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New Methods

Posterior Papillary Muscle Suspension for Treating Systolic Anterior Motion in Hypertrophic Obstructive Cardiomyopathy

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Systolic anterior motion of the anterior mitral leaflet can persist after ventricular septal myectomy for obstructive hypertrophic cardiomyopathy, resulting in residual pressure gradients and mitral regurgitation. However, additional procedures for systolic anterior motion involving mitral valve leaflet suturing and resection may lead to future valve disease. Therefore, we adopted posterior papillary muscle suspension, a subvalvular procedure for functional mitral regurgitation, to treat systolic anterior motion without directly intervening in the mitral valve leaflets. Papillary muscle suspension toward the posterior mitral annulus moved the papillary muscles away from the interventricular septum and successfully eliminated the systolic anterior motion and midventricular pressure gradient. In terms of avoiding direct mitral interventions, this procedure is a viable option for systolic anterior motion, especially in cases of very mild mitral regurgitation.

Keywords: obstructive hypertrophic cardiomyopathy, systolic anterior motion, papillary muscle suspension, mitral valve repair

Introduction

Systolic anterior motion (SAM) of the anterior mitral leaflet is frequently observed in hypertrophic obstructive cardiomyopathy (HOCM) and exacerbates the pressure gradient (PG) in the left ventricular outflow tract (LVOT) and mitral regurgitation (MR). Although transaortic septal myectomy is the first-line treatment, SAM can persist even after sufficient myectomy.[1)] Various surgical techniques have been proposed to address SAM.[2)] However, some of these techniques involve suturing and resecting the mitral valve leaflets, which may increase the risk of future mitral valve disease. Papillary muscle suspension (PMS) was initially developed to treat ventricular functional MR.[3)] Posterior PMS, in which the papillary muscles are suspended toward the posterior mitral annulus, has an anti-SAM effect because it results in a posterior shift of the mitral valve coaptation line, exaggerates posterior mitral tethering, and bends the transmitral blood flow posteriorly. Herein, we present a simple technique for the successful release of SAM using posterior PMS with septal myectomy without mitral leaflet interventions.

Technique

After commencing a standard cardiopulmonary bypass through median sternotomy, cardioplegic cardiac

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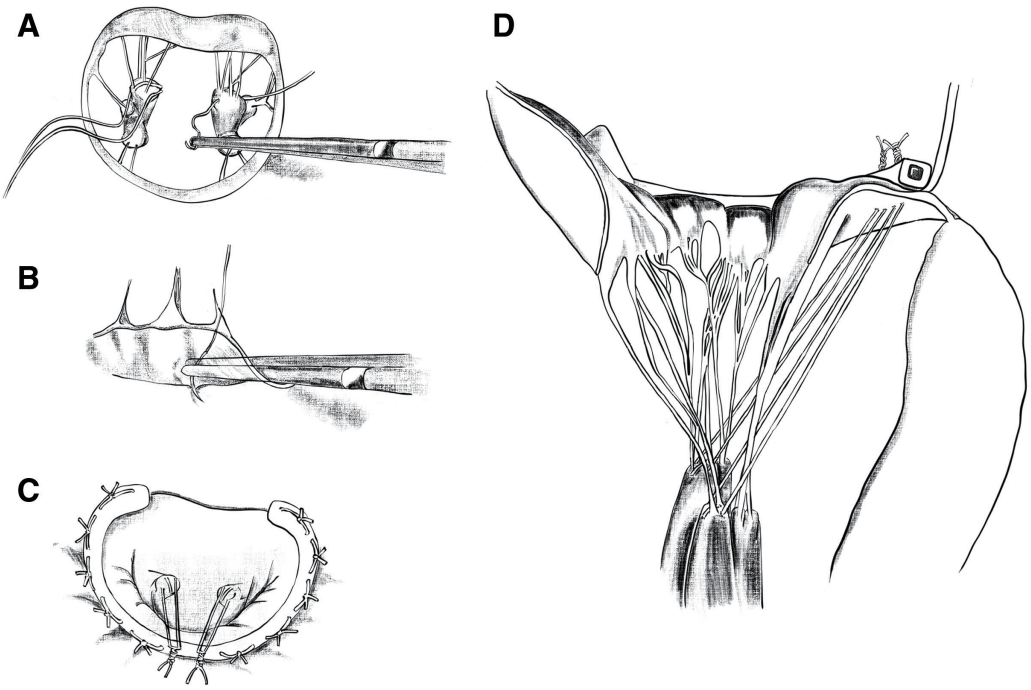

