Editorial Comment

The Challenge of Assessing Heart Valve Prostheses by Doppler Echocardiography

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The assessment of prosthetic valve function remains challenging. Echocardiography has become the key diagnostic tool not only because of its noninvasive nature and wide availability but also because of limitations inherent in alternative diagnostic techniques. Invasive evaluation is limited particularly in mechanical valves that cannot be crossed with a catheter, and in patients with both aortic and mitral valve replacements, full hemodynamic assessment would even require left ventricular puncture. Although fluoroscopy and more recently computed tomography allow the visualization of mechanical valves and the motion of their occluders, the evaluation of prosthetic valves typically relies on Doppler echocardiography.

Although Doppler echocardiography has become an ideal noninvasive technique for the evaluation of native heart valves and their function, the assessment of prosthetic valves has remained more difficult. Although the evaluation of secondary effects on heart chambers, ventricular function, and pulmonary circulation can in general be provided accurately, the evaluation of prostheses themselves has major limitations. The assessment of valve morphology as well as valvular and perivalvular regurgitation is complicated by artifacts and shadowing caused by the prosthetic material.[1] This is particularly the case when transthoracic echocardiography is used, but it also remains a major limitation for transesophageal echocardiography.[2,3] Although the latter may provide important information on bioprosthetic valve function by visualizing leaflet morphology and motion, and on mechanical valve function in mitral prostheses in which it frequently allows the diagnostic evaluation of occluder motion, prosthetic valve function is primarily assessed using Doppler echocardiography (mainly using transthoracic echocardiography). As for native valves, Doppler echocardiography can be used to measure transvalvular velocities and gradients and to calculate effective orifice areas in patients with valve prostheses. However, major differences and some limitations must be considered when interpreting Doppler measures of transprosthetic flow velocities and orifice areas.

First, transvalvular velocities cannot be used to accurately calculate the pressure drop across certain valve types, because of the rather complex flow velocity profiles in mechanical valves.[4,5] This is particularly the case in bileaflet prostheses, in which flow contraction causes a low-pressure field followed by significant pressure recovery within the central orifice and flow channel between the two leaflets.[6] This phenomenon results in high central velocities, which are detected by continuous-wave Doppler measurement. Using these velocities for the calculation of transvalvular gradients results in marked overestimation of the actual pressure drop across the prostheses.[6] The fact that this phenomenon more or less disappears in malfunctioning bileaflet prostheses when the funnel-shaped central flow channel ceases to exist because of restricted leaflet motion makes the interpretation of Doppler data and their use for accurate detection of prosthesis malfunction even more complicated.[7] Furthermore, the lack of a flat velocity profile and the central high velocities described above cause erroneous calculations of valve areas when the continuity equation incorporates such measurements.[8] For these reasons, the analysis of occluder motion using fluoroscopy (in mitral prostheses, this may also be obtained on transesophageal echocardiography) remains essential to avoid the misinterpretation of high Doppler velocities across bileaflet prosthetic valves.

The second specific problem that complicates the interpretation of Doppler data in prosthetic heart valves is that most normally functioning prostheses slightly obstruct the flow compared with normal native valves. This means that velocities, corresponding gradients, and pressure half-time measures are generally higher than in normal native valves. This frequently makes it difficult to differentiate between normal and abnormal prosthetic valve function; in other words, to decide when elevated velocities, gradients, or pressure half-times indicate prosthetic valve malfunction. The meaningful interpretation of Doppler data requires first of all the knowledge of the type and size of the valve that is interrogated. A stented bioprosthesis causes more flow obstruction than a stentless valve, and a smaller sized valve causes more obstruction than a larger valve. Normally functioning bileaflet valves present with higher Doppler velocities than tilting disc valves, and so on.[9,10] In addition, transvalvular velocities and gradients are highly flow dependent.[10] Thus, even when looking at a specific size of a certain valve type, the measurements reported for normally functioning valves vary markedly,[9,10] and additional consideration of the individual flow rate may be required to decide whether a certain value of velocity or gradient must be considered abnormal or if it is still consistent with normal prosthetic valve function. In any case, the availability of normal values for Doppler measurements, gathered in large groups of patients with apparently normally functioning valves, and specifying valve type and valve size, are essential for assessing heart valve prostheses in daily practice. Such data have been provided in the past[11,12] but have always been more or less incomplete, considering the great and constantly increasing number of different valve products and the relatively small number of patients in most published reports.

