Left Ventricular Global Systolic Longitudinal Deformation and Prognosis 1 Year after Femoral and Apical Transcatheter Aortic Valve Implantation

Brian Bridal Løgstrup, MD, PhD, Henning R. Andersen, MD, DMSci, Leif Thuesen, MD, DMSci, Evald H. Christiansen, MD, DMSci, Kim Terp, MD, DMSci, Kaj-Erik Klaaborg, MD, DMSci, and Steen H. Poulsen, MD, DMSci, *Skejby, Denmark*

Background: Aortic valve replacement is the recommended therapy for patients with severe aortic stenosis who have symptoms or decreased left ventricular (LV) function. Transcatheter aortic valve implantation (TAVI) is a treatment alternative in surgically high-risk or inoperable patients with severe aortic stenosis. The objective of this study was to analyze LV function assessed by global LV longitudinal systolic strain (GLS) and relation to prognosis in patients with severe aortic stenosis treated with femoral or apical TAVI.

Methods: Two-dimensional echocardiography was performed before and 1 year after TAVI. Ejection fraction (EF) was retrospectively measured using the biplane Simpson's method, and GLS was obtained as an average of 16 segments in the three standard apical views by speckle-tracking. GE Vivid 7 and Vivid 9 machines were used for echocardiography, and speckle-tracking analysis was performed using EchoPAC PC '08 version 7.0.1.

Results: The total population consisted of 100 TAVI patients. Eighty-one patients survived to 1-year follow-up, with a mean age of 81 ± 7 years (range, 64–93 years) and a mean European System for Cardiac Operative Risk Evaluation score of 9.6 ± 2.7. Nineteen patients died before 1-year follow-up (12 women), with a mean age of 82 ± 7 years (range, 66–92 years) and a mean European System for Cardiac Operative Risk Evaluation score of 10.5 ± 2.8. No differences were found between the 19 patients who died before follow-up and the 81 patients who survived to 1-year follow-up. GLS was increased significantly 1 year after TAVI. In 34 patients with EFs > 50%, GLS increased from −15.3 ± 3.4 to −17.1 ± 3.6 ($P = .04$). In these patients, the mean EF increased numerically from 57.9 ± 5.3% to 60 ± 7.7% ($P = .19$). In 74 patients with EFs ≤ 50%, mean GLS and EF improved significantly from −10 ± 2.8 to −13.8 ± 3.8 ($P < .0001$) and 39 ± 9.4% to 52 ± 12.5% ($P < .0001$), respectively. The 1-year gain in EF was the same after femoral TAVI (9.7 ± 10.1%) and after apical TAVI (8 ± 10.8%) ($P = .52$). Furthermore, GLS did not differ significantly after femoral and apical TAVI (−3.8 ± 3.3 and −2.6 ± 3.7, respectively, $P = .21$). There was no difference in causes of death according to approach. In the total population ($n = 100$), 35 deaths occurred, 19 before 1-year follow-up and 16 afterward. The median follow-up time was 30 months. Twenty-five patients (71%) died from cardiac causes. Overall 1-year mortality was 19%, and overall 2-year mortality was 28%. In the patients who died, the median survival time in the apical group was 28.5 ± 15.4 months, compared with 31.6 ± 19 months in the femoral group ($P = .47$). There was no impact on prognosis according to high (≥47.5%) versus low (<47.5%) baseline EF or high (≥11.95%) versus low (<11.95%) baseline GLS. However, the magnitude of changes in GLS seemed to have a prognostic impact.

Conclusions: LV EF and longitudinal systolic deformation were improved in TAVI independent of technical approach using the Edwards SAPIEN valve prosthesis during 1-year follow-up. The mortality rate was comparable between technical approaches and independent of baseline LV function. However, patients with the greatest improvement in LV systolic longitudinal deformation after TAVI had a lower mortality rate. (J Am Soc Echocardiogr 2013;26:246-54.)

Keywords: Transcatheter aortic valve, TAVI, Left ventricle, Speckle-tracking, Global longitudinal strain

From the Department of Cardiology (B.B.L., H.R.A., L.T., E.H.C., S.H.P.) and the Department of Cardiothoracic Surgery (K.T., K.-E.K.), Aarhus University Hospital, Skejby, Denmark.

Reprint requests: Brian Bridal Løgstrup, MD, PhD, Aarhus University Hospital Skejby, Department of Cardiology, Brendstrupsgaardsvej 100, 8200 Aarhus N, Skejby, Denmark (E-mail: *bbl@dadlnet.dk*).

0894-7317/$36.00

http://dx.doi.org/10.1016/j.echo.2012.12.006

Abbreviations

AS = Aortic stenosis

EF = Ejection fraction

EuroSCORE = European System for Cardiac Operative Risk Evaluation

GLS = Global left ventricular longitudinal systolic strain

LV = Left ventricular

LVMI = Left ventricular mass index

RWT = Relative wall thickness

TAVI = Transcatheter aortic valve implantation

WMSI = Wall motion score index

Surgical aortic valve replacement is the recommended therapy for patients with severe aortic stenosis (AS) who have symptoms or decreased left ventricular (LV) function. The development of transcatheter aortic valve implantation (TAVI) offers an alternative and "less invasive" treatment option for patients with AS with high surgical risk. TAVI may be performed by retrograde passage of the aortic valve, using the femoral approach, or transapically through a thoracotomy and direct puncture of the left ventricle at the apex. AS induces LV remodeling, with progressive myocardial hypertrophy and fibrosis due to increased afterload,[1,2] and myocardial deformation analysis has been proposed as a reliable tool for the detection of clinical and subclinical regional LV dysfunction.[3,4] The assessment of global longitudinal LV systolic strain (GLS) may elucidate the pathologic mechanisms of AS.[5,6] It has been demonstrated that indices of longitudinal regional myocardial deformation are significantly reduced in patients with AS, particularly in association with coexisting coronary artery disease.[7,8]