Fig. 1 Illustration of the posterior papillary muscle suspension technique. Polytetrafluoroethylene sutures are placed on the anterior heads of both papillary muscles (**A**). After passing the sutures through the posterior mitral annulus and an annuloplasty ring, they are pulled sufficiently and tied to the ring (**B, C**). The papillary muscles are suspended posteriorly (**D**).

arrest was achieved. First, extended left ventricular septal myectomy was performed through an ascending aortic incision. Second, the left atrium was opened using a transseptal approach. After inspecting the mitral valve coaptation, the subvalvular apparatus was visualized. A double-armed polytetrafluoroethylene suture (CV-4 Gore-Tex® Suture; W. L. Gore & Associates Inc., Newark, DE, USA) was placed in a figure-of-8 fashion on the anterior heads of the anterior and posterior papillary muscles (**Fig. 1A**). The sutures were passed through the middle of the posterior mitral annulus from the ventricular side to the atrial side (**Fig. 1B**). A true-sized partial annuloplasty ring (CG Future Annuloplasty Band; Medtronic Inc., Minneapolis, MN, USA) was placed, and the CV-4 sutures were passed through the ring. A saline test was performed to confirm mitral valve competence and to adjust the extent of PMS. By pulling the CV-4 sutures toward the atrial side, the mitral valve coaptation line was moved toward the posterior annulus (**Fig. 1C**). The CV-4 sutures were tied after being pulled until the coaptation line almost touched the posterior annulus (**Fig. 1D**). The procedure was completed after the left atrium and ascending aorta were closed (**Video 1**).

To date, this procedure has been performed in two patients with HOCM and SAM (a woman in her 50s and a man in his 50s). The interventricular septal thickness was 21 mm and 20 mm; the height of the mitral valve was 25 mm and 22 mm; the LVOT-PG was 65 mmHg and 73 mmHg; and the severity of MR was mild and moderate, respectively, in these two patients. Preoperative magnetic resonance imaging (MRI) showed no obvious abnormalities in the papillary muscles other than mild hypertrophy. No abnormal chordae tendineae were observed during the operation. The first patient underwent posterior PMS alone during the second aortic cross-clamp for 50 min due to residual SAM after extended septal myectomy. The cross-clamp time in the second patient was 169 min. The postoperative course was uneventful, with trivial MR and no SAM on postoperative echocardiography for both patients. The postoperative LVOT-PG was 26 mmHg and 5.6 mmHg, respectively. The postoperative MRI revealed an increase in the anterior-to-posterior leaflet height ratio (**Supplemental Table 1**). Four-dimensional flow MRI in the second patient revealed a decrease in color flow striking the posterior aspect of the mitral valve leaflets (**Fig. 2**) (**Video 2**).

Discussion

SAM is caused by an abnormal intraventricular blood flow in early systole, which strikes the posterior

