

In Vitro Haemodynamic Evaluation of Inner- vs. Outer-Branched Thoracoabdominal Endografts

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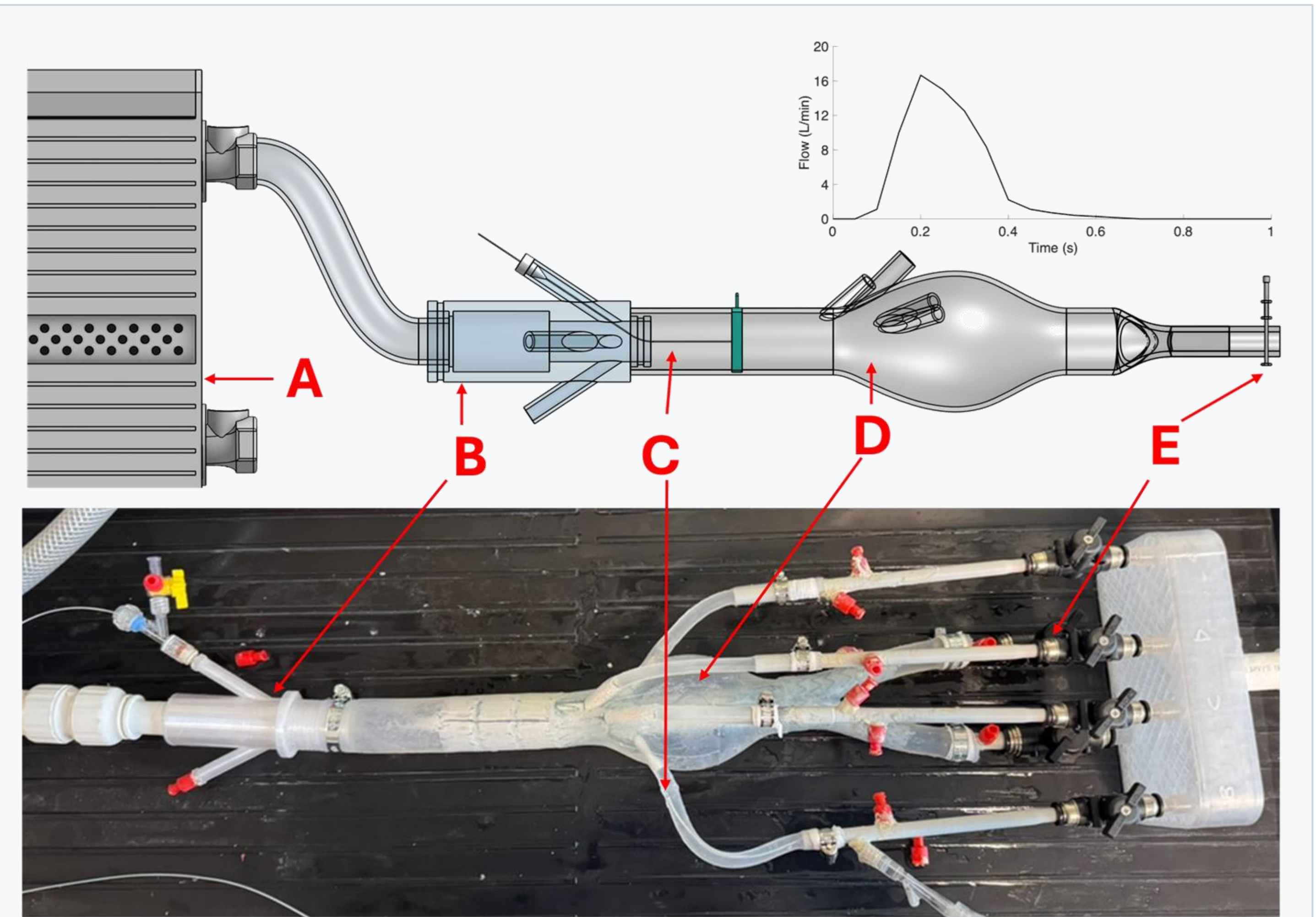
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01 Research question

How do inner- and outer-branched repairs differ in target-vessel haemodynamics under pulsatile conditions?

