Chordal translocation for ischemic mitral regurgitation may ameliorate tethering of the posterior and anterior mitral leaflets

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Objective: Treatment of ischemic mitral regurgitation accompanied by strong tethering remains a challenge. Undersized ring annuloplasty is frequently associated with residual/recurrent mitral regurgitation caused by mitral-leaflet tethering. Although chordal cutting is a simple procedure for repairing severe tethering of the anterior mitral leaflet, it often affects mitral valvular-ventricular continuity. In this study, using 3-dimensional echocardiography, we investigated the effects of "chordal translocation" on the geometry of the mitral components in a canine model of acute ischemic mitral regurgitation.

Methods: In 6 mongrel dogs, under cardiopulmonary bypass with cardiac arrest, artificial chordae were implanted to each papillary-muscle tip and passed through the midseptal annulus to an external tourniquet to control the tension of the stitch thereafter. Subsequently, secondary chordae were cut near their point of attachment to the anterior leaflet. After weaning from cardiopulmonary bypass, acute ischemic mitral regurgitation was induced by ligating the obtuse marginal branches. We obtained data in 2 states of the artificial chordae: relaxation (simulating chordal cutting) and gentle traction (simulating chordal translocation).

Results: In the chordal translocation state versus the chordal cutting state, the left ventricle ejection fraction (42.6% ± 2.9% vs 33.2% ± 2.3%, $P < .0001$), preload recruitable stroke work (54.8 ± 2.7 mm Hg vs 34.1 ± 2.2 mm Hg, $P = .0002$), and end-systolic elastance (6.7 ± 0.5 mm Hg/mL vs 4.2 ± 0.2 mm Hg/mL, $P = .0013$) improved markedly. The mitral-valve tethering volume, defined as the volume enclosed by the mitral annulus and 2 leaflets, was smaller in the chordal translocation state than in the chordal cutting state (812 ± 88 mm^3 vs 1213 ± 41 mm^3, $P = .03$). In the chordal translocation state (CT-1 and CT-2) versus the chordal cutting state, the posterior mitral-leaflet tethering area (15.7 ± 0.7 mm^2 vs 25.1 ± 1.2 mm^2, $P < .0001$ for CT-1 and 15.0 ± 0.7 mm^2 vs 25.1 ± 1.2 mm^2, $P < .0001$ for CT-2) showed a greater improvement than the anterior mitral-leaflet tethering area (41.0 ± 0.7 mm^2 vs 46.1 ± 1.3 mm^2 for CT-1, $P = .01$ and 812 ± 88 mm^2 vs 1213 ± 41 mm^2 for CT-2, $P = .03$). The mitral annular geometry did not differ between the states.

Conclusion: Compared with chordal cutting alone, chordal translocation improved both the left ventricle function and mitral geometry in a canine model of acute ischemic mitral regurgitation. Chordal translocation may be beneficial because it ameliorates the tethering of both the anterior and *posterior* leaflets, which is aggravated by mitral annuloplasty alone.

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Ischemic mitral regurgitation (IMR) is a severe complication arising after myocardial infarction and is associated with excessive mortality, independently of the underlying condition of left ventricular (LV) dysfunction.[1-4] Despite considerable progress in the field of cardiac surgery, surgical treatment of IMR currently remains a challenge for surgeons. Undersized ring annuloplasty has gained popularity.

Abbreviations and Acronyms

AML = anterior mitral leaflet
CC = chordal cutting
CPB = cardiopulmonary bypass
CT = chordal translocation
Ees = end-systolic elastance
IMR = ischemic mitral regurgitation
LV = left ventricular
LVEF = left ventricular ejection fraction
MR = mitral regurgitation
PM = papillary muscle
PML = posterior mitral leaflet
PPM = posterior papillary muscle
PRSW = preload recruitable stroke work
3D = 3-dimensional

However, this procedure may have various outcomes, and it is frequently associated with residual/recurrent mitral regurgitation (MR).[5-7]

The chordal cutting (CC) procedure, which involves disruption of the secondary chordae, is a simple method performed to repair severe tethering.[8] Some authors reported that this method could improve leaflet coaptation and that it did not adversely affect LV function in an animal model.[9,10] However, the secondary chordae maintain mitral valvular-ventricular continuity, which plays an important role in LV structure and function.[11] Thus, the CC method may reduce anterior leaflet tethering and mitral valve regurgitation at the cost of the LV systolic geometry or function.

