Simulating the Mitral Apparatus

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Mitral valve apparatus is a complex dynamic system that requires a timed coordination of the left ventricular muscle, papillary muscles, chordae tendinea, anterior and posterior leaflets, and mitral annuls. The strict interaction of these structures allows achieving a competent valve closure. Nevertheless, failure of one of these anatomical structures may cause mitral regurgitation. In this issue of *Seminars*, Park et al developed a mathematical 3D model of the mitral apparatus, describing how its primary components interact and modify during the cardiac cycle.[1] In this regard, authors highlight the importance of understanding the physiological mechanisms of the mitral apparatus for better treatment of mitral valve disease. A geometric model of human mitral valve has been recently proposed[2]; however, the strength of this study regards the thorough interaction of mitral valve with the other components of its apparatus. Furthermore, it gives the possibility of manipulating various variables to obtain the desired outcome. Most important, this model was applied to Carpentier's functional classifications. Despite the lack of viscoelastic properties limits this 3D model, implications might very useful for mitral valve repair.

The principles of mitral valve repair are to create a large surface of coaptation, preserve or restore the normal leaflet motion, and stabilize the mitral annulus with a remodeling annuloplasty. A plenty of surgical techniques have been proposed over the past years. All of them are valid and often associated with excellent results; however, many controversies are still unresolved. The selection of a prosthetic ring (flexible, semirigid or rigid; incomplete or complete, planar or saddle shape) and the respect or resect technique for degenerative mitral valve are still left to surgeon's preference rather than an evidence-based selection. A flexible open band has been proposed to preserve the 3D contour of the native annulus when the native mitral annular anatomy is still conserved. Nonetheless, a more rigid and complete saddle-shaped ring should be considered in the presence of a flattened and dilated annulus, with the aim of restoring the annular geometry and its function. Previously, I proposed a complete semirigid ring as the solution for all types of degenerative mitral valve regurgitation, as it restores the normal 3:4 (vertical:transverse) annular dimension, maintaining its flexibility during cardiac cycle.[3]

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Central Message

Software, which integrates imaging and mathematical model, will allow simulating the mitral valve apparatus, its disease, and potential surgical treatment.

The "French correction" described by Carpentier has been considered the gold standard technique for the correction of posterior leaflet prolapse, but now criticized for altering the anatomy of mitral valve with loss of mobility of the resected leaflet.[4,5] To avoid the effect of a "frozen leaflet," Perier et al recommend a more extensive use of artificial chordae without leaflet resection.[6] This ensures a large surface of coaptation and preserves the leaflet tissue. Both techniques have provided excellent results, but a more realistic approach could be "Respect when you can, resect when you should."[7]

Finally, a more complicated topic is secondary mitral regurgitation, caused by left ventricle remodeling, annular dilatation, and papillary muscles displacement. Whereas the benefit of mitral valve repair compared with mitral valve replacement is established for degenerative mitral regurgitation, the optimal surgical strategy for the management of functional mitral regurgitation is still a subject of debate, especially in the presence of LV dysfunction. A plenty of studies aimed to clarify the geometric change of the LV remodeling,

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highlighting the importance of posterolateral displacement of posterior papillary muscle for the development of MR.[8,9] For many years, mitral valve annuloplasty has been the treatment choice for these patients, but there is now evidence that the solely reductive mitral annuloplasty is destined to failure over the time if the subvalvular apparatus is not addressed.[10]

In light of all these controversies, a thorough comprehension of the mitral apparatus will allow to identify the problem and improve the surgical outcomes. Many progresses have been made in the field of radiological images. Software that integrates mathematical models with echocardiogram, MRI, and CT scan images might be useful in simulating the mitral apparatus and its disease. This information will improve the timing of surgical procedures as well as new treatment options to yield better patient outcomes.

REFERENCES

1. Park J, Geirsson A, Bonde P: Mathematical blueprint of a mitral valve. Semin Thorac Cardiovasc Surg 31:399–411, 2019
2. Shen X, Wang T, Cao X, et al: The geometric model of the human mitral valve. PLoS One 12:e0183362, 2017. https://doi.org/10.1371/journal.pone.0183362
3. Miceli A: The lord of rings. J Thorac Cardiovasc Surg 154:1925–1926, 2017
4. Carpentier A: Cardiac valve surgery—The "French correction". J Thorac Cardiovasc Surg 86:323–337, 1983
5. Braunberger E, Deloche A, Berrebi A, et al: Very long-term results (more than 20 years) of valve repair with Carpentier's techniques in nonrheumatic mitral valve insufficiency. Circulation 104:I8–I11, 2001
6. Perier P, Hohenberger W, Lakew F, et al: Toward a new paradigm for the reconstruction of posterior leaflet prolapse: Midterm results of the "respect rather than resect" approach. Ann Thorac Surg 86:718–725, 2008. discussion 718−725
7. Dreyfus GD, Dulguerov F, Marcacci C, et al: Respect when you can, resect when you should: A realistic approach to posterior leaflet mitral valve repair. J Thorac Cardiovasc Surg 156:1856–1866, 2018
8. Miceli A: A thorough understanding of the mitral apparatus will improve the results of mitral valve repair. J Thorac Cardiovasc Surg 150:238–239, 2015
9. Di Bacco L, Miceli A: A thorough understanding of the mitral apparatus will improve the results of mitral valve repair: Part 2. J Thorac Cardiovasc Surg 2018. In press
10. Bothe W, Timek T, Tibayan F, et al: Characterization of three dimensional papillary muscle displacement in in vivo ovine models of ischemic/functional mitral regurgitation. J Thorac Cardiovasc Surg 2018. In press