Intraoperative Echocardiography for Congenital Aortic Valve Repair: Predictors of Early Reoperation

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Background. **We sought to identify transesophageal echocardiography (TEE) predictors of early reoperation for recurrent aortic regurgitation (AR) after cardiopulmonary bypass (CPB) in patients undergoing repair for congenital aortic valve disease.**

Methods. **We analyzed post-CPB TEEs in patients with congenital aortic valve disease undergoing repair for predominant AR. Case patients underwent reoperation for recurrent AR within 2 years, whereas control patients were free from reoperation for more than 3 years.**

Results. **Case patients (n = 22; median time to reoperation 0.3 years) and control patients (n = 22; median freedom from reoperation ≥4.4 years) were similar for demographic characteristics, aortic dimensions, and preoperative AR grade. Among post-CPB TEE variables, univariate logistic regression analysis identified shorter coaptation height (odds ratio [OR] for 1-mm increase 0.72, 95% confidence interval [CI]: 0.54 to 0.95; $p = 0.02$), decreased ratio of coaptation height to annulus diameter (OR for a 5% decrease 1.37, 95% CI: 1.06 to 1.77; $p = 0.02$), and increased percentage difference (%diff) between longest and shortest coaptation lengths in a short-axis view (OR for 10% increase 1.84, 95% CI: 1.15 to 2.92; $p = 0.01$) as risk factors for early reoperation for recurrent AR. Multivariable analysis identified %diff in short-axis coaptation lengths as the strongest post-CPB TEE predictor (area under receiver operator curve = 0.743). The sensitivity and specificity of a %diff of 50% were 0.45 and 0.91, whereas a % diff of 30% had a sensitivity of 0.75 and specificity of 0.67.**

Conclusions. **Coaptation asymmetry, measured as increased %diff in short-axis coaptation lengths on post-CPB TEE, is associated with early reoperation for recurrent AR after congenital valve repair.**

(Ann Thorac Surg 2015;■:■–■)

Aortic valve (AoV) repair is an attractive alternative to valve replacement for pediatric and congenital AoV disease [1–4]. Although data are encouraging for the durability of repair for adult patients with predominant aortic regurgitation (AR) [5–7], freedom from reoperation in the pediatric population is reduced [8, 9].

Although intraoperative transesophageal echocardiography (TEE) after cardiopulmonary bypass (CPB) is routinely performed to evaluate the adequacy of AoV repair [10], findings associated with early recurrent AR are not defined in the pediatric population. Predictors are described in the adult population, primarily for patients with aortic root dilation or bicommissural AoV, and include shorter coaptation length and reduced coaptation height [11–13]. However, these may not be applicable in the pediatric population, given the differences in underlying disorders. Many pediatric patients have either had prior interventions for relief of aortic stenosis (AS) or have severe associated cardiac anomalies that affect the geometry of the left ventricular (LV) outflow and aortic root [14, 15]. Defining intraoperative markers of recurrent regurgitation that leads to early reoperation may help identify candidates for intraoperative revision. We undertook an investigation to identify such markers.

Patients and Methods

Patients

This was a retrospective single-center case–control study. The institutional review board of Boston Children's Hospital approved the investigation and waived the requirement for informed consent. The electronic database was queried for patients who underwent AoV surgery between January 2004 and May 2012. Case patients underwent repair for moderate or greater AR with subsequent reoperation within 2 years for recurrent AR. Control patients were free from reintervention on their AoV for at least 3 years. Patients with severe AS were excluded.

Preoperative Variables

A single investigator (K.W.D.S.) blinded to case–control status reviewed all examinations. AoV Doppler gradients, LV size, and function were obtained from preoperative TTE reports. Measurements performed by the investigator on the preoperative TEE by using Heartsuite

Accepted for publication May 1, 2015.

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Published by Elsevier

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2015.05.002

VERICIS workstations (Emageon, Hartland, WI) included aortic annulus and root diameters in systole, vena contracta (VC) width of the AR jet from long-axis views, and cross-sectional area of the VC jet from short-axis views. If 2 or more AR jets were present, these were measured separately and summed. Data obtained from the cardiac magnetic resonance report included LV size and function and AR fraction. The reports from cardiac catheterizations were reviewed for AR grade and peak AoV gradient (after intervention, if performed). AoV structural characteristics, AR grade, and AS grade were determined by consensus of surgical description, imaging reports, and investigator review. AR severity was recorded according to recommendations of the American Society of Echocardiography [16]. AS severity was graded on the basis of cardiac catheterization (when available) or continuous wave Doppler as none-to-trivial (peak gradient, <15 mm Hg), mild (15 to 35 mm Hg), moderate (36 to 70 mm Hg), or severe (>70 mm Hg).