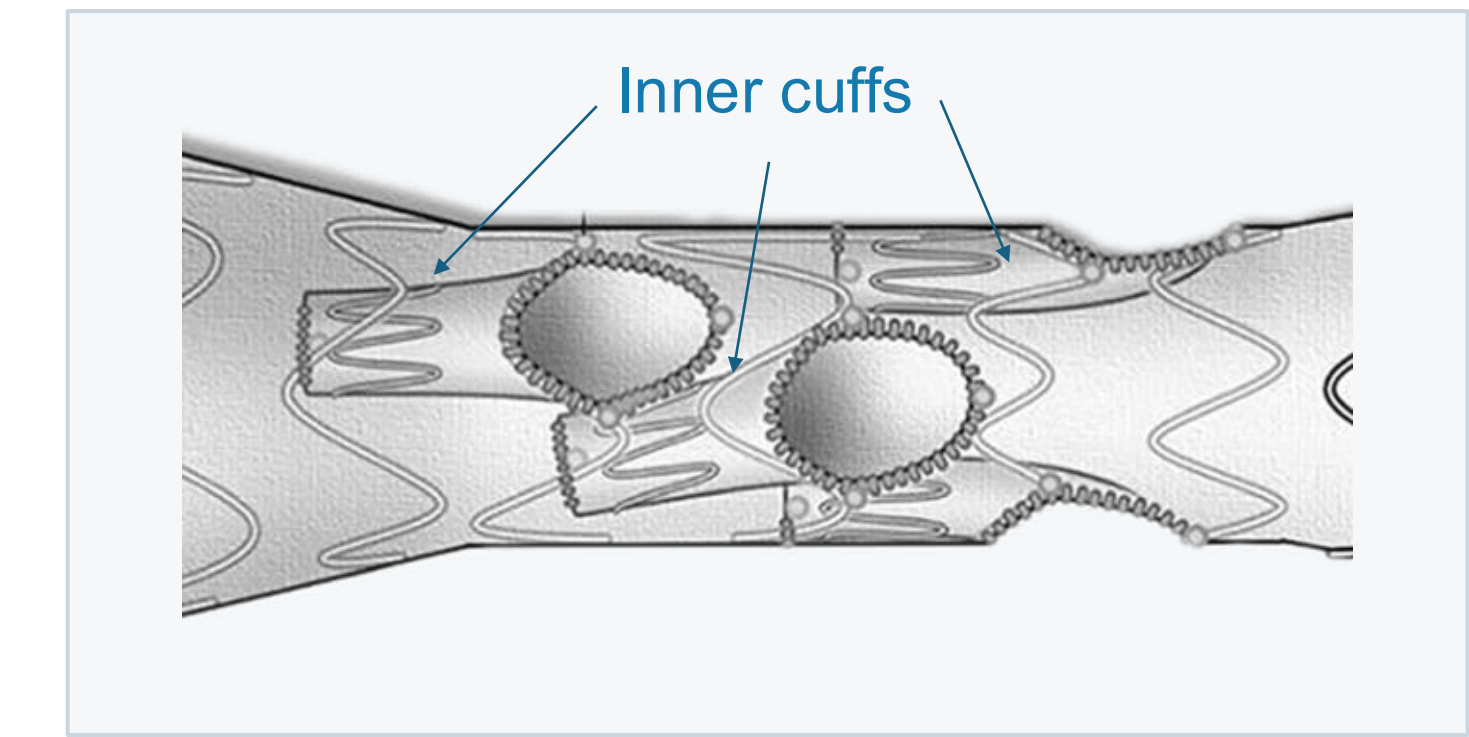
Endovascular aortic repair is an established treatment for aortic aneurysmal disease, offering lower morbidity and mortality compared to open surgery [1]. Fenestrated endovascular aortic aneurysm repair (FEVAR) requires precise planning and positioning to prevent misalignment [2]. Branched endovascular aortic aneurysm repair with external branches fits a wider range of anatomies but requires a wider working aortic lumen and longer aortic cover, increasing the risk of spinal cord ischaemia [3]. The haemodynamic consequences of inner- versus outer-branched repair remain insufficiently characterised. This project utilises an in vitro bench to analyse the arterial pressure differences between Artivion E-xtra Design Multibranched and Cook Medical Zenith t-Branch EVAR solutions.

