Operative Techniques in Thoracic and Cardiovascular Surgery

# Idiopathic Hypertrophic Subaortic Septal Obstruction: Robotic Transatrial and Transmitral Ventricular Septal Resection

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Hypertrophic obstructive cardiomyopathy (HOCM) is a primary myocardial disease in which either a site-specific or a generalized portion of the left ventricle is hypertrophied without any obvious etiology. With HOCM, myocyte sarcomeres are increased in size, resulting in a thickened heart muscle. Moreover, the normal alignment of cardiac muscle cells is disrupted, causing an abnormal disarray pattern. Most often symptoms relate to aortic outflow tract obstruction; however, generalized and midseptal hypertrophy can occur. This pathologic condition can be either symptomatic or asymptomatic until the development of secondary arrhythmias or sudden cardiac death.

Idiopathic hypertrophic subaortic stenosis (IHSS) is a site-specific form of HOCM in which the aortic outflow tract is obstructed by an abnormally thickened interventricular septum. In 1960, Braunwald et al, working at the National Institutes of Health, first detailed the clinical, hemodynamic, and angiographic manifestations of IHSS.[1] Their extensive investigations eventuated from the Morrow operation for IHSS.[2] This transaortic valve procedure consisted of a generous interventricular septal resection. Over the years, this operation with little modification has remained the gold standard for treating IHSS. Complications of the Morrow operation have included heart block, creation of a ventricular septal defect, injury to the aortic valve, and/or residual systolic anterior motion of the anterior mitral leaflet (SAM). Other current nonsurgical treatments for IHSS include rhythm resynchronization and percutaneous catheter alcohol septal ablation.

IHSS can be complicated by a dynamically displaced anterior mitral valve leaflet, which during systole can appose closely the thickened ventricular septum. In this case high velocity flow creates the Venturi effect that can drag the anterior leaflet toward the septum, increasing the obstruction. Moreover, the septal distraction of the anterior papillary muscle can alter dynamic mitral leaflet coaptation, eventuating in the anterior leaflet slack that effectively elongates it. Levine and coworkers defined the effects of abnormal anterior papillary muscle displacement in IHSS and the effects on dynamic leaflet geometry.[3] In this instance, thickened septal bands distract the anterior papillary muscle toward the outflow tract, causing anterior mitral leaflet displacement, which can contribute to additional subvalvular aortic outflow tract obstruction. Thus, outflow tract obstruction often not only can be related to the thickened septum but also can be related to a combination of other conditions, including (1) the length and displacement of the mitral valve anterior leaflet, (2) abnormal septal-papillary muscle attachments that prevent free movement of chords and leaflet away from the septum; and (3) a small left ventricular cavity. Cooley et al addressed the phenomenon of SAM by replacing the mitral valve.[4] Later, McIntosh and associates combined an anterior leaflet plication with septal resection to avoid this problem.[5] Other dynamic forces that can aggravate outflow tract obstruction include increased cardiac contractility, low ventricular filling volume, arrhythmias, and reduced peripheral arterial afterload.

## Innovative Techniques for the Transatrial Surgical Treatment of IHSS

In 2002, Casselman and Vanermen first performed a septal myectomy for IHSS endoscopically via a left atrial approach.[6] They incised the base (aortomitral curtain) of the anterior mitral leaflet to expose the hypertrophic interventricular septum. This was predicated on their extensive experience with endoscopic minimally invasive mitral valve repair surgery.[7] From our experience in using the daVinci robotic telemanipulation system for mitral valve repairs, we developed a new method for resolution of IHSS by generous septal resection combined with papillary muscle release and repositioning.[8] The daVinci robotic device provides superb minimally invasive, ergonomic intracardiac access with 3-dimensional high-definition visual magnification (×10). As this device allows fluid and accurate access to the mitral valve anatomy, we concluded that interventricular septal resection for IHSS would not only be possible but very effective for the correction of this condition. Additionally, this technique could enable any mitral valve operation that is needed to prevent postoperative SAM. To this end, we present a new and innovative alternate to the standard transaortic Morrow operation for IHSS.

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# Operative Techniques

Details of our minimally invasive and robotic surgical approaches to mitral valve repairs, cryoablation for atrial fibrillation, and other left atrial operations have been described earlier.[9-11] Briefly, peripheral cardiopulmonary perfusion is established at 28°C using femoral arterial inflow combined with suction-assisted internal jugular and femoral venous drainage. Aortic occlusion is affected using a transthoracic cross-clamp, placed via the transverse sinus from the lateral right thorax. Myocardial protection is provided using either intermittent blood cardioplegia or single-dose Bretschneider's crystalloid cardioplegia infused into the aortic root. To lessen the chance of residual intracardiac air, carbon dioxide is insufflated continuously into the thoracic cavity throughout the procedure. Following a left atriotomy, the mitral valve anterior leaflet and fibrous trigones are exposed using the dynamic robotic retractor. To scavenge any residual pulmonary vein drainage into the left atrium, a weighted sucker is placed into the left superior pulmonary vein.