Intraoperative Post-CPB TEE Variables

Width and area of the VC of AR jets were determined. Additional measurements are depicted in Figure 1. In systole, the percentage of opening of the aortic leaflet tips relative to the aortic annulus, an indicator of systolic leaflet restriction, was calculated. The lengths of the anterior and posterior leaflets relative to their respective aortic sinuses, a measurement of leaflet length adequacy, was recorded.

In diastole, the ratio of the heights of the tip and base of leaflet coaptation relative to the annulus diameter was calculated, as was the percentage difference between the distances from leaflet coaptation tip to the anterior and posterior aortic walls, a measure of coaptation symmetry. From short-axis views, the coaptation lengths (distance from commissure to central coaptation point) and cusp areas were measured in diastole. For bicommissural valves, median raphes were measured, even if they were not patent, and conjoint cusps were measured as 2 separate cusps. To quantify coaptation symmetry, percentage difference between longest and shortest coaptation lengths on short-axis views (%diff-short) during diastole was calculated as follows: %diff-short = [difference between longest and shortest coaptation lengths/ average of longest and shortest coaptation lengths] × 100 (Fig 2). Median raphes were measured because for %diff-short to truly represent coaptation symmetry, at least 3 coaptation lengths are required. The percentage difference between the largest and smallest cusp areas was also calculated.

Postoperative and Follow-Up Variables

First postoperative TTEs were reviewed for AoV gradients, VC of AR jets, and AR severity. For case patients, mechanism of recurrent AR from surgical description and reoperation details were recorded. For control patients, the latest available TTE was used as the follow-up examination. When available, follow-up cardiac magnetic resonance and catheterization data were also collected. A consensus AR and AS grade were determined.

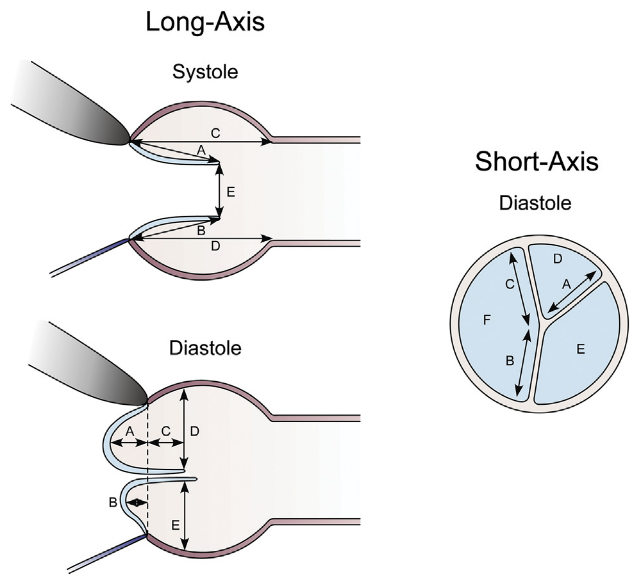

Fig 1. Echocardiographic measurements. Long-axis systole: (A, B) Length of anterior and posterior aortic leaflets; (C, D) Height of anterior and posterior sinuses of Valsalva; (E), Distance between aortic leaflet tips. Long-axis diastole: (A, B) Prolapse of anterior and posterior leaflets below annular plane; (C) Coaptation height; (D, E) Tip of leaflet coaptation to anterior and posterior aortic walls; Short-axis diastole: (A, B, and C) Coaptation lengths; (D, E, and F) Cusp areas.

Statistical Analysis

Continuous variables were summarized with median and range, unless otherwise noted. Categorical variables were summarized as frequencies and percentages. Covariates were compared between case and control patients by using Fisher exact test for categorical variables and the unpaired *t* test or the Wilcoxon rank sum test for normally and nonnormally distributed continuous variables, respectively. Univariate logistic regression analysis was performed for each variable to calculate odds ratios (ORs) and 95% confidence intervals (CIs) for early reoperation. For categorical variables with 1 or more levels experiencing low event rates for case or control patients, Firth logistic regression was used to correct for potential bias in the OR and CI [17]. For variables with a *p* value less than 0.20 in univariate analysis, a forward-selection model-building procedure was then performed to find the most parsimonious model for early reoperation for AR. A *p* value less than 0.05 was considered statistically significant. Statistical analysis was performed with Stata (Version 12; Stata Corp, College Station, TX).

Results

Baseline Characteristics and Operative Variables

Of 310 potential patients, 266 were excluded (Fig 3). The demographic and procedural data of the 22 case patients and 22 control patients are summarized in Table 1. Isolated congenital AoV disease was the most common diagnosis in both case and control patients. The degree of