03 Experimental setup



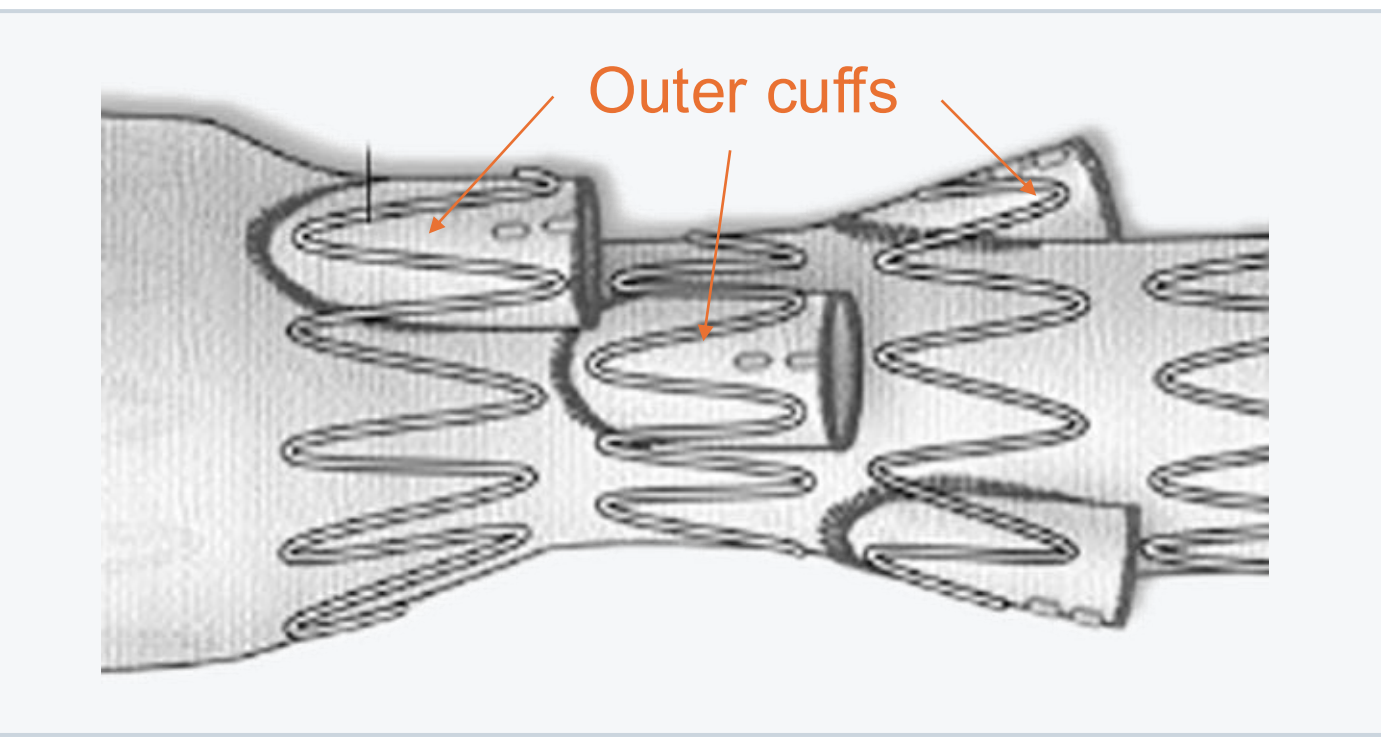
02 Repair configurations

Inner-branched



Inner-branched EVAR
Artivion E-xtra Design Multibranched

Outer-branched



Outer-branched EVAR
Cook Medical Zenith t-Branch

A CardioFlow 5000MR pump (Simutec, Canada) was used to generate a standardised descending aortic flow waveform. The pump was connected to an injection-moulded silicone rubber phantom with a 60 mm aneurysm, built to an idealised specification based on computed tomography measurements. Pressure was measured using a catheter wire. A glycerol-based blood-mimicking fluid was used in the loop. Dextran and Orgasol were added to simulate the viscosity and ultrasound properties of blood, respectively. The solution was heated to 40°C, allowing shape memory alloy stents to expand. A Windkessel chamber was added to simulate compliance, and a flow restrictor simulated peripheral resistance.

The pressure catheter wire was inserted 3 cm distal to the bridging stents and 60 cardiac cycles were recorded at 1 kHz. The process was conducted at the right renal artery, superior mesenteric artery, and coeliac trunk. Three separate runs were performed, and the individual cycles were separated using beat detection and ensemble averaged. Inflow at the descending aorta was maintained at 1.5 L/min, and branch flow splits were maintained between runs and verified using an ultrasonic flow sensor. Systolic, diastolic and mean pressures were compared between configurations at each measurement site. Percentage reductions in mean pressure for the inner-branched configuration were calculated relative to the corresponding outer-branched value.

