Ventricular Function Before and After Surgery for Isolated and Combined Regurgitation in the Young

Thomas L. Gentles, MBChB, FRACP, A. Kirsten Finucane, MBChB, FRACS, Bo Remenyi, MBBS, FRACP, Alan R. Kerr, MBChB, FRACS, and Nigel J. Wilson, MBChB, FRACP

Green Lane Paediatric and Congenital Cardiac Service, Starship Children's Hospital, Auckland, New Zealand

Background. **Chronic mitral and aortic regurgitation (MR and AR) are associated with progressive contractile dysfunction. In the young, the risk of left ventricle (LV) dysfunction after operation for isolated and combined AR and MR is poorly defined. We aimed to compare LV mechanics in children and young adults with isolated and combined AR and MR, and identify risk factors for LV dysfunction after valve surgery.**

Methods. **Echocardiograms from children and young adults undergoing surgery for isolated severe AR (group I, n = 14), MR (group II, n = 21), or combined AR and MR (group III, n = 13), before and up to 18 months after surgery were compared with a normal population (n = 89). Normalized measures of LV geometry and mechanics were expressed as z scores.**

Results. **Before surgery all groups had LV dilatation, while groups I and III had afterload elevation and LV dysfunction. After operation LV dysfunction was more common in group III than in groups I and II (11 [84.5%] vs 5 [35.7%] vs 12 [57.1%], $p = 0.04$). The preoperative end-systolic volume z score predicted LV dysfunction after surgery in group I and II patients ($p = 0.047$, area under the curve = 0.75) but not in group III, where moderate LV dysfunction was related to the preoperative stress velocity index (−2.6 with vs –1.1 without, $p = 0.04$).**

Conclusions. **Left ventricular mechanics in combined AR and MR closely resemble those of AR. End-systolic volume predicts postoperative LV dysfunction in patients with isolated valve regurgitation, while those with combined disease were at high risk of postoperative LV dysfunction.**

(Ann Thorac Surg 2015;100:1383–9)

Combined mitral and aortic regurgitation (MR and AR) in children and young adults is usually a consequence of rheumatic fever and is an uncommon condition in the developed world. The combination of valve lesions exposes the left ventricle (LV) to varying degrees of preload and afterload, and carries a risk of long-term LV dysfunction. Minimizing the risk of postoperative LV dysfunction is an important priority. This is especially so given the long-term risks of thromboembolism, prosthetic valve dysfunction, the possibility of reoperation, and in the case of mitral valve repair, deterioration in valve function with progressive MR or stenosis [1–5].

There are few descriptions of LV mechanics in this setting and data relating the preoperative state to postoperative outcome are sparse, particularly in children and young adults [6, 7]. The latter is also the case for children with isolated AR and MR [8–10], where late ventricular dysfunction may have an impact on quality of life and limit life expectancy by many decades [3]. Despite these outcome issues, risk factors for postoperative LV dysfunction and guidelines for timing of surgery in children are ill defined and decisions are often made by extrapolating data from adult populations [11].

In view of the above we reviewed LV function after isolated and combined valve surgery for AR and MR in children and young adults. We related these findings to preoperative indices of LV geometry and mechanics in order to identify risk factors for postoperative LV dysfunction.

Patients and Methods

Study Population

Patients who underwent operation for severe AR or MR, or a combination of the 2 (severe of 1 and at least moderate of the other) were retrospectively identified from our departmental database. Those with adequate preoperative echocardiograms, including color Doppler assessment of the degree of regurgitation and two-dimensional and

Accepted for publication June 1, 2015.

Address correspondence to Dr Gentles, Green Lane Paediatric and Congenital Cardiac Service, Starship Children's Hospital, Private Bag 92 024, Auckland, New Zealand; e-mail: tomg@adhb.govt.nz.

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2015.06.009

M-mode echocardiography, phonography, and indirect carotid pulse measurement [12] were included provided they had postoperative echocardiography and clinical assessment within 18 months of operation. Those not in sinus rhythm were excluded as were those with severe abnormalities of LV geometry, including severe septal displacement as a consequence of pulmonary hypertension and those with any degree of mitral or aortic stenosis. Regurgitation was graded using standard criteria. Mitral regurgitation was considered moderate if there was a dense continuous wave (CW) Doppler envelope, systolic blunting of flow in the pulmonary veins, and in the case of central MR a broad proximal jet filling half the left atrium. These criteria, with the addition of systolic flow reversal in the pulmonary veins, were required for the diagnosis of severe MR. Aortic regurgitation was considered moderate if the diameter of the regurgitant jet was greater than 25% of the diameter of the LV outflow tract, in association with diastolic flow reversal in the proximal thoracic descending aorta. The addition of diastolic flow reversal in the abdominal descending aorta was required for the diagnosis of severe AR [13–15].

