and that timing of cardiac catheterization remains an important measure of quality of care (2).

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REFERENCES


High Flow Velocity and Low Systolic Pressure

Compliance of the Aortic Wall or Venturi Effect Within

On the basis of hemodynamic studies before and after transcatheter aortic valve replacement (TAVR), Yotti et al. (1) report that the aorta in calcific aortic stenosis is abnormally stiffened, with such stiffening apparent before valve replacement but exposed after TAVR. The authors base their conclusions on comprehensive measures of aortic elasticity, compliance (using a Windkessel model), wave intensity analysis (with or without Windkessel model), and aortic input impedance utilizing a transmission line model.

This study is very important because it bears on the difficulty in managing such patients during and after TAVR, despite successful ability to normalize the gradient across the aortic valve.

There is, however, another issue, and a precedent (2,3) (Figure 1) where a high velocity jet in an artery causes relative reduction in lateral pressure, resulting in the interpretation (with flow volume similar during ejection), that any change in systolic and pulse pressure must be due to altered compliance/distensibility of the artery beyond the source of the jet. In the precedent case (2), low pulse pressure in the distal pulmonary artery beyond an encircling flow meter cuff was reported to reduce compliance of the pulmonary circulation, but can be explained as a Venturi effect, when flow velocity approached or exceeded 90 cm/s (4,5). In the present case (1) flow velocity in the aorta beyond the stenotic valve approached or exceeded 200 cm/s and focus was on distensibility alone, with this considered to be normal before and abnormally high after TAVR. It is not surprising that multiple indices of distensibility were low pre-TAVR,

![Figure 1](image-url)

**Figure 1** Pressure and Flow in the Main Pulmonary Artery of a Dog

Relationship between pressure (above) and flow (below) in the main pulmonary artery, with pressure recorded distal to a tight electromagnetic flow cuff through a needle whose bevel is first directed toward the direction of flow, then at 90° to the direction of flow, then again toward and then again at 90° to the direction of flow. Amplitude of the flow wave was similar and ~130 cm/s for all recordings. A normal pressure wave of some 15 mm Hg was recorded when the bevel faced the direction of flow but was reduced to virtually zero when twisted to face across the direction of flow (and so to be reduced through presence of a high velocity, turbulent jet).
because all were calculated from the same aortic pressure waveform, which had been reduced and distorted when pressure was measured side-on to the direction of flow, by a Venturi effect at peak flow velocity.

The authors appear not to have considered this issue (which was illustrated in the previous paper [3]) (Figure 1); it does explain different features of waveforms, including the slow rising (<400 mm Hg/s) anacrotic pressure pulse, the grossly abnormal values of peripheral resistance, and central impedance prior to TAVR (the authors’ Figure 1 and Central Illustration).

REFERENCEs

REPLY: High Flow Velocity and Low Systolic Pressure

Compliance of the Aortic Wall or Venturi Effect Within

We have read with great interest the letter by Drs. O’Rourke and Nichols, and we appreciate his valuable comments. The issue of conversion of potential (static pressure) to kinetic (dynamic pressure) energy is a very well taken point, and needs to be considered when assessing vascular properties at high flow-velocity rates. As elegantly pointed out by Drs. O’Rourke and Nichols, impact pressure should be preferred over lateral pressure to accurately characterize the arterial load in the scenario of aortic stenosis. Unfortunately, because there are no clinically approved micromanometer catheters capable of measuring impact pressure, lateral pressure has been used in all previous work on arterial hemodynamics of aortic stenosis (1–3). Moreover, notice that in our study we balanced the pressure micromanometer against the impact pressure measured by a fluid-filled guiding catheter aligned facing the flow direction. Because we were aware of non-negligible dynamic pressure, we performed this balancing procedure in situ in the ascending aorta at the measurement point (see the Central Illustration from Yotti et al. [4]). Although the mean pressure matching method we used for balancing may introduce some small time-dependent errors from the fluid-filled system, it grants an accurate measurement of both static and dynamic components.

We have confirmed that dynamic pressure was properly captured by our calibration procedure. In most cases, peak-systolic micromanometer pressure after balancing was in fact slightly higher than guiding catheter impact pressure (Figure 1)—probably due to overdamping in the fluid-filled system. This error did not change after transcatheter aortic valve replacement (TAVR) and did not correlate with peak flow velocity (R = 0.01). Thus, although there may have been some subtle impact on the morphology of the pressure tracings, there was no significant Venturi effect on our data. Additionally, TAVR modified vascular resistance and pressure-decay compliance, indices that are insensitive to the systolic morphology of the pressure waveform. Finally, we would like to emphasize that the slow upstroke and other features of aortic pressure waveforms attributed by Drs. O’Rourke and Nichols to measurement artifacts are universally accepted signs of aortic stenosis.

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