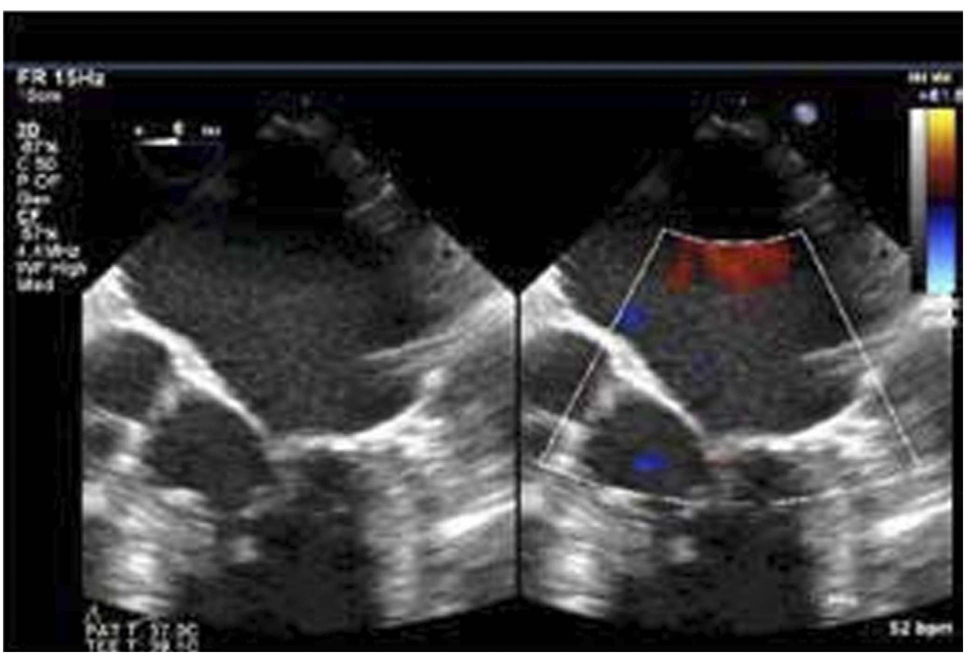


**Figure 1** Transesophageal echocardiogram. This shows the mitral valve anterior leaflet approximating the hypertrophied interventricular septum during systole. This phenomenon increases the aortic outflow tract obstruction. (Color version of figure is available online at http://www.optechtcs.com.)

