Biomechanical and Hemodynamic Flow Analysis of Surgical Alfieri Stitch and Transcatheter-Edge-to-Edge Devices

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Summary

This study compared the surgical Alfieri stitch with Transcatheter-Edge-To-Edge Repair (TEER) devices (MitraClip, Pascal), using silicone valve models in a heart simulator. The results suggested that the Alfieri stitch induced lower pressure gradient, higher flow areas, lower systolic strain and greater vorticity during diastole.

Introduction

Mitral regurgitation (MR), one of the most prevalent valvopathies worldwide, causes a backflow of blood during systolic closure[1]. The most frequent repair technique for treating high-risk surgical patients with severe MR is the TEER approach, which is based on the Alfieri stitch [2]. The TEER consists of suture-like clipping of the two leaflet segments by dedicated devices (Mitraclip, Abbott, USA and Pascal, Edward LifeSciences, USA). Due to their novelty, their long-term biomechanical consequences and impact on diastolic ventricular efficiency are not well-known. This study aims to compare the biomechanical and hemodynamic effect of the TEER devices and the Alfieri stitch.

Methods

Silicon mitral valves were based on micro-CT scan (NanoScan PET-CT, Mediso) of Lifelike MV (BioTissue Inc., Canada) and fabricated using a 3D printed mold that was filled with a combination of two silicones (EcoFlex00-50 and DragonSkin10, Smooth-On Inc., USA). Mitral chordae were created using polyester strings. TEER devices (Mitraclip NT and Pascal Ace Implant) and Alfieri stitch were placed in A2P2 configuration. A left-heart double activation simulator [3] was used under the following conditions: Heart rate: 70bpm, Stroke Volume:70 ml, Mean Aortic Pressure: 100 mmHg and Fluid viscosity: 3.9 cP. Hemodynamic results were obtained using transthoracic echography (iE33, Philipps Healthcare, USA) and analyzed using vector flow mapping. Digital image correlation software (VIC 3D, Correlated Solutions, USA) was used to evaluate systolic strain.

Results and Discussion

Hemodynamic values (Table1) differed between the surgical and transcatheter approaches, with the Alfieri stitch exhibiting lower gradient and higher orifice areas ($p<0.001$). The surgical approach also induced less energy loss and less systolic principal major strain (E1) (Table 1).

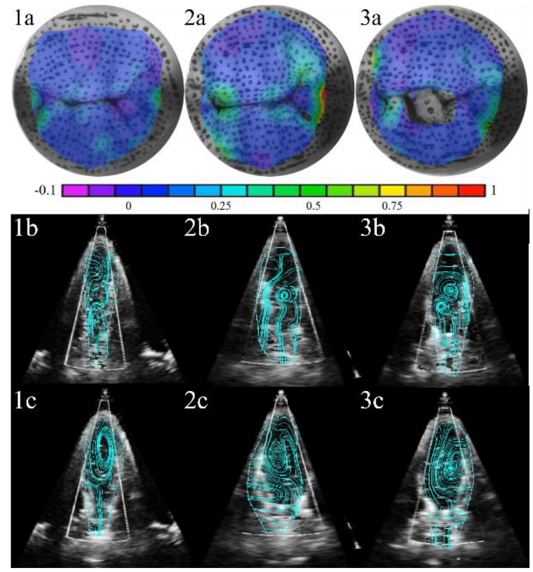

Figure 1: E1 (1) and early-diastole (2) and late-diastole flow patterns (3) induced by (a) Alfieri, (b) Mitraclip and (c) Pascal.

Finally, E1 presented a homogenously distributed pattern for the Alfieri technique while the Mitraclip and Pascal induced higher strains found on both lateral sides of the devices. When comparing the ventricular flow streamline at early and end-diastole (Figure 1), Alfieri's stitch seemed to induce more vorticity than the transcatheter approaches which might result in a more efficient blood filling and ejection.

Conclusions

The Alfieri stitch proved to be more efficient in preserving ventricular filling and ejection efficiency than TEER devices, while also reducing systolic strain on the leaf surface. Although there was a 30% difference in E1 between Mitraclip and Pascal, the two TEER devices had similar hemodynamic behavior.

References

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Table 1: Hemodynamical parameters induced by the different edge-to-edge technique.

	Mean Pressure Gradient (mmHg)	Effective Orifice Area (cm^2)	Geometric Orifice Area (cm^2)	Energy Loss (mW/m)	Strain E1
Alfieri	4.13 ± 0.19	2.15 ± 0.09	2.42 ± 0.02	4.7	0.05 ± 0.02
Mitraclip	6.87 ± 0.21	1.63 ± 0.09	1.96 ± 0.02	7.1	0.09 ± 0.03
Pascal	6.29 ± 0.22	1.74 ± 0.08	2.10 ± 0.02	6.5	0.06 ± 0.02