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INVITED COMMENTARY

In this issue of *The Annals of Thoracic Surgery*, Imbrie-Moore and colleagues [1] presented an elegant and interesting in vitro study on neochordoplasty for mitral valve (MV) repair. The authors examined the effect of anchoring position, length, and the angle of leaflet attachment using expanded polytetrafluoroethylene chords on chordal and leaflet stresses. They demonstrated that apical fixation of expanded polytetrafluoroethylene chords resulted in higher chordal forces compared with chords implanted with a papillary muscle fixation point, an observation in line with previous publications [2, 3]. They also discerned that the angle of the artificial chord implantation on the leaflet significantly affects the maximal force required for leaflet failure. As explained by the authors, these results provide insight into the possible reasons for failure of early percutaneous neochordoplasty procedures.

Indeed, the results of this study substantiate the technique refinements undertaken by early adopters of percutaneous neochordoplasty procedures. The first procedure, NeoChord, was performed with the implantation of 1 to 2 chords via left ventricular access at the apex [2, 4]. Given early failures, investigators modified ventricular access to a posterolateral location, allowing for parallel alignment with the native chords and a perpendicular orientation to the mitral valve plane [5, 6].

Analysis of chordal positioning using three-dimensional and four-dimensional computed tomographic reconstruction demonstrated the importance of interpapillary positioning and vertical alignment with the posterior leaflet, which prevents interference with the native subvalvular apparatus [3, 6], and reduces the "spinnaker effect" on the posterior leaflet. This effect was illustrated by Imbrie-Moore and colleagues [1], confirming the advantages of a vertically aligned chordal implantation pathway.

A limitation in Imbrie-Moore and colleagues [1] is the absence of an evaluation on load force, in cases of multiple chord implantation. Learning from early failures with the NeoChord procedure [4], surgeons determined that implantation of multiple chords was necessary to diminish load force maximums across each chord. The benefit of this decision has been confirmed recently with in vivo observations by French researchers [7].

A recent publication revealed that the mechanisms of NeoChord repair failure were not only limited to chord positioning [4]. Patient selection and procedural (left ventricle navigation, MV crossing, chord number, chord tensioning) and pathophysiologic (posterior mitral annular displacement, reverse ventricular remodeling) factors were also critical to success. These observations demonstrate the complexity of MV structure and that successful repairs will be multifactorial and complex. As a result, transcatheter MV repair will likely require combinations of multiple technologies to target the unique components of the MV apparatus to mitigate disease etiology.

It is evident that traditional repair approaches will be strongly challenged to achieve truly minimally invasive procedures that benefit patients. Transeptal NeoChord techniques aim to repair the valve in an even less invasive manner and achieve a more physiologic restoration of leaflet coaptation. Clearly ventricular interpapillary chordal implantation is less physiologic than a papillary muscle fixation, leading to disadvantages as described by

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Imbrie-Moore and colleagues [1]. Future transcatheter-based chordal repair technologies will likely target papillary muscle fixation of the chords, while still allowing for multiple chord implantation and chord length adjustment.

As a surgical community, we need to keep an open mindset, learning from our strong background of MV mechanics to help build future technologies and techniques that will address the common desire to have the least invasive surgery possible.

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Andrea Colli, MD, PhD

Department of Cardiac, Thoracic Vascular Sciences
and Public Health
University of Padua
Via Giustiniani 2
35128 Padua, Italy
email: andrea.colli@unipd.it

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