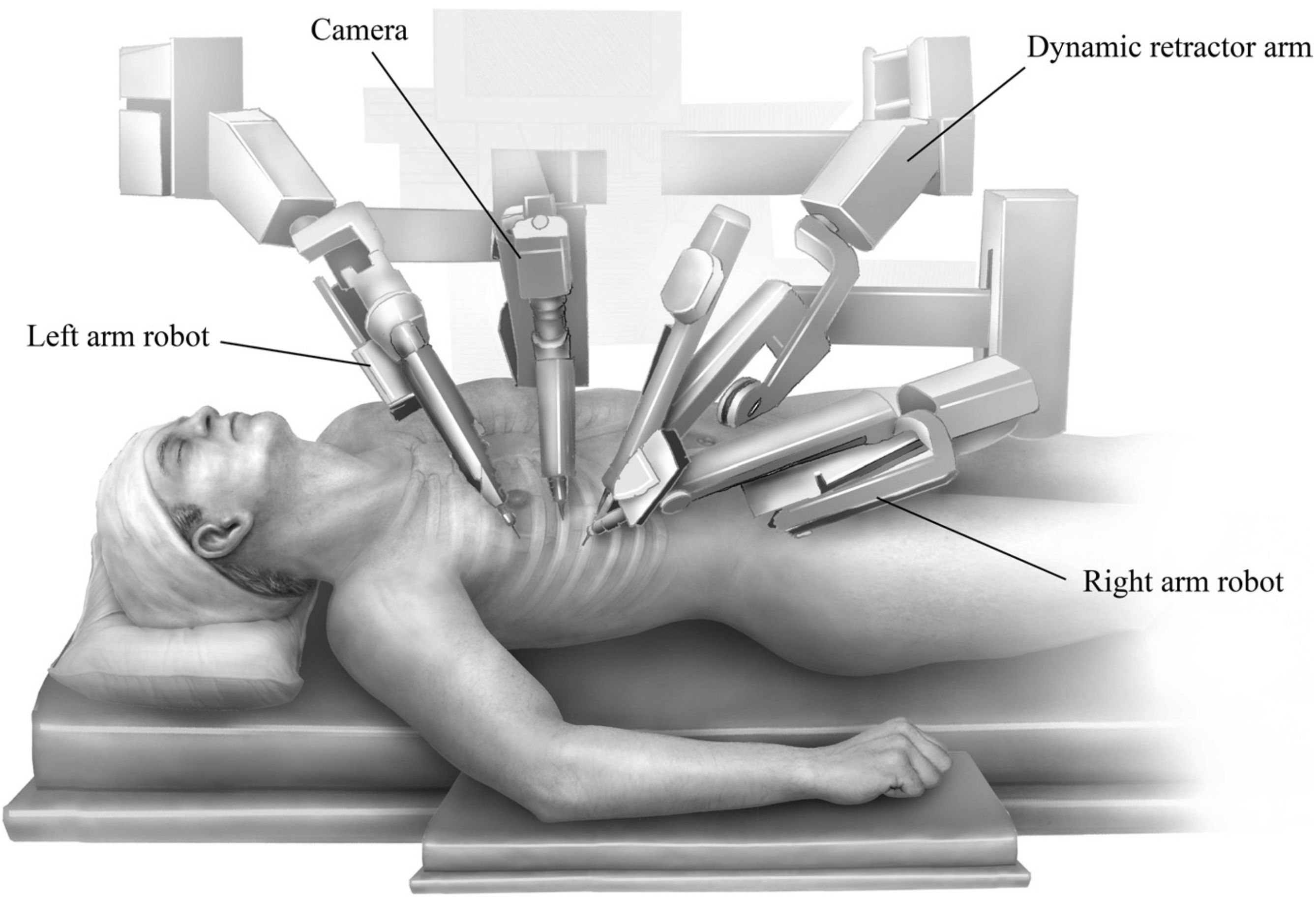


**Figure 2** Setup for a robotic interventricular septal resection. The patient is positioned with the right hemithorax elevated 30° and the right arm tucked by the patient's side. The instrument cart then is positioned on the left side of the patient. Two operative robot instrument arms are inserted through the chest wall. The endoscopic camera is passed through either the 4-cm incision or a separate trocar. To provide operative site exposure, the dynamic left atrial retractor is passed into the thoracic cavity through a trocar and positioned in the left atrium.