Fig 1: Mock circulatory loop setup for haemodynamic analysis. A: Pulsatile flow pump, B: One-way flow valve, C: Pressure catheter wire, D: Stented phantom, E: Peripheral resistance

TEST CONDITIONS:

Heart rate: 60 bpm Inflow: 1.5 L/min
Temperature: 40°C Independent runs: 3
Cycles per run: 60

04 Target-vessel pressure

Mean branch pressures were higher with the outer-branched configuration in this in vitro comparison

Lower mean pressure with inner-branched repair (% relative to outer-branched)

15.6%

Right renal artery

17.1%

Superior mesenteric artery

12.7%

Coeliac trunk

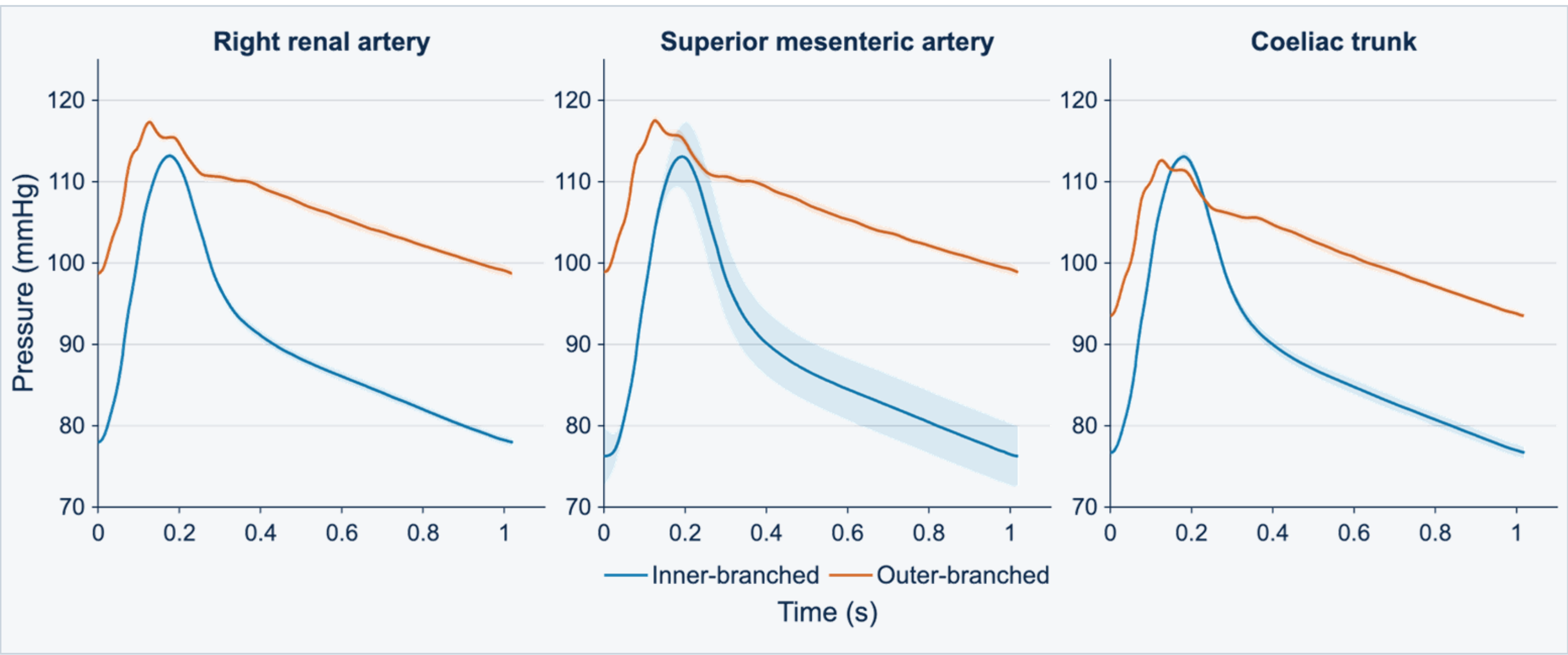
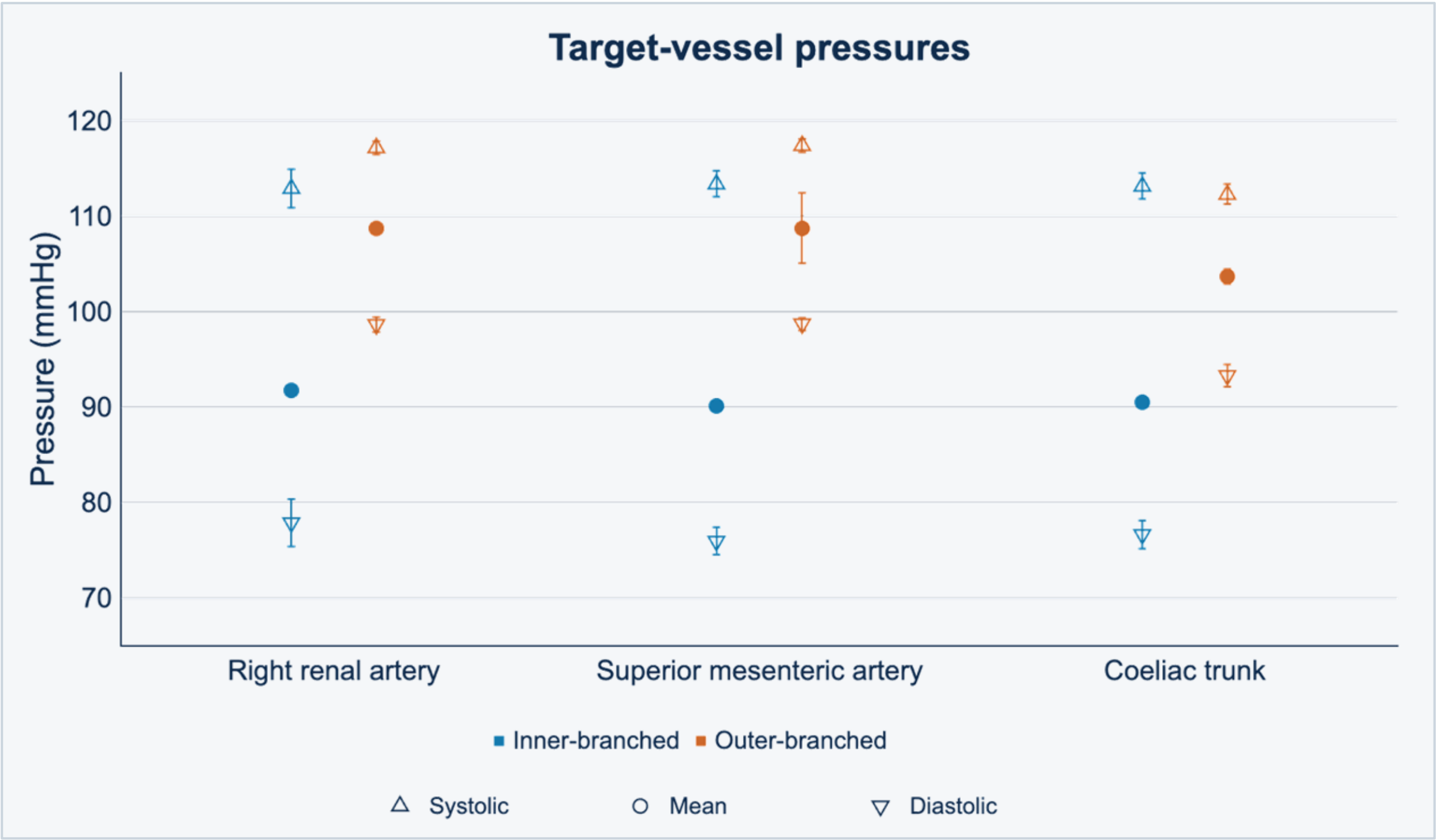