Patients were categorized into 3 groups: group I with severe AR who underwent aortic valve replacement (n = 14); group II with severe MR who underwent mitral valve repair or replacement (n = 21); and group III with AR and MR who underwent aortic valve replacement and mitral valve repair or replacement (n = 13). No patient in group I had more than mild MR and none in group II had more than mild AR, while patients in group III had severe regurgitation from 1 valve and moderate (n = 6) or severe (n = 7) regurgitation from the other. An age- and body size-matched subset from a previously recruited normal population [16] was used for comparative purposes (n = 89, age 14.8 ± 5.8 years; body surface area, 1.48 ± 0.4 m^2).

Echocardiograms

At the preoperative assessment, standard M-mode measurements of LV dimensions, wall thickness, and function indices were recorded. Ejection time was measured from the carotid pulse trace. End-systolic fiber stress, a measure of afterload, was calculated according to the formula of Regan [17]. This index was used as it is a superior measure of afterload in ventricles with an abnormal mass to volume characteristic [18]. The LV volume was calculated from two-dimensional images using the area-length algorithm, where volume = short axis cross sectional area × length × 5/6. The LV size and function variables were expressed as *z* scores with respect to the normal population. The *z* score (or normal deviate) is a dimensionless number indicating the number of standard deviations from the normal population mean a measurement lies with respect to body surface area (dimensions and volumes) or the unadjusted population mean (fiber stress and function indices) [16]. The stress-velocity index, a measure of contractile function, was calculated as a *z* score expressing the rate-corrected velocity of circumferential fiber shortening to the level of afterload (fiber stress) [19]. At the postoperative assessment LV volume was measured using the same technique described above. The primary outcome was LV dysfunction at the follow-up study, defined as an ejection fraction *z* score less than −2 (equating to an ejection fraction less than 0.562). For subanalysis, moderate LV dysfunction was defined as an ejection fraction *z* score less than −3 (ejection fraction < 0.526). The interobserver coefficient of variation for end-diastolic volume, end-systolic volume, and ejection fraction in our laboratory is 7.5%, 10%, and 6.7%, respectively, as calculated by the method of Bland and Altman [20].

Statistical Analysis

Summary statistics are expressed as mean ± standard deviation. The normality of distribution was confirmed using the Shapiro-Wilk test. The Student *t* test was used for between group comparison of continuous measurements while one way analysis of variance with the Bonferroni multiple comparison test was used for multiple group comparisons. The Fisher exact test was used to examine relationships between categoric variables. Associations between demographic, clinical, and echocardiographic variables and the primary endpoint (postoperative LV dysfunction) were investigated with univariate logistic regression. Variables with a *p* value less than 0.20 were entered into multiple logistic regression models. The best subset method was used to select the final model where Akaike's information criterion was minimized and the area under the receiver operating curve (AUC) was maximized. Independency between variables in the model was checked by correlation coefficients. Two-sided tests were used and a *p* value less than 0.05 was considered statistically significant. Stata IC version 10 (StataCorp, College Station, TX) was used for all analyses.

Results

Preoperative Assessment

Demographic and clinical variables are summarized in Table 1. Patients in group I (AR) were larger and tended to be older than those in groups II (MR) and III (combined AR and MR). Rheumatic heart disease was the predominant etiology in groups I and II patients and was the only etiology in group III. New York Heart Association (NYHA) functional class was similar between groups, as was diuretic and angiotensin-converting enzyme (ACE) inhibitor use.

Left ventricular geometry was similar in all 3 groups, and was characterized by severe dilatation (Fig 1), eccentric hypertrophy, relative wall thinning, and increased sphericity (Table 2). The LV mechanics differed significantly between the groups. In group I they were characterized by increased afterload, decreased velocity of shortening, depressed ejection fraction, and depressed contractile function, while these parameters were normal in group II. Group III mechanics were similar to those in group I.

Cardiac Surgery

All those in group I had aortic valve replacement with an autograft (n = 7), a homograft (n = 5), or a prosthetic valve