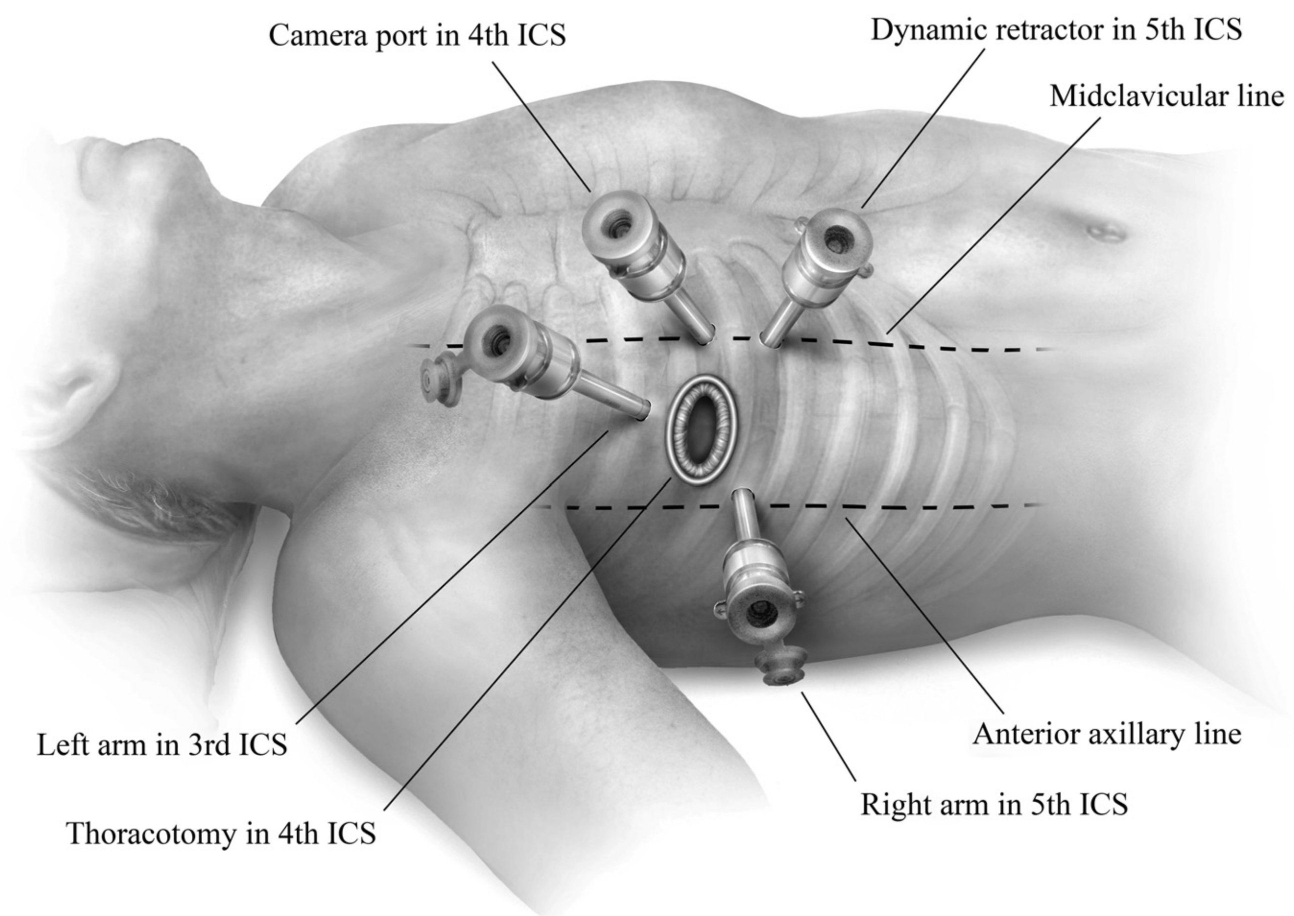


**Figure 3** Robotic instrument arm trocar placement. A 4- to 5-cm mini-thoracotomy is made in the fourth intercostal space (ICS) between the midclavicular and anterior axillary lines. To avoid rib spreading, a soft tissue retractor is placed. The 3-dimensional camera port is inserted anterior to the incision in the fourth ICS at the midclavicular line. Operating trocars are placed in the third ICS for left instrument arm insertion and in the fifth ICS anterior axillary line for the right instrument placement. For insertion of the dynamic left atrial retractor arm, a final trocar is placed in the inframammary fifth ICS, along the midclavicular line.

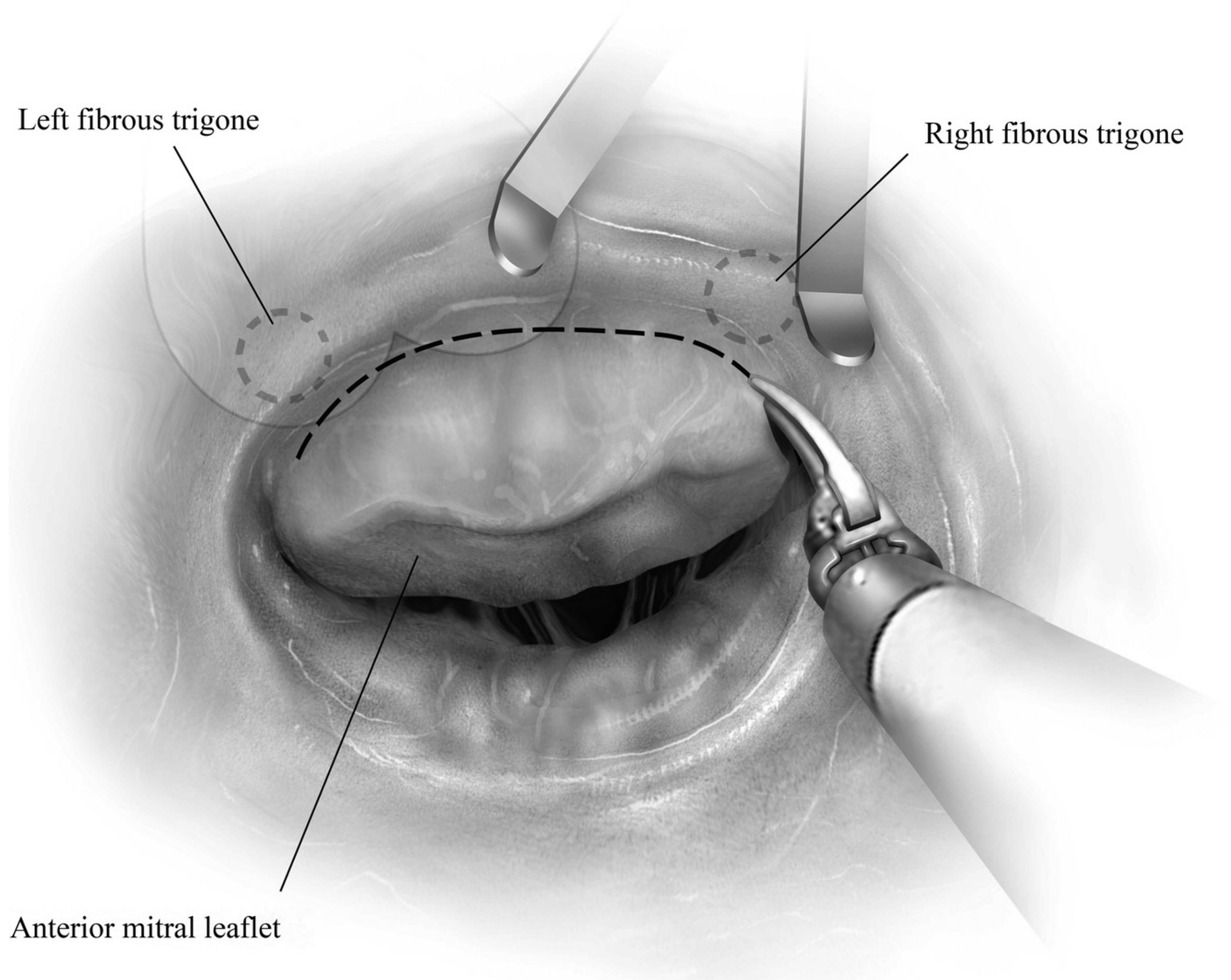


**Figure 4** Mobilizing the mitral valve anterior leaflet. After establishing cardiac arrest and mitral valve exposure using the dynamic retractor, the anterior leaflet is incised radially, beginning at the right fibrous trigone and proceeding counterclockwise toward the left fibrous trigone and aortic valve. We use curved robotic scissors for this part of the operation. Care must be taken to avoid injury to the aortic valve leaflets. Generally, we give antegrade cardioplegia to define the nadir of the aortic leaflets. We preserve the right fibrous trigone-leaflet attachment while the left side of the anterior leaflet is released and rotated to expose the interventricular septum. We leave a rim anterior leaflet (2 mm) to facilitate a uniform mitral reconstruction at the end of the operation.

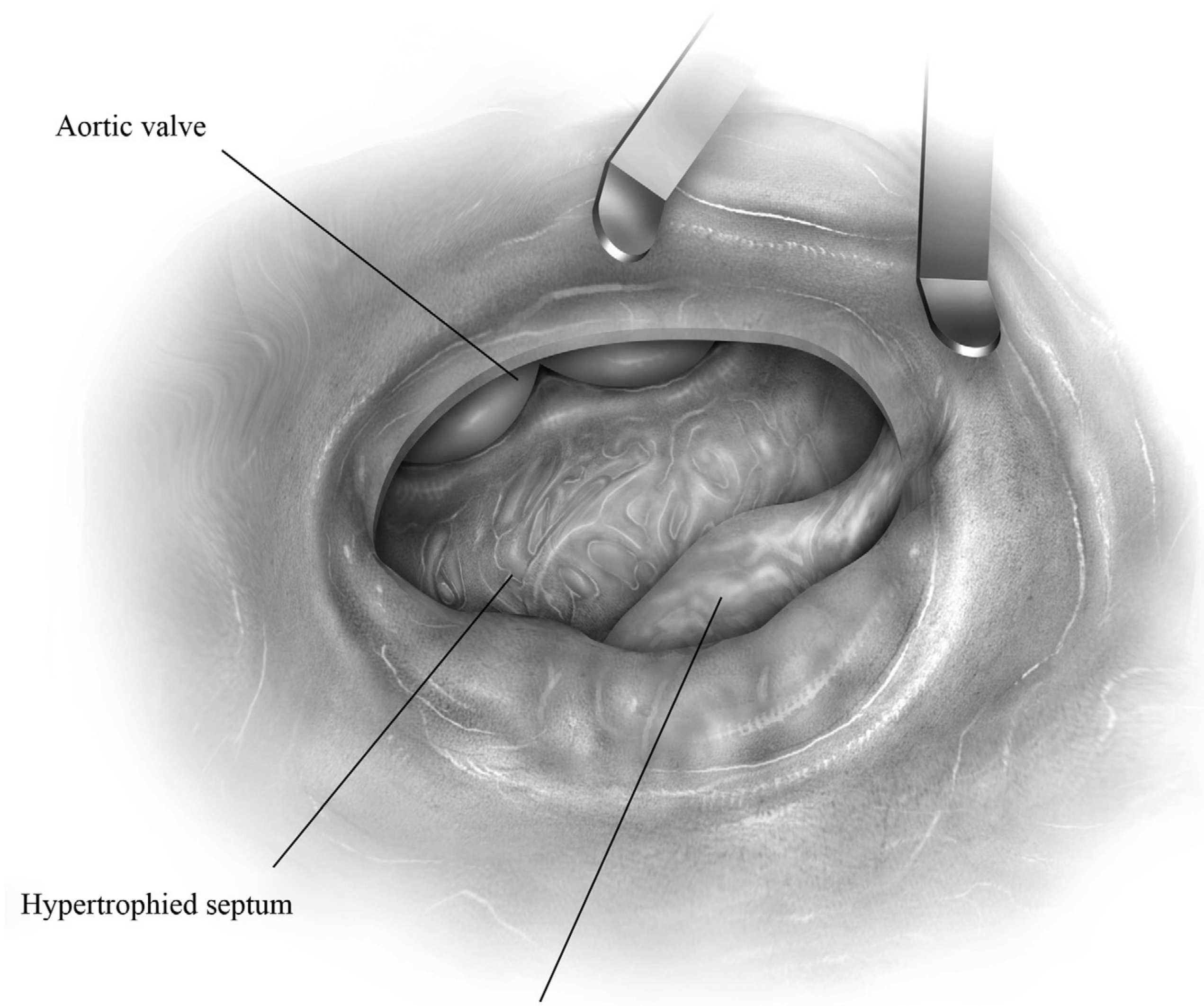


**Figure 5** Exposure to the interventricular septum. After the anterior mitral leaflet has been released from the left fibrous trigone and rotated into the left ventricle, wide exposure of the hypertrophied interventricular septum is present. When septal hypertrophy is localized to just below the left fibrous trigone, only partial incision with limited mobilization of the anterior leaflet becomes necessary.

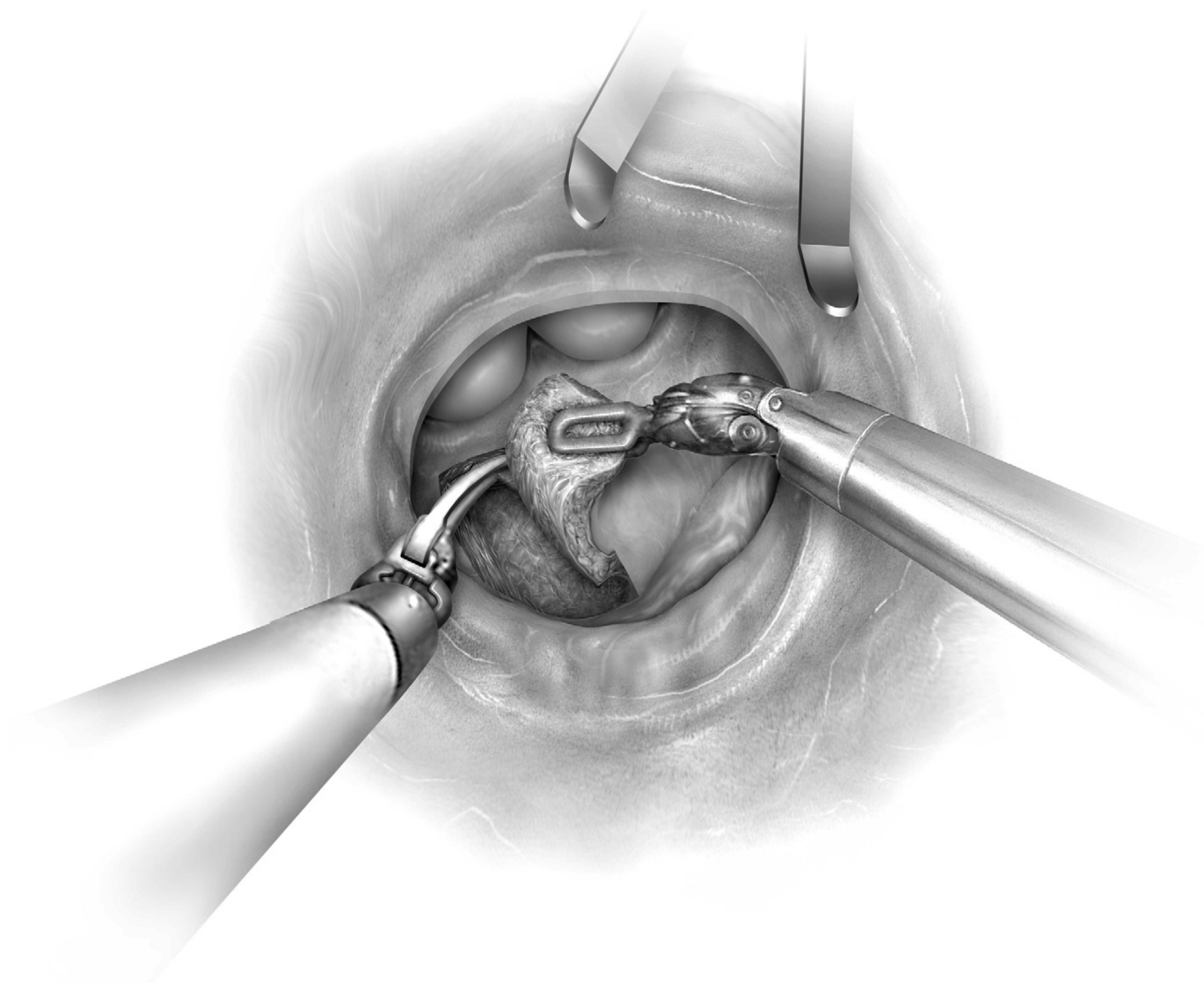

**Figure 6** Resection of septal muscle. The depth of the needed septal resection should be predetermined from the transesophageal echocardiographic study. We begin the resection near the left fibrous trigone at the level of the noncoronary aortic cusp. The rectangular resected tissue trench is continued clockwise to the nadir of the right coronary cusp, thus avoiding the region of the interventricular (His) conduction bundle. We measure the depth of this resection using a small millimeter ruler. The resection should be continuous from the base of the aortic valve cusps to the base of the anterior papillary muscle.