Fig 2: Target-vessel pressures for inner-branched (blue) and outer-branched (orange) configurations. (Left) Systolic, mean and diastolic pressures; error bars indicate ± 1 SD across three runs. (Right) Ensemble-averaged pressure waveforms measured 3 cm distal to the bridging stents; shaded bands indicate ± 1 SD across cardiac cycles. Results are shown for the right renal artery, superior mesenteric artery and coeliac trunk.

Mean pressure is calculated by examining the time average over a cardiac cycle. The inner-branched configuration showed lower mean pressures in all three evaluated vessels, with reductions of 15.6% in the right renal artery, 17.1% in the superior mesenteric artery and 12.7% in the coeliac trunk relative to the outer-branched configuration. Diastolic pressures were also consistently lower, whereas systolic differences were smaller and varied between vessels. The inner-branched waveforms exhibited a more pronounced pressure decline following the systolic peak, whereas the outer-branched configuration maintained higher pressures throughout diastole.

05 Conclusions and limitations

Under matched flow conditions, the outer-branched configuration exhibited higher mean and diastolic target-vessel pressures than the inner-branched configuration, while systolic differences were smaller and vessel-dependent. These findings demonstrate differences in pressure magnitude and waveform shape between the complete repair systems tested. They do not isolate the contribution of branch topography or establish consequences for long-term bridging-stent patency. Further testing with high-speed clinical ultrasound will be undertaken.

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