In this issue of the *Journal of the American Society of Echocardiography*, Blauwet et al[13] add important new information in this respect by providing comprehensive echocardiographic data from a large group of patients with Carpentier-Edwards Duraflex mitral bioprostheses (Edwards Lifesciences, Irvine, CA), a type of prosthesis for which few data have been published on normal Doppler values. In a retrospective analysis, the authors report comprehensive echocardiographic data from 240 patients studied early after valve replacement. All patients had either ratios of the time-velocity integral (TVI) for the mitral valve prosthesis to the TVI for the left ventricular outflow tract < 3.9 or E velocities < 2.8 m/s. Pressure half-times were <130 ms

in all patients, and 97% had TVI ratios < 3.9 and E velocities < 2.8 m/s, regardless of bioprosthesis size, left ventricular function, heart rate, hemoglobin, or hematocrit. Blauwet et al conclude that these cutoff values may therefore be useful in identifying on Doppler echocardiography prosthetic valve dysfunction in patients with this type of mitral bioprosthesis.

Although it is true that patients with measurements beyond these reported cutoff values are very likely to have prosthetic valve dysfunction, caution is required when applying these results and conclusions in clinical practice. The major limitation of Blauwet et al's[13] study was that only normal valves were included. Thus, the authors can only report the range of measurements found in a group of patients assumed to have normal prosthetic valve function. Clinically valid cutoff values for the distinction between normal and malfunctioning valves, however, cannot be identified in such a patient group. It remains uncertain from these data how frequently valve malfunction can be encountered in patients with values below the reported cutoffs. In other words, these cutoffs may have reasonable specificity for diagnosing prosthesis malfunction but insufficient sensitivity. In fact, on the basis of everything we know about such Doppler measurements and looking at the wide range of numbers presented even for specific valve sizes in previous reports as well as in Blauwet et al's study, the value of these cutoffs for clinical practice appears uncertain. For example, a patient with an increase in E velocity from somewhere between 1 and 1.5 to somewhere between 2.5 and 3 is indeed very likely to have dysfunction (significant regurgitation or obstruction), although both values are within the reported normal range. Although E velocity is highly flow dependent, the TVI ratio has the advantage of compensating for changes in cardiac output. However, this measurement remains dependent on mitral and aortic regurgitation as well as individual valve size and left ventricular outflow tract size. Looking at the wide range of reported "normal ratios" (from slightly above 1 to >4), it is again unlikely that a single measurement in an individual patient can define valve function, as long as it is not beyond the reported range. Indeed, the data support the accepted wisdom that serial follow-up measurements, with well defined baseline measurements for later comparison and consideration of valve size, flow situation, and the presence of additional valvular regurgitation, are required for the appropriate assessment of function in individual prosthetic valves.

Additional limitations of Blauwet et al's[13] study are its retrospective design and the fact that some of the measurements were performed post hoc. Furthermore, baseline data obtained very early after surgery may also have limitations. Patients may not have reached stable baseline conditions with regard to preload and afterload as well as ventricular function. It is important that the authors excluded patients who were on pressors during their exams. Postoperative anemia may also have affected the measurements.

In conclusion, the Doppler echocardiographic assessment of prosthetic valve function remains challenging. In particular, the interpretation of Doppler data remains difficult with regard to the separation of normal prosthetic valve function and malfunction. Although currently available literature, including Blauwet et al's[13] study, are helpful to some degree, serial follow-up measurements with well-defined baseline measurements for later comparison, together with careful consideration of valve type, valve size, flow situation, and the presence of additional valvular regurgitation, are required for appropriate individual prosthetic valve function assessment. Additional fluoroscopy or computed tomography for the analysis of occluder motion may be required in mechanical valves.

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