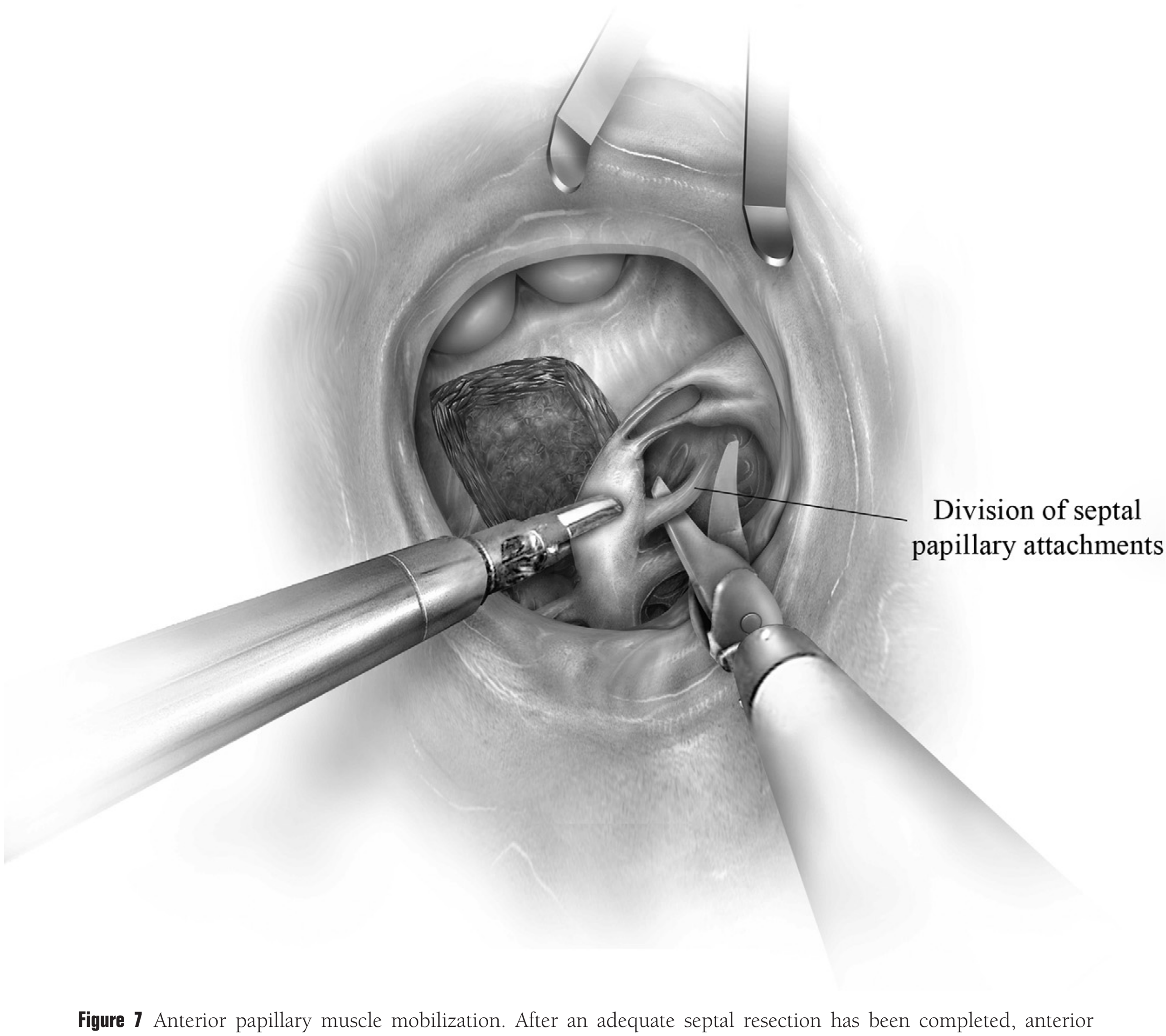


**Figure 7** Anterior papillary muscle mobilization. After an adequate septal resection has been completed, anterior papillary basal muscle connections to the septum should be divided. This allows posterior displacement of an obstructing anterior papillary muscle, moving the associated chordae tendineae and leaflet away from the septum during systole. In the presence of a very large anterior papillary muscle, we suture displace it to the posterior papillary muscle, distracting it even farther away from the septum.

