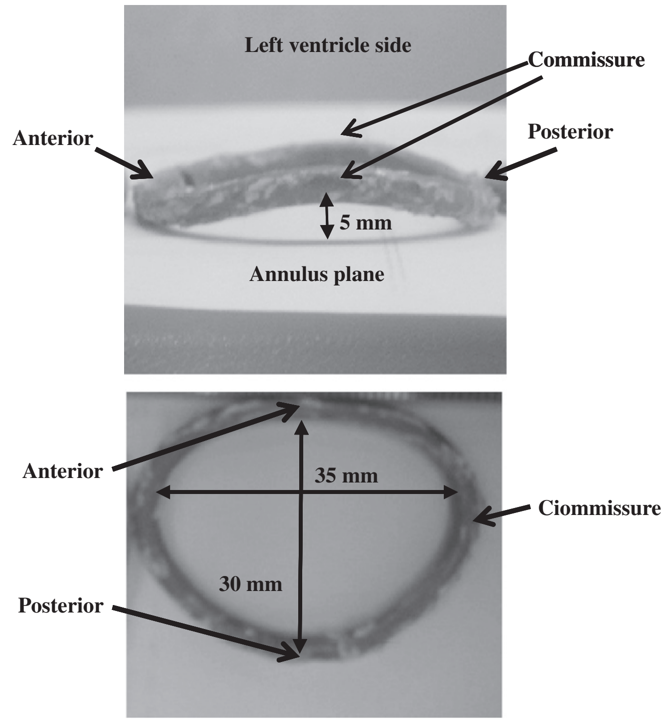

Fig. 2. A picture of normal annulus support ring with 5 mm saddle height made according to the M36 Edwards ring sizer.

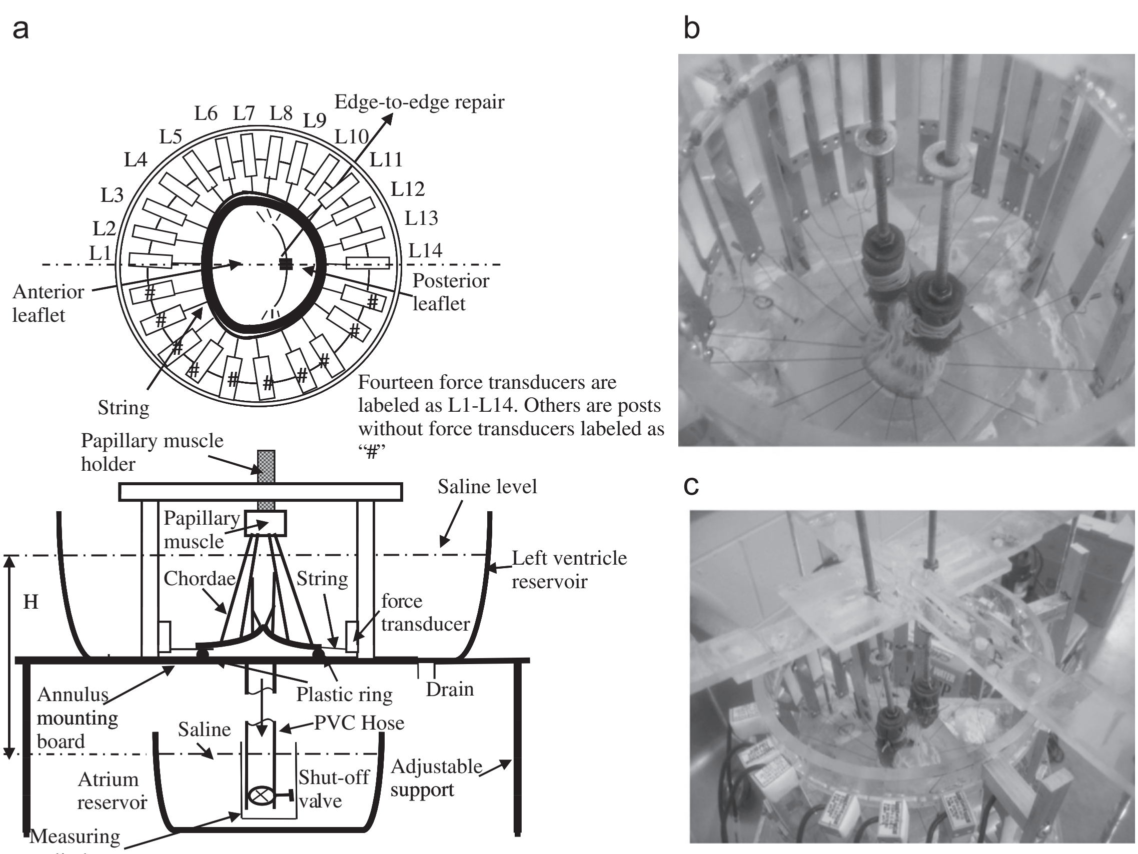

Fig. 1. (a) Schematic of the MV closure test rig for AT measurement system, (b) and (c) Photograph of the actual test rig for AT measurement system.