Cardiol Young 2003; 13: 253–257
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ISSN 1047-9511

Original Article

Optimal timing of the Ross procedure in the management of chronic aortic incompetence in the young

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Abstract The appropriate timing of intervention in patients with chronic aortic incompetence allows recovery of ventricular function. We sought to determine the optimal timing of the Ross procedure for chronic aortic incompetence in young patients. We retrospectively analysed case notes, and measured pre- and postoperative echocardiographic indexes of left ventricular function, in patients who had undergone the Ross procedure for chronic aortic incompetence. *Methods and results:* We found 21 patients with preoperative and postoperative data suitable for analysis. Their age at operation ranged from 5.6 to 26 years, with a median of 13.8 years, and the duration of follow-up was from 0.5 to 6.8 years, with a median of 2.4 years. The preoperative left ventricular end-diastolic dimension was converted to a z-score, and this was used as a threshold to divide the population. Using the threshold of a preoperative left ventricular z-score of more than 3 to divide the population did not show any difference in postoperative parameters of left ventricular function. Significant differences were found postoperatively, however, in both the left ventricular z-score and the ratio of left ventricular end-diastolic radius to posterior wall thickness in diastole, with a cutoff preoperative threshold z-score greater than 4. *Conclusion:* The increase in the ratio of left ventricular end-diastolic radius to the thickness of the posterior wall in diastole would suggest that there is disruption of left ventricular short axis architecture and myocