Doppler Parameters Derived from Transthoracic Echocardiography accurately Detect Bioprosthetic Mitral Valve Dysfunction

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Background: Detecting bioprosthetic mitral valve dysfunction on transthoracic echocardiography can be challenging because of acoustic shadowing of regurgitant jets and a wide normal range of transvalvular gradients. Several studies in mechanical mitral valves have demonstrated the utility of the transthoracically derived parameters E (peak early mitral inflow velocity), pressure half-time, and the ratio of mitral inflow velocity-time integral (VTI_{MV}) to left ventricular outflow tract velocity-time integral (VTI_{LVOT}) in detecting significant prosthetic dysfunction. Uncertainty exists as to their applicability and appropriate cutoff levels in bioprosthetic valves. This study was designed to establish the accuracy and appropriate normal limits of routinely collected transthoracic Doppler parameters when used to assess bioprosthetic mitral valve function.

Methods: A total of 135 clinically stable patients with bioprosthetic mitral valves who had undergone both transthoracic and transesophageal echocardiography within a 6-month period were retrospectively identified from the past 11 years of the echocardiography database. Transthoracic findings were labeled as normal ($n = 81$), regurgitant ($n = 44$), or stenotic ($n = 10$) according to the patient's transesophageal echocardiographic findings. Univariate and multivariate analyses were performed to identify Doppler parameters that detected dysfunction; then receiver operating characteristic curves were created to establish appropriate normal cutoff levels.

Results: The VTI_{MV}/VTI_{LVOT} ratio was the most accurate Doppler parameter at detecting valvular dysfunction, with a ratio of >2.5 providing sensitivity of 100% and specificity of 95%. E > 1.9 m/sec was slightly less accurate (93% sensitivity, 72% specificity), while a pressure half-time of >170 msec had both 100% specificity and sensitivity for detecting significant bioprosthetic mitral valve stenosis, (although it did not differentiate between regurgitant and normal).

Conclusions: This study demonstrates that Doppler parameters derived from transthoracic echocardiography can accurately detect bioprosthetic mitral valve dysfunction. These parameters, particularly a VTI_{MV}/VTI_{LVOT} ratio of >2.5, are a sensitive way of selecting patients to undergo more invasive examination with transesophageal echocardiography. (J Am Soc Echocardiogr 2017;■:■-■.)

Keywords: Bioprosthetic mitral valve dysfunction, Echocardiography, Doppler, Transthoracic

Detecting bioprosthetic mitral valve dysfunction (significant stenosis or regurgitation) on transthoracic echocardiography (TTE) can be challenging yet vital to appropriately select patients for more invasive evaluation by transesophageal echocardiography (TEE). The large normal range of transmitral gradients published for each individual prosthesis[1] complicates the assessment of pathologic stenosis, and acoustic shadowing of the regurgitant jet by the prosthesis can render significant regurgitation invisible to standard color Doppler imaging.[2] Transmitral gradients are also significantly affected by heart rate and cardiac output, and normal mean gradients have been reported to be as high as 15 mm Hg.[1,3,4] Transthoracically derived Doppler parameters that do not rely on visualization of the regurgitant jet and are relatively independent of heart rate and stroke volume (SV) have been shown to be effective in detecting significant mechanical mitral prosthetic dysfunction.[5,6] Few studies, however, have evaluated these parameters in bioprosthetic valves. Current American Society of Echocardiography guidelines recommend assessing various Doppler parameters in prosthetic mitral valve function but note uncertainty in cutoff values in bioprosthetic valves.[7] Several studies have reported the full range of Doppler values for normally functioning, in vivo bioprosthetic mitral valves,[1,3,4] but none have investigated these parameters in dysfunctional valves.

Early Doppler studies on normal bioprosthetic valves focused on peak gradient and valve area, calculated via the pressure half-time (PHT).[8-11]

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Conflicts of Interest: None.

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Abbreviations

AUC = Area under the curve

BSA = Body surface area

EF = Ejection fraction

LVOT = Left ventricular outflow tract

PHT = Pressure half-time

SV = Stroke volume

TEE = Transesophageal echocardiography

TTE = Transthoracic echocardiography

VTI = Velocity-time integral

VTI_{LVOT} = Left ventricular outflow tract velocity-time integral

VTI_{MV} = Mitral inflow velocity-time integral

More recently, E (the peak velocity of early left ventricular filling), the PHT, and the ratio of mitral inflow velocity-time integral (VTI_{MV}) to left ventricular outflow tract velocity-time integral (VTI_{LVOT}) have been shown to be the most accurate Doppler parameters when assessing mechanical mitral prosthetic dysfunction.[5,6,12,13] In mechanical valves, these studies have shown that either an E of ≥1.9 m/sec or a VTI_{MV}/VTI_{LVOT} ratio of ≥2.2 detect significant prosthetic valve dysfunction (stenosis or regurgitation) with an accuracy of >90%. No studies have evaluated whether these cutoffs apply to modern bioprosthetic valves. The few studies that have reported these Doppler parameters for normally functioning bioprosthetic valves have suggested that higher cutoffs may be needed.[3,4] The present study was therefore designed to determine the accuracy and best cutoff levels of routinely collected Doppler values when used to detect significant bioprosthetic mitral valve dysfunction, using both normal and abnormally functioning bioprosthetic mitral valves.

METHODS

Population

All patients with bioprosthetic mitral valves who had undergone both TTE and TEE within a period of 6 months were retrospectively identified in our echocardiography database. Patients were included if they had undergone comprehensive transthoracic studies within 180 days of their transesophageal studies and had no interval clinical evidence of a change in valvular function. All studies between January 2004 and May 2015 were eligible for inclusion. Exclusion criteria were subvalvular left ventricular outflow tract (LVOT) obstruction or moderate or greater aortic regurgitation (both of which affect VTI_{LVOT}) or image quality precluding accurate measurement on transthoracic imaging. Of the approximately 220,000 studies in the database, 146 transthoracic studies met the inclusion criteria, with 135 included in the final analysis after the exclusion of three patients because of subvalvular LVOT obstruction, four patients because of insufficient image quality, and four patients because of moderate or greater aortic regurgitation (Figure 1).

Patients' transthoracic studies were divided into three categories on the basis of prosthetic mitral function on TEE (which served as the gold standard in the majority of cases): normal, regurgitant (defined as those with moderate or severe regurgitation), or stenotic (defined as two-dimensional evidence of abnormal valve structure on TEE [thickened leaflet with decreased mobility, thrombus, or pannus] with a mean gradient of >5 mm Hg on TTE and no more than mild regurgitation). Because stenotic values were required to have two-dimensional evidence of abnormal function on TEE, a mean gradient of >5 mm Hg was chosen, because this level is given as the upper limit of definitely normal valves in the 2009 American

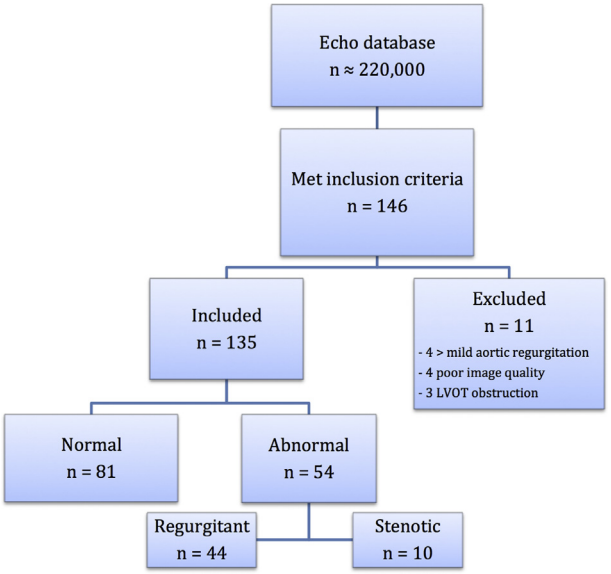

Figure 1 Study flowchart showing included and excluded patients. See text for definitions of regurgitant and stenotic dysfunctional valves.

Society of Echocardiography guidelines on prosthetic valvular assessment.[7] Additionally, we prospectively elected to include in the regurgitant group any transthoracic studies judged to have greater than moderate prosthetic mitral regurgitation by color Doppler (as judged by two independent reviewers). This enabled inclusion of those patients with clearly significant regurgitation who did not proceed to TEE or surgery, thus reducing selection bias. Multiple transthoracic studies from a single patient were included only in cases of redo mitral valve surgery in which preoperative TEE demonstrated bioprosthetic dysfunction, and intraoperative images obtained after valve replacement demonstrated normal valve function. In this case, preoperative TTE was allocated to the dysfunctional group (regurgitant or stenotic) and postoperative TTE to the normal group. Ethical approval for the study was obtained from the University of British Columbia.

Echocardiography

Studies were performed using commercially available ultrasound systems (iE33 [Philips Medical Imaging, Andover, MA], Vivid I [GE Healthcare, Milwaukee, WI], or HP Sonos 5500 [Hewlett-Packard, Andover, MA]) and recorded on an image management system (Xcelera; Philips Medical Imaging).

During TEE, leaflet mobility was examined with two-dimensional imaging, and the maximum mean gradient through the bioprosthetic mitral valve was sought using continuous-wave Doppler from multiple views. The presence of mitral regurgitation on TEE was evaluated with color Doppler with adjustment of the transducer to maximize the regurgitant jet. The source of the jet was established, and the maximal area of the high-velocity regurgitant flow was traced to assist in classifying severity. Central jets were classified as mild (jet area < 4 cm^2), moderate (4–7 cm^2), or severe (>7 cm^2).[14,15] Eccentric jets were considered moderate if the jet impacted the left atrial wall and changed direction and severe if this was associated with systolic pulmonary vein flow reversal.[16] These criteria are in accordance with the latest American Society of Echocardiography guidelines on prosthetic valve assessment[7] and were used to allow

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