The conventional measurement of LV function, LV ejection fraction (EF), reflects primarily radial function, but this function is load dependent and therefore less useful in AS. In contrast, GLS focus on the longitudinal myocardial fibers and may add more information to LV function than the conventional EF.

Therefore, the objective of this study was to analyze LV function assessed by GLS, regional LV longitudinal systolic strain and LV mass in patients with severe AS treated with femoral or apical TAVI. Furthermore, we investigated if baseline and/or changes in LV function after TAVI had any impact on prognosis.

METHODS

Patients

In our retrospectively conducted study, a total of 131 symptomatic patients with isolated AS not amenable to conventional aortic valve replacement because of severe comorbidities were suitable for enrollment. At least two surgeons and one cardiologist had to agree that a patient was not a suitable candidate for surgery. Nineteen patients died before 1 year of follow-up, 14 patients underwent echocardiography on an ultrasound machine produced by a different manufacturer, and 17 patients had poor echocardiographic quality or missing follow-up echocardiograms. Thus, the final study population consisted of 81 patients who survived for 1 year after TAVI with Edwards SAPIEN valves (Edwards Lifesciences, Irvine, CA) inserted using either the femoral or the apical approach. The recruitment period was from February 2006 through September 2010. The study was approved by the local ethics committee and the Danish Data Protection Agency.

Echocardiography

Transthoracic echocardiography was performed immediately before and 1 year after TAVI using a commercially available ultrasound system (Vivid 7 or Vivid 9; GE Vingmed Ultrasound AS, Horten, Norway). All images were stored digitally and analyzed randomly and offline by a single investigator blinded to all clinical data. All measurements were analyzed using EchoPAC version 7.0.1.

LV EF was calculated from conventional apical two-chamber and four-chamber images using the biplane Simpson's technique. For the assessment of wall motion score index (WMSI), the left ventricle was divided into 16 segments. A semiquantitative scoring system was used. Global WMSI was calculated as the sum of the segmental scores divided by the number of segments scored. From standard chamber projections, LV EF and WMSI were measured.

LV dimensions were obtained from the parasternal long-axis view, with measurement of end-diastolic interventricular septal thickness, LV posterior wall thickness, and LV end-diastolic diameter just below the tips of the anterior mitral leaflet. LV mass was calculated using the Devereux formula[9] and indexed to body surface area to obtain the LV mass index (LVMI). LV hypertrophy was defined as an LVMI > 115 g/m^2 for men and an LVMI > 95 g/m^2 for women. Relative wall thickness (RWT) was calculated as $2 \times$ (LV posterior wall thickness/LV end-diastolic diameter) and considered abnormal when >0.42.[10] RWT and LVMI were used to assess LV geometry. Patients were categorized as having normal geometry (normal RWT and normal LVMI), concentric remodeling (increased RWT and normal LVMI), eccentric hypertrophy (normal RWT and increased LVMI), or concentric hypertrophy (increased RWT and increased LVMI). LV end-diastolic and end-systolic volumes were obtained from the apical view and indexed to body surface area.

GLS

GLS was assessed using the Automated Function Imaging technique (GE Vingmed Ultrasound AS) on the basis of two-dimensional longitudinal strain imaging. This was obtained from two-dimensional gray-scale images of the apical four-chamber, two-chamber, and long-axis view with an optimized frame rate (50–90 frames/sec). Aortic valve closure timing was marked (to determine the end of systole) in the selected views, and three points were anchored inside the myocardial tissue, two placed at the basal segments along the mitral valve annulus and one at the apex. These points triggered the automatic process, which analyzed myocardial motion by tracking features (natural acoustic tags). Longitudinal strain, defined as the physiologic change in the length (L) of the region of interest from end-diastole to end-systole and expressed as a percentage (longitudinal strain [%] $= [L_{\text{end-systole}} - L_{\text{end-diastole}}]/L_{\text{end-diastole}} \times 100\%$), was automatically determined in 16 LV segments. Thus, during contraction, strain attains negative values as the length of the region of interest decreases relative to the resting value. The percentages of wall lengthening and shortening were displayed for each plane, representing longitudinal strain. Segments that failed to be tracked by the software were manually adjusted by the operator. Any segments that subsequently failed to be tracked were automatically discarded for the calculation of global strain. Analysis was feasible in 94% of the segments. For GLS analysis, digital cine loops were processed offline using commercially available software.

Intraobserver and interobserver variability was assessed in 25 randomly selected patients. The intraobserver repeatability analysis showed a mean absolute difference of 0.6% (95% confidence interval, −0.4% to 0.8%) for GLS. The interobserver repeatability analysis showed a mean absolute difference of 1.3% (95% confidence interval, −0.9% to 1.6%) for GLS.