Impact of aortic valve replacement on valve hemodynamic performance in a simulated calcified aortic valve: An in vitro study

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Summary

This study aims to compare the hemodynamic performance of different treatment options for patient specific calcified aortic valve. The hemodynamic performance of severely calcified valves has considerably improved after either surgical or transcatheter aortic valve replacement and it was comparable to those of healthy native aortic valve.

Introduction

Aortic valve (AV) stenosis is the third most frequent cardiovascular disease in high-income countries responsible for ~125,000 deaths and ~350,000 aortic valve replacement procedures per year worldwide [1]. For years, surgical aortic valve replacement (SAVR) was the only effective treatment for patients with severe AS, but in the last years, new techniques such as transcatheter aortic valve replacement (TAVR) has been growing steadily. This *in vitro* study aims to compare the hemodynamic performance of simulated aortic valves from healthy to calcified conditions and assess the performance of each treatment option.

Methods

The patient-specific calcified AV was segmented from CT scan. To mimic the rheology of healthy (Fig 1.a) and calcified (Fig 1.b) AV valve tissue, a silicone (DragonSkin30, Smooth-On, Inc., PA, USA) was used. The calcifications were replicated using Gypsum plaster. Four SAVR bioprosthetic valves (Epic Supra 23 (Fig 1.c), 25 mm and Perimount Magna 23 (Fig 1.d), 25 mm) and two TAVR valves (Sapien 3 23 mm (Fig 1.e) and Evolut PRO 26 mm (Fig 1.f)) were used to perform aortic valve replacement in this patient-specific calcified AV. In vitro experiments were realized on a left-heart double activation simulator [2] under the following standardized conditions: Heart rate: 66 bpm, Stroke volume: 70 ml, Mean aortic pressure: 100 mmHg. Mean pressure gradient (MPG), and Effective orifice area (EOA) were acquired using continuous-wave Doppler (iE33, Philipps Healthcare, USA). The geometric orifice area (GOA) was obtained using high speed en-face, imaging (FASTCAM Mini AX50, Photron Inc., CA, USA) and custom-coded Matlab program.

Results and Discussion

TAVR and 25 mm label size SAVR valves presented MPGs comparable to those of healthy native AV (Table 1). The 23 mm label size SAVR valves showed significant increases in MPGs and decreases in EOAs relative to healthy native AV ($p<0.001$). Both porcine and bovine pericardial SAVR valves, with a 25 mm label size, had larger EOAs compared to healthy native AV (1.64±0.04 and 1.70±0.07 vs. 1.60±0.06 cm^2). Similar findings were observed in the GOA.

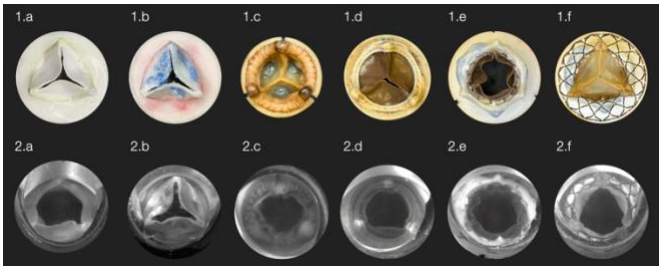

Figure 1: Tested valves (1.a-1.f) and their respective maximal geometric opening areas / GOAs (2.a-.2.f)

Conclusions

This study demonstrates that it is possible to reproduce the valve hemodynamics of a severely calcified and stenotic native AV and to predict the hemodynamic results according to different type of aortic valve replacements and bioprosthetic valves.

References

[1] Roth GA et al. (2019). *J Am Coll Cardiol*. **76(25)**: 2982-3021
[2] Tanné D et al. (2010) *Exp Fluids*. **48**: 837-850

Table 1: Interesting data from well-executed experiments. The data have been arranged in an interesting and clear manner.

	Label Size	True ID (mm)	MPG (mmHg)	EOA (cm^2)	EOAi	GOA (cm^2)
Healthy native AV	-	21.5	8.88±0.24	1.60±0.06	1.25	1.84±0.00
Severe native AV stenosis	-	21.5	55.98±1.57	0.67±0.01	0.58	0.79±0.00
SAVR porcine leaflets (Epic Supra)	23	21	12.98±0.40	1.32±0.05	1.03	1.47±0.00
	25	23	9.06±0.42	1.64±0.04	1.28	1.89±0.00
SAVR bovine pericardial leaflets (Perimount Magna)	23	21	10.92±0.45	1.41±0.03	1.10	1.57±0.00
	25	23	8.69±0.27	1.70±0.07	1.33	1.86±0.00
TAVR bovine pericardial leaflets (Sapien 3)	23	21-25	9.10±0.36	1.50±0.08	1.17	1.61±0.00
TAVR porcine pericardial leaflets (Evolut PRO)	26	20-23	9.02±0.33	1.53±0.05	1.20	1.83±0.00