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Congenitally Corrected Transposition of the Great Arteries

Ventricular Function at the Time of Systemic Atrioventricular Valve Replacement Predicts Long-Term Ventricular Function

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Objectives The objective was to evaluate the systemic ventricular ejection fraction (SVEF) at the time of systemic atrioventricular valve (SAVV) replacement as a predictor of SVEF ≥1 year after surgery in patients with congenitally corrected transposition of the great arteries (CCTGA).

Background Progressive SAVV regurgitation causes systemic ventricular failure in CCTGA patients, who are commonly referred late for intervention. Survival after surgery is poor when the pre-operative SVEF is <44%.

Methods We retrospectively reviewed 46 patients (pre-operative SVEF ≥40% in 27 patients and <40% in 19 patients) with 2 good-sized ventricles, a morphologically right systemic ventricle, and SAVV regurgitation requiring surgery. Median follow-up was not different in patients with a pre-operative SVEF ≥40% (8.8 years) or <40% (7.7 years, p = 0.36).

Results Pre-operative SVEF was the only independent predictor of ≥1-year post-operative SVEF (p < 0.0001). The late SVEF was preserved (defined as ≥40%) in 63% of patients who underwent surgery with an SVEF ≥40% compared with 10.5% of patients who underwent surgery with an SVEF <40%. Pre-operative variables associated with late mortality were an SVEF ≤40%, a subpulmonary ventricular systolic pressure ≥50 mm Hg, atrial fibrillation, and New York Heart Association functional class III to IV.

Conclusions Post-operative systemic ventricular function after SAVV replacement can be predicted from the pre-operative SVEF. For best results, operation should be considered at an earlier stage, before the SVEF falls below 40% and the subpulmonary ventricular systolic pressure rises above 50 mm Hg. (J Am Coll Cardiol 2011;57:2008–17)

In congenitally corrected transposition of the great arteries (CCTGA), atrioventricular and ventriculoarterial discordance maintains the appropriate direction of blood flow. The morphological right ventricle (RV) supports the systemic circulation and the morphological tricuspid valve is the systemic atrioventricular valve (SAVV) (1). In up to 70% of cases, the SAVV is abnormal and may be inferiorly displaced: the so-called Ebstein's anomaly of the SAVV (2,3). It is the presence of an anatomically abnormal SAVV rather than ventricular dilatation and dysfunction that predicts the occurrence of regurgitation (3). SAVV regurgitation may also occur after closure of a ventricular septal defect (4). In the series of Prieto et al. (3), SAVV regurgitation was the only independent predictor of death in CCTGA. In a retrospective cohort, more than 50% of deceased patients had systemic ventricular failure, associated with severe SAVV regurgitation in most cases (5).

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Beauchesne et al. (6) found that 53% of adult CCTGA patients are referred late, already suffering from moderate to severe SAVV regurgitation and ventricular dysfunction for more than 6 months. In patients referred for SAVV replacement, 10-year post-operative survival is only 19.5% when the pre-operative systemic ventricular ejection fraction (SVEF) is below 44% (7). Survival with CCTGA thus

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appears closely linked to the presence of SAVV regurgitation and systemic ventricular dysfunction. Although it is often assumed that when the morphological RV functions as a systemic ventricle it is doomed to fail, failure most commonly occurs as a result of volume overload from SAVV regurgitation (3). If this holds true, then timely SAVV replacement may preserve ventricular function and, ultimately, improve long-term outcomes (3,7,8). This has been shown for the analogous situation of mitral regurgitation and left ventricular ejection fraction (9). The objectives of this study were: 1) to evaluate the SVEF at the time of SAVV replacement as a predictor of systemic ventricular function ≥1 year after surgery; and 2) to identify pre-operative variables that are associated with post-operative survival. The hypothesis is that patients with CCTGA undergoing SAVV replacement with a preserved SVEF (≥40%) maintain a preserved SVEF in the long term.

Methods

Patients. Patients with CCTGA were identified from the Mayo Clinic clinical databases. Inclusion criteria were: 1) SAVV regurgitation that required valve replacement performed at Mayo Clinic; and 2) a known SVEF at the time of SAVV replacement. Patients with pulmonary atresia or double outlet RV or who had a Fontan or a double-switch operation were excluded. Patients were grouped according to their SVEF (<40% or ≥40%). The patient selection is outlined in Figure 1. Follow-up was deemed complete if an SVEF was measured ≥1 year after surgery. The 12 patients who were without SVEF follow-up were included in the survival analysis.

After a review of records, 41% of patients with a pre-operative SVEF ≥40% had not returned for follow-up after year 2006 and were not known to be deceased, compared with only 11% of patients with a pre-operative SVEF <40%. It was possible that patients with a better systemic ventricular function were doing well and did not perceive the need to follow up in a tertiary care center such as ours. To strengthen this follow-up, 11 patients with a pre-operative SVEF ≥40% and no follow-up after year 2006 were surveyed with mailed questionnaires and brief phone interviews. Questionnaires were returned by 8 patients, 1 patient was reached by phone, and 2 patients could not be retraced. The protocol was approved by the Mayo Clinic Institutional Review Board.

Data collection. Medical records were retrospectively reviewed. A medication was deemed used if taken after surgical dismissal. Functional status was assessed with the Warnes-Somerville ability index (10), the New York Heart Association (NYHA) functional class, and the functional aerobic capacity. The primary outcomes examined were the SVEF and survival or freedom from heart transplantation ≥1 year after surgery.

Measurement of SVEF. SVEF measurements were extracted from reports of echocardiography, angiography, MRI, or CT angiograms performed preferentially at Mayo Clinic. Selected studies were reviewed by 2 investigators (F.P.M. and C.A.W.) when information was deemed insufficient or not available otherwise.

Assessment of SVEF by echocardiography is most frequently used at our institution, either by visual estimate (11) or additional M-mode and 2-dimensional measurements. Priority was given to MRI-derived SVEF, followed by echocardiography and angiography. An SVEF ≥40% was selected to define preserved systemic ventricular function on the basis of previous series (7,12).

The pre-operative SVEF measurement closest to surgery was recorded. The immediate post-operative SVEF was measured within 30 days of surgery or during the surgical hospitalization, whichever was longer. The late SVEF was the most recent measurement, obtained ≥1 year after surgery.

Abbreviations and Acronyms

CCTGA = congenitally corrected transposition of the great arteries
CT = computed tomography
FAC = functional aerobic capacity
MRI = magnetic resonance imaging
NYHA = New York Heart Association
PVOTO = pulmonary ventricular outflow tract obstruction
RV = right ventricle
SAVV = systemic atrioventricular valve
SPVSP = subpulmonary ventricular systolic pressure
SVEF = systemic ventricular ejection fraction

Hemodynamic and anatomic assessments. Data were preferentially abstracted from echocardiograms acquired with standardized protocols (13,14). A few patients only had angiograms, MRI, or CT angiograms. The SAVV regurgitation was assessed qualitatively as absent, trivial, mild, moderate, moderate to severe, and severe. Nonsystemic (or subpulmonary) atrioventricular valve regurgitant jet systolic velocity by continuous-wave Doppler was used for noninvasive estimation of the subpulmonary ventricular systolic pressure (SPVSP) (15). Ebstein's anomaly, prolapse, or dysplastic features defined an abnormal SAVV and were confirmed at surgical inspection.

SAVV replacement. Standard techniques for cardiopulmonary bypass were used. Cold potassium, blood cardioplegic solution has been used for myocardial protection since 1977. Given the poor late results of valvuloplasty, our institution has favored valve replacement in CCTGA patients (7). The benefits of this approach have also been reported by others (16).

Statistical analysis. Descriptive statistics for categorical variables are reported as frequency and percentage, whereas continuous variables are reported as mean ± SD or median (range) as appropriate. Categorical variables were compared between patients with pre-operative SVEF ≥40% and SVEF <40% using chi-square test or Fisher exact test where appropriate, and continuous variables were compared using 2-sample *t* test or Wilcoxon rank sum test where appropriate. Linear regression models were used to find univariate and multivariate predictors of late SVEF.