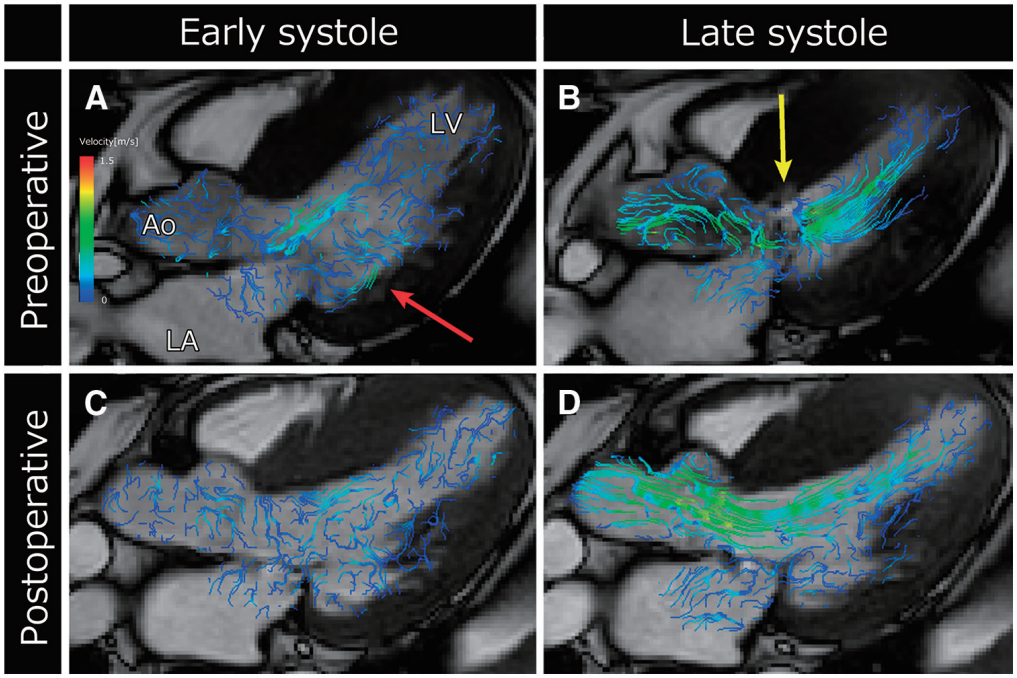

Fig. 2 4D flow MRI before and after surgery. The red arrow points to the color flow impacting the posterior surface of the mitral leaflet (**A**). The yellow arrow represents the blockage of flow by the mitral valve (**B**). After posterior PMS, flow impacting the mitral leaflet is resolved (**C**), and orderly flow is observed in the outflow tract (**D**). MRI: magnetic resonance imaging; LA: left atrium; LV: left ventricle; Ao: aorta; PMS: papillary muscle suspension

aspect of the mitral valve leaflets and sweeps them toward the septum. This phenomenon is caused by the elongation of the anterior mitral leaflet and the anterior positioning of the anterolateral papillary muscle.[2] Therefore, posterior PMS is a reasonable procedure for treating SAM, as it tethers the leaflets posteriorly and prevents them from being swept toward the septum.[4] Similar procedures that address the papillary muscles to treat SAM have been reported previously. Hodges approximated the heads of both anterior and posterior papillary muscles to move the mitral coaptation away from the outflow tract.[5] Sakaguchi more aggressively reoriented the papillary muscles by suture fixation of the approximated anterior and posterior papillary muscle heads to the posterior ventricular wall.[6] The key difference between the previously reported reorientation procedures and our posterior PMS was the adjustability and confirmability of the anti-SAM effect, which depended on the extent of suspension in posterior PMS. A posterior movement of the mitral coaptation line was securely achieved by adjusting the extent of suspension using a saline test of the mitral valve. Suspending the papillary muscles to the extent that the coaptation line nearly reached the posterior annulus successfully eliminated SAM. However, care should be taken to avoid excessive suspension, as this may induce mitral valve prolapse. The length of PMS can be predicted through the use of perioperative imaging modalities in the future. Additionally, a partial annuloplasty ring was required to achieve sufficient suspension without deforming the annulus or reducing the anteroposterior diameter of the mitral valve. Significant hypertrophy of the papillary muscles can attenuate the anti-SAM effect of papillary muscle procedures. For such patients, mitral valve replacement with resection of the papillary muscles may be effective. Careful follow-up is necessary, and more cases are required to clarify the indications and limitations of the procedure.

Conclusion

Posterior PMS is a simple and viable option to treat SAM without direct interventions on the mitral valve leaflet.

Declarations

Ethics approval and consent to participate

We obtained written informed consent from the patient for participation.

Consent for publication

We obtained written informed consent from the patient for publication.

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Data availability statement

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Authors' contributions

T.I. wrote most of the manuscript, and S.W. conceived the configuration of the study. All other authors have read and approved the manuscript.

Disclosure statement

The authors declare that they have no conflict of interest, nor competing interests.

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