Spiral suspension, a novel repair technique for severe functional tricuspid regurgitation

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▶ Video clip is available online.

In patients with severely tethered leaflets, repair with ring annuloplasty alone results in residual or recurrent tricuspid regurgitation (TR).¹ Accordingly, our team has developed a technique that we call “spiral suspension” as a novel approach to papillary muscle (PM) relocation.

Various terminologies are used for the 3 leaflets in the tricuspid valve,^{2,3} but they should be described as anterosuperior, septal, and inferior leaflets because they

are located within the body.² In our procedure, the anterior PM, the accessory PM for the inferior leaflet (accessory inferior PM), and the inferior PM were approximated and

Schematic suture for the spiral suspension.

Central Message

With precise knowledge of tricuspid subvalvular anatomy, spiral suspension is a technically less demanding procedure that potentially enables the surgeon to reduce leaflet tethering and secure coaptation.

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FIGURE 1. A, Schematic suture is depicted. Inferior papillary muscle is being held by forceps. The anterior papillary muscle is visualized on the left side; the accessory inferior papillary muscle is visible to its right, and the inferior papillary muscle is located at the top. Blue triangles indicate the root of each papillary muscle. B, The image on the right shows approximated papillary muscle roots.

VIDEO 1. Intraoperative video. Minimally invasive right thoracotomy incision surgery under a microscope view. Video available at: [http://www.jtcvsonline.org/article/S0022-5223\(18\)30358-1/fulltext](http://www.jtcvsonline.org/article/S0022-5223(18)30358-1/fulltext).

suspended as follows. With the patient under cardiac arrest, before the annuloplasty, 4-0 pledgeted polytetrafluoroethylene suture was placed at the base of anterior PM. Then, in a clockwise fashion, the base of the accessory inferior PM and that of inferior PM were continuously sutured by each arm. The arms were passed into the interventricular septum and then exteriorized onto the septal annulus at the right atrium (Figure 1). The distance between the anterosuperior-septal and the septal-inferior leaflet commissures was used to decide the ring size. After annuloplasty with a 3-dimensional incomplete rigid ring, the polytetrafluoroethylene sutures were passed through the ring. The adjustment of the suture length was performed under a saline solution test, and the sutures were then tied (Video 1).

SURGICAL RESULTS

From 2015 to 2016, spiral suspension was performed for 7 patients with severe functional TR (age,

74 ± 9 years; 5 male). Preoperatively, the annular diameter at diastole, the end-diastolic right ventricular diameter, and both tenting height and area at midsystole were obtained from the apical 4-chamber view by 2-dimensional transthoracic echocardiography (TTE). Tenting height was measured as the maximum distance between the annular plane and the leaflet surface; tenting area was measured as the enclosed area between the annular plane and the leaflet surface. These measurements are summarized in Table 1. It has been reported that tenting height greater than 5.1 mm or tenting area greater than 0.8 cm² predicts at least moderate TR after annuloplasty.¹ As the indication for spiral suspension, these values were referred. Isolated spiral suspension was performed in 3 cases (Table 1, cases 1, 2, and 6). Concomitant procedures were mitral repair in 2 (Table 1, cases 5 and 7), mitral repair plus aortic valve replacement in 1 (Table 1, case 3), and atrial septal defect closure in 1 (Table 1, case 4). After the surgery, leaflet tethering was effectively repaired, and postoperative tenting height and area were no longer measurable because they were almost zero in all patients. During the 12.2 ± 6.8 months of follow-up, 1 patient (case 7) died 34 days after the surgery of severe liver dysfunction. In this patient, mild to moderate residual TR had been observed on the last TTE. In the other 6 patients, TR was well controlled, with a reduction in right ventricular size (from 40.8 ± 5 to 27.3 ± 3.3 mm) and a reduction in pulmonary artery systolic pressure estimated by TTE (from 51.0 ± 9.1 to 30.2 ± 7.9 mm Hg). In cases 1 through 6, recent New York Heart Association functional class was I (cases 1, 3, 4, and 5) or II (cases 2 and 6), and more than mild residual TR was not observed on the recent (14 ± 5 postoperative months) TTE.

Preoperative and postoperative tricuspid complex visualized by 3-dimensional transesophageal echocardiography with a transgastric approach in case 4 are shown in Figures 2 and 3. The volume rendering images demonstrated the subvalvular apparatus in detail (Figure 2 and

TABLE 1. Clinical summaries

Case	Age		BSA (m ²)	Preop LVDD (mm)	Preop LVEF (%)	Preop TV annular diameter (mm)	Selected ring size (mm)	RV diameter (mm)		Preop tenting		Estimated PAP (mm Hg)	
	(y)	Sex						Preop	Postop	Height (mm)	Area (cm ²)	Preop	Postop
1	82	F	1.5	42	55	41	26	38	23	5.2	1.4	48	23
2	79	M	1.7	53	70	43	26	34	29	4.5	2.2	62	44
3	82	M	1.4	49	78	40	26	36	29	5.7	2.4	47	36
4	60	M	1.9	41	67	47	28	50	33	7.8	1.8	60	22
5	60	M	1.6	47	63	48	28	47	25	9.5	3.1	54	25
6	77	M	1.6	48	65	44	26	38	25	8.1	2.6	35	31
7	79	F	1.5	42	72	38	26	42	43	6.1	1.4	51	52

Mean follow-up period was 12.2 ± 6.8 months. BSA, Body surface area; Preop, preoperative; LVDD, left ventricular diastolic dimension; LVEF, left ventricular ejection fraction; TV, tricuspid valve; RV, right ventricle; Postop, postoperative; PAP, systolic pulmonary artery pressure.

FIGURE 2. Subvalvular apparatus in diastole visualized in volume rendering image by 3-dimensional transesophageal echocardiography with transgastric approach. *PM*, Papillary muscle; *RVOT*, right ventricular outflow tract; *LV*, left ventricle.

[Video 2](#)). Reconstructed preoperative and postoperative 3-dimensional images by dedicated software (Real View, Nara, Japan) depicted the effectiveness of the spiral suspension by demonstrating postoperative elimination of tethering and decreased distances between the PM tips and the annulus ([Figure 3](#)).

DISCUSSION

The mechanism of recurrent TR after annuloplasty is associated with leaflet tethering, which is basically the same as that in mitral valve. Unlike in the mitral valve, however, which has PMs tightly connected to the left ventricle, PMs in the tricuspid valve are connected to ventricle wall by

FIGURE 3. Preoperative (*Pre-op*) and postoperative (*Post-op*) reconstructed tricuspid valve images in midsystole are shown. *Upper images* show tricuspid leaflet, annulus, and papillary muscle tips. *Lower images* show projected annulus and papillary muscle tips from the right atrial (*RA*) perspective. *RV*, Right ventricle; *A*, tip of the anterior papillary muscle; *I*, tip of the inferior papillary muscle; *accI*, tip of the accessory inferior papillary muscle.

VIDEO 2. Preoperative (*Pre-op*) and postoperative (*Post-op*) volume rendering images. Video available at: [http://www.jtcvsonline.org/article/S0022-5223\(18\)30358-1/fulltext](http://www.jtcvsonline.org/article/S0022-5223(18)30358-1/fulltext).

loose trabeculation in a low-pressure ventricle. This allows PM approximation and suspension with less stress and tension than in the mitral valve. With our technique, apically and radially shifted PMs are expected to be approximated effectively and suspended toward the midseptal annulus by

means of a simple spiral suture, which eliminates leaflet tethering and therefore prevents the recurrence of TR after annuloplasty. Although patients with an aberrant or fragile subvalvular structure might be excluded from the indication for the procedure, we have not seen any such cases to date.

With a precise understanding of the tricuspid subvalvular anatomy, spiral suspension is a technically less demanding procedure that potentially enables the surgeon to reduce leaflet tethering and secure leaflet coaptation. Further investigation is warranted to confirm the effectiveness of the spiral suspension for severe functional TR.

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