Is the Valve OK or Not? Immediate Evaluation of a Replaced Aortic Valve

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Transesophageal echocardiography (TEE) is a crucial tool in intraoperative evaluation of newly implanted/repaired heart valves because suspected valvular malfunction needs to be identified and sometimes surgically corrected. Although color Doppler is often adequate in evaluating the expected regurgitant jets, as well as excluding pathologic paravalvular leaks, spectral Doppler techniques are the most commonly used methods for estimating transvalvular gradients in the operating room. However, these methods are subject to a variety of confounding factors, including subvalvular gradients and pressure recovery. Other methods of valve area estimation should also be used when evaluating a prosthetic aortic valve, including the continuity equation and the left ventricular outflow tract/aortic valve velocity ratio.

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Discussion

Use of TEE after valvular procedures is essential in ensuring adequate functioning of the newly implanted or repaired valve (2–6). In our case, 2-dimensional images of the prosthesis suggested a problem with one leaflet, whereas Doppler examination showed an unusually high peak velocity through the new valve, raising clinical suspicion of prosthesis malfunction. However, fluoroscopy in the catheterization laboratory the next day showed normal motion of both leaflets. We believe several factors must be considered for proper interpretation of Doppler data in this confusing clinical setting.

Bernoulli’s Equation, as it is applied to echocardiography, is adapted to give the modified Bernoulli Equation as follows:

\[\frac{\text{Pressure Gradient}}{\text{H}^2} = \frac{\left(\frac{1}{2} \times \text{V}_2^2 - \text{V}_1^2\right)}{\text{H}^2}\]

where \(\text{V}_2\) is the peak velocity through the valve, and \(\text{V}_1\) is the subvalvular velocity; that is, through the LV outflow tract (LVOT) (7). In general practice, \(\text{V}_1\) is generally ignored, yielding the simplified form of the equation:

\[\text{Pressure Gradient} = 4(\text{V}_2^2 - \text{V}_1^2)\]

A second point is the need to calculate valve area using the continuity equation. With a measured LVOT diameter of 0.9 cm, \(\text{V}_1\) of 2.6 m/s, and \(\text{V}_2\) of 5.14 m/s, the prosthetic valve area is 1.30 cm², a value close to 1.54 cm², the effective area of a 21-mm Carbomedics valve (1). Even more useful is measurement of the peak flow ratio (LVOT/AV), which in this case (2.6/5.14) is approximately 0.5, very near the published normal for this size and type of valve (0.4) (9,10). Both of these calculations confirm normal function of the new valve.

Pressure recovery is responsible for the observed differences between Doppler-derived gradients and catheter-measured gradients and is probably the least recognized factor involved. As flow traverses a narrow orifice, the flow stream contracts (vena contracta) and subsequently expands on reaching a wider passage. Pressure exerted by the flow stream decreases with increasing velocity, and “recovers” as the fluid slows distal to the maximal obstruction. Thus, pressure measured in the LVOT will decrease at the level of the AV and recover in the proximal ascending aorta. Spectral Doppler measurements allow calculation of the maximal pressure gradient between the proximal flow stream (LVOT) and the vena contracta (valve orifice), whereas catheter measurements record gradients between the proximal flow stream (LVOT) and the recovered pressure beyond the vena contracta (proximal ascending aorta).

Pressure recovery may be responsible for a significant portion of our misleading measurements. In St. Jude bileaflet valves, the proportion of the peak laboratory-measured gradient (analogous to the Doppler-derived gradient) attributed to pressure recovery was 53% for

Figure 1. A continuous-wave Doppler measurement through the prosthetic aortic valve from the transgastric position. The peak velocity recorded is 5.3 meters/s, which is abnormally high, even for mechanical prosthetic valves.
the central orifice and 29% for the slightly larger side orifices (11). Interestingly, a smaller proximal aorta may be an important predictor for pressure recovery. In a series of 23 patients with native aortic stenosis, all of those with Doppler-catheter gradient differences more than 20 mm Hg had aortas that measured <3 cm in diameter (12). In our patient, the diameter of the proximal aorta was 2.8 cm.

Several other factors may have been important in our case. The presence of postbypass anemia and an increased CO, as well as factors such as patient/prosthetic mismatch and technical errors, may have contributed. The possibility of measurement or operator error must also be considered. Measurement through the smaller central orifice of a bileaflet prosthesis will yield a higher peak velocity than the larger side orifices, an error decreased by multiple measurements.

Diagnostic evaluation in the OR can use a variety of echocardiographic and other maneuvers depending on the expertise of the anesthesiologist and the surgeon, as well as the stage of the operation. Use of epiaortic scanning in the hands of a skilled surgeon may settle the question definitely by imaging the leaflets more clearly. However, when using Doppler techniques, the same issues would apply as with TEE. If the chest has been closed, or if doubt remains before leaving the OR, a TTE could be performed, which may be able to image the leaflets or give a more superior Doppler signal of the LVOT given its more flexible position on the chest. Various case reports have been published describing similar cases in which gradients have been measured with the use of needles placed directly into the LV and ascending aorta. Unfortunately, these directly-measured gradients are subject to error from similar sources as Doppler-measured gradients (that is, pressure recovery), as well as confounding factors from impact energy interacting with single-holed needles and acoustic shadowing from the prosthesis itself (13). Thus, these data should be interpreted with caution.

In summary, we report a case during which an unusually high peak velocity measured after aortic prosthetic valve implantation, combined with an inability to visualize leaflet motion, raised serious concerns of prosthesis malfunction or stuck leaflet. In this setting, it is imperative to consider the presence of a subvalvular gradient and apply the modified rather than the simplified Bernoulli Equation. Furthermore, effective valve area should be calculated using the continuity equation and, most importantly, by the LVOT/AV velocity ratio to assess AV function (normal, 0.35–0.5 for range of prosthetic valves) (13). The phenomenon of pressure recovery should be considered in evaluating prosthetic valve function when small prostheses (19, 21 mm) are implanted, and especially when the proximal ascending aorta is small. Other echocardiographic techniques may be helpful, especially epiaortic scanning by a skilled surgeon, and TTE, if the chest is already closed.

References