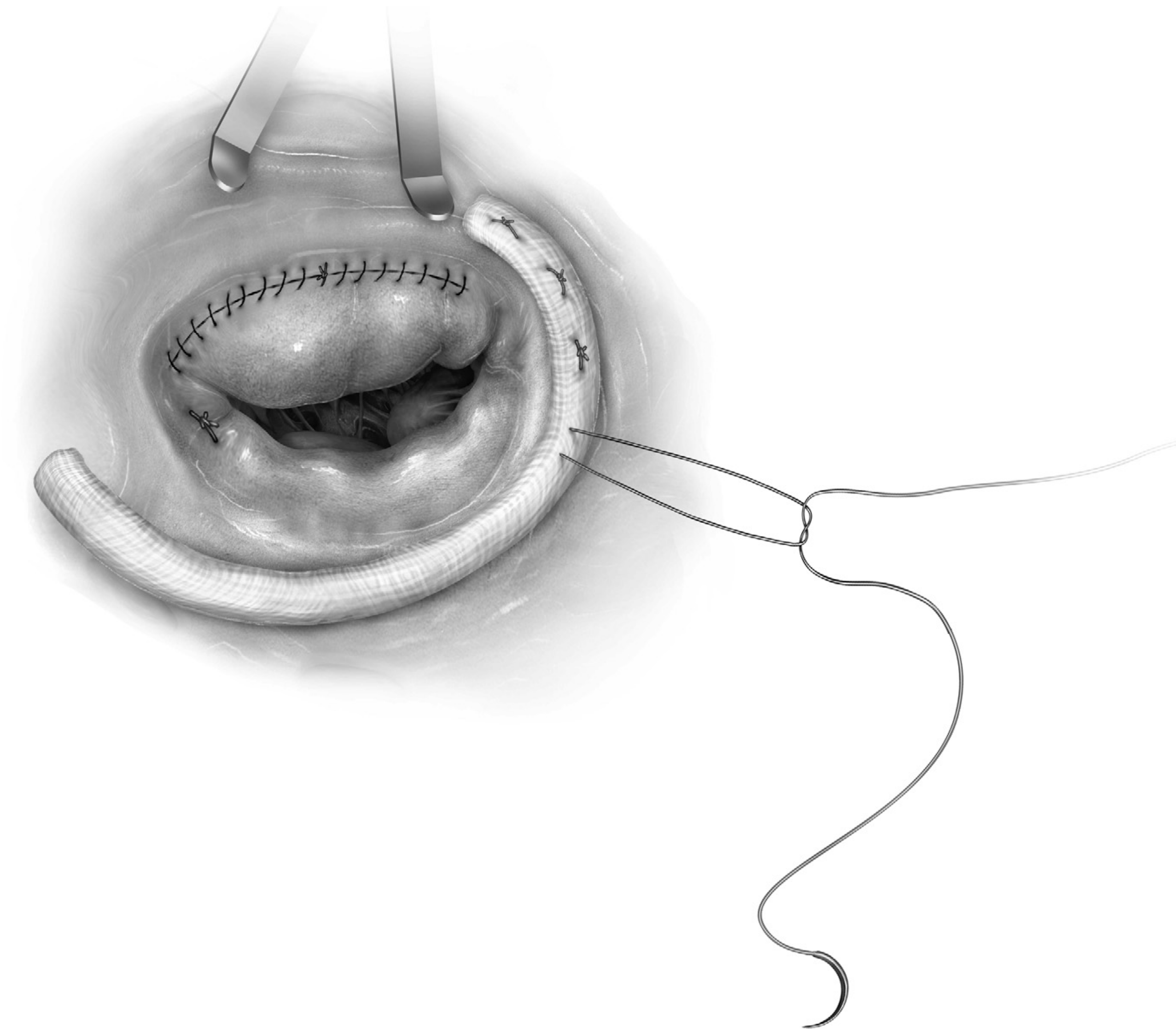

**Figure 8** Anterior mitral leaflet resuspension and annuloplasty. Following the septal resection and papillary muscle mobilization (and possible relocation), the anterior leaflet should be reapproximated to the 2-mm residual anterior leaflet rim using 4-0 polytetrafluoroethylene suture. We begin the suture line at the left fibrous trigone to avoid injury to the noncoronary aortic valve cusp. Often the anterior leaflet has been altered pathologically by recurrent septal coaptation. Any adherent anterior leaflet fibrous tissue should be removed to provide full mobility. To be sure that there will be adequate dynamic mitral valve coaptation, an annuloplasty band should be implanted using 2-0 braided suture material. To provide optimal bileaflet coaptation without SAM, other surgeons have suggested augmenting the anterior leaflet using a pericardial patch.

## Conclusions

We have been effective in performing adequate interventricular septal resections for IHSS. This included mobilization of the anterior papillary muscle out of the ventricular outflow tract by dividing septal-papillary connecting bands. The illustrations depict the level of videoscopic detail that can be attained using the high-definition 3-dimensional robotic camera. Moreover, the ergonomic robotic instruments facilitate the septal resection greatly in very tight quarters. We have been pleased with the significant decrease in aortic outflow tract gradients as well as the reduction in the possibility of residual SAM. If SAM persists after weaning from cardiopulmonary bypass (avoiding inotropic drug support and with ventricular volume loading), then the addition of a mitral leaflet edge-to-edge suture (an Alfieri technique) may become necessary. In our patients, mitral valve replacement was never used and residual mitral leakage was avoided. In summary, the combination of the techniques described in this article can aid modern surgeons in approaching this complex surgical problem with an effective clinical outcome.

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