well illustrated with echocardiographic images before and after resection, but an important message is that these types might be identified on preoperative studies or intraoperative echocardiography, and thus surgeons need to be alert and assess for their presence and then follow the suggested recommendations for resection. Type I, with insertion only into the body of the anterior leaflet, should be safely divided/resected to open the left ventricular outflow tract and relieve obstruction. For type II, the papillary muscle can be mobilized and the insertion into the body of the anterior leaflet should be resected but not to the anterior leaflet free edge, which would create an unsupported free edge and organic mitral regurgitation (not functional from systolic anterior motion). For type III, with only insertion into the free edge, resection is not appropriate.

Although I may be considered a high-volume HOCM surgeon because I do more than 25 myectomy operations annually, I learn from the subtleties that surgeons like Dr Hartzell

Schaff describe after performing thousands of these operations. Medicine and surgery advance not only from randomized trials and guidelines, but also from the experience and academic contributions of individual surgeons and programs.

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See Article page 83.

Commentary: Bringing conformity to anomaly

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Hypertrophic cardiomyopathy (HCM) is a genetic disease with varied phenotypes, many of which cause left ventricular outflow tract (LVOT) obstruction. Extended septal myectomy is the mainstay of surgical therapy for HCM with obstruction, effectively relieving symptoms of heart failure in most patients by eliminating LVOT obstruction and mitral valve regurgitation.¹ Variations in pathoanatomy such as anomalous papillary muscles inserting directly into the anterior mitral leaflet may require modification of the operation. Although these anomalous muscles have been

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CENTRAL MESSAGE

A classification system for anomalous papillary muscles inserting directly into the anterior mitral leaflet will aid surgeons performing operations for obstructive HCM.

described,² they have not been classified into a system to guide surgical management.

In this issue of the *Journal*, Carvalho and colleagues³ describe a series of patients with anomalous papillary muscles who underwent surgery for obstructive HCM. These 73 patients comprised 2.3% of the patients who underwent

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septal myectomy at the Mayo Clinic between 1961 and 2018. The authors propose a novel classification system along with guidelines for management of this anomaly.

Their system divides anomalous papillary muscles into 3 types based on the location of insertion on the anterior leaflet. Papillary muscles inserting directly into the body of the anterior leaflet are classified as type I, muscles with attachments both to the body and to the free margin are classified as type II, and muscles inserting into the free margin only are classified as type III. The authors believe that those inserting into the body of the leaflet contribute to LVOT obstruction and should be resected (preserving chordal attachments to the free margin in type II). Type III muscles provide support to the free margin, do not contribute to LVOT obstruction, and therefore should not be resected.

The series is retrospective and because of the rarity of the subject contains a small number of patients, making statistical analysis of hemodynamic data and efficacy of resection according to type not feasible. The authors describe residual obstruction and need for reoperation in patients with aberrant muscles left unresected at the initial operation, lending support to their belief that this anomaly contributes to outflow tract obstruction.

Most of the papillary muscle anomalies in these patients were not diagnosed on preoperative imaging studies, with transthoracic echocardiography having only 11% sensitivity and transesophageal echocardiography only 27%. Even magnetic resonance imaging had a limited role in preoperative diagnosis. The difficulty in preoperative identification of the pathology emphasizes the need to identify these abnormalities by direct inspection during surgery.

One could argue that a classification system for such an unusual anomaly has limited application and is not necessary. On the contrary, because it is so unusual, most surgeons will see few examples of this pathology and may benefit from the framework of this classification system to guide their surgical decision-making. Centers that perform a low volume of HCM surgery observe higher mortality and morbidity and perform more concomitant mitral valve replacements than high-volume centers.⁴ Guidance such as that provided in this study, although not a substitute for the experience of a dedicated HCM center,⁵ may help surgeons achieve better outcomes. The authors are to be commended for distilling the extensive collective experience of their institution with a rare subset of patients into a system of classification and management that will benefit surgeons and their patients with HCM.

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