Neochordal Goldilocks: Analyzing the Biomechanical Impact of Neochord Length on Hemodynamics and Papillary Muscle Forces Suggests Higher Tolerance to Shorter Neochordae

Objective: Neochordal mitral valve (MV) repair is a common technique used for treating mitral regurgitation (MR). However, setting neochord lengths is difficult, as surgeons must estimate and evaluate lengths in arrested hearts largely based on intuition and experience. Our objective was to evaluate the impact of neochord length on papillary muscle (PM) forces and MV hemodynamics in an ex vivo model, especially as increased PM forces have been recently linked to the development of localized fibrosis and worsening arrhythmia.

Methods: Porcine MVs (n=8) were mounted in an ex vivo left heart simulator (Fig A), and PMs were fixed to high resolution strain gauges, while hemodynamic data was continuously recorded. To modulate neochord lengths, we created a length adjustment system that consisted of custom PM mounts with interlocking, 3D-printed pledgets, of which stacking modulated the lengths of the two P2 primary, GoreTex, CV-5 neochordae, one implanted to each PM (Fig B). Optimal length was qualitatively verified by a single operator, and neochordae were randomly lengthened or shortened in 1 mm increments up to ±5 mm from the optimal length (Fig C-E).

Results: Our system kept consistent ventricular and transmitral pressures across all conditions (122.18±0.18 mmHg and 98.23±0.13 mmHg, respectively). We found that optimal length neochordae resulted in the lowest peak composite PM forces (6.94±0.29 N), significantly different from all lengths >±1 mm. Both longer and shorter neochordae increased forces linearly according to length difference from optimal (Fig F). Moreover, both peak PM forces and MR (Fig G) scaled more aggressively for longer neochord lengths as opposed to shorter lengths, scaling faster by factors of 1.6 and 6.9, respectively. Statistical significance and p-values are visualized in Fig H.

Conclusions: Leveraging the advanced engineering precision of ex vivo heart simulation technology, we evaluated the biomechanics of varying neochord lengths. We found that millimeter-level differences in lengths can result in significant differences in PM forces and MR, altering the biomechanics of the valve. Surprisingly, the differences in lengthened neochordae scaling of PM forces and MR, relative to that of shortened neochordae, may indicate a higher level of biomechanical tolerance towards shorter neochordae. Our findings highlight the need for more thorough biomechanical understanding of neochordal repair, establishing new intuition for MR treatment.

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