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Using robotic Stewart platforms to simulate papillary muscle motion in ex vivo heart simulators

Stanford scientists have developed waterproofed six-axis robotic Stewart platforms that accurately replicate papillary muscle motion in ex vivo heart simulators. This technology enables more realistic simulation of cardiac biomechanics and could transform the evaluation of surgical techniques and cardiac devices.

Ex vivo heart simulators serve as essential platforms for evaluating surgical techniques by replicating physiologic conditions for valve analysis. However, current simulators cannot reproduce the dynamic motion of papillary muscles during the cardiac cycle. These muscles anchor critical support structures for the mitral valve, and their translation and rotation substantially influence valve mechanics. The inability to simulate this papillary muscle motion limits both the accuracy of biomechanical analysis and the evaluation of surgical interventions. Since papillary muscle displacement plays a critical role in heart valve disease, incorporating this motion could significantly improve our ability to optimize surgical repairs.

Implementation of the coupled Stewart platforms in a validated heart simulator demonstrated significant impact on chordal force profiles compared to traditional stationary setups. Using high-resolution CT imaging data, the platforms precisely replicate physiologic papillary muscle motion with six degrees of freedom. This system represents a critical advancement for ex vivo cardiac simulation, enabling more accurate analysis of valve biomechanics and optimization of surgical techniques. The technology's ability to simulate patient-specific papillary muscle motion enhances the evaluation of new minimally invasive devices and the study of valve diseases associated with papillary muscle displacement.

Stage of Development:

- Prototype

- Continued research: use of the Stewart Platform to simulate papillary muscle motion in ex
  vivo experiments to optimize cardiac surgery techniques

Applications

- Optimization of surgical valve repair techniques and devices
- Analysis of valve biomechanics in healthy and diseased states
- Development and testing of new valve repair technologies

Advantages

- Enables six degrees of freedom for precise papillary muscle motion
- Integrates with existing heart simulator platforms
- Allows patient-specific motion profiles using CT imaging data
- Significantly improves physiologic relevance compared to stationary setup

Publications

- Imbrie-Moore, A. M., Park, M. H., Paulsen, M. J., Sellke, M., Kulkami, R., Wang, H., ... & Joseph Woo, Y. (2020). Biomimetic six-axis robots replicate human cardiac papillary muscle motion: pioneering the next generation of biomechanical heart simulator technology. Journal of the Royal Society Interface, 17(173), 20200614.

Patents

- Published Application: 20210268643
- Issued: 11,945,112 (USA)

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