We previously reported an improvement in the LV function after chordal translocation (CT) (ie, CC accompanied by restoration of continuity between the papillary tips and the anterior mitral annulus by using artificial chordae) in a normal canine model.[12] Although this technique has been shown to improve LV function after CC, details of the geometric changes it induces in the mitral valve components, particularly in the mitral-valve leaflet and annulus in the IMR model, remain unknown.

In the present study, we investigated the effects of the CT technique with regard to the geometry of the mitral valve components by performing real-time 3-dimensional (3D) echocardiography in a canine model of acute IMR.

Materials and Methods

Surgical Preparation

Six mongrel dogs (weight, 18.2 ± 0.8 kg) were premedicated with ketamine hydrochloride (20 mg/kg administered intramuscularly), and general anesthesia was induced with propofol (1–3 mg/kg^{-1}/h^{-1} administered intravenously). Anesthesia was maintained by inhalation of isoflurane (0.5%–1.5%).

The dogs were placed in the right lateral decubitus position, and a left anterior thoracotomy was performed through the fifth intercostal space. The pericardium was opened, and the heart was suspended in a cradle. A rubber catheter, used as an inferior vena cava occluder, was placed around the inferior vena cava to provide transient preload reduction.

Under cardiopulmonary bypass (CPB), the ascending aorta was crossclamped, and antegrade crystalloid cardioplegia was injected. Left atriotomy was performed via the appendage; for CT, artificial chordae of 4-0 polypropylene sutures were placed on the tip of each papillary muscle (PM), which represents the origin of the secondary chordae, and were put through the midseptal annulus (ie, the saddle horn) to an external tourniquet to ensure the smooth movement of the suture. Damage to the aortic valve, especially the noncoronary cusp, is potentially a major concern. We paid attention not to injure aortic valves, and no damage was noted at autopsy. This process is shown in Figure 1. The length of the artificial chordae for CT was determined under the "taut" condition, which has been described.[12] The natural secondary chordae were cut near the point of attachment to the anterior leaflet. The secondary chordae were clearly identified by turning over the anterior leaflet.

The left atrium was subsequently closed, and the tourniquets were taken out of the left atrium to control the artificial chordal length/tension thereafter. The dogs were weaned from CPB, and polypropylene 4-0 sutures were then passed around the second and third obtuse marginal branches of the left circumflex coronary artery to induce the posterior LV wall ischemia thereafter.

Experimental Protocol

After the dogs were weaned from CPB, the hemodynamic state was stabilized. Inotropic agents were not used during the weaning process. The dogs were studied in the right lateral decubitus position with the chest open, and anesthesia was maintained with isoflurane (0.5%–1.5% via inhalation) and propofol (1–3 mg/kg^{-1}/h^{-1} administered intravenously).

In regard to the anatomy, the release of the artificial chordae represented the CC state, and gentle traction of the artificial chordae in the taut condition represented the CT state. The length of the artificial chordae was controlled during each state.

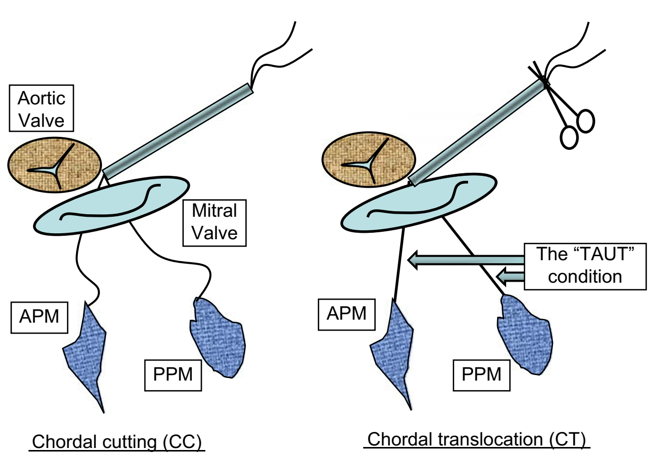

Figure 1. Schematic representation of CC and CT. "CT sutures" were implanted by anchoring 4-0 polypropylene sutures to each PM tip, which represents the origin of the secondary chordae, and through the midseptal annulus (saddle horn) to an external tourniquet to ensure the smooth movement of the suture. *APM,* Anterior papillary muscle; *PPM,* posterior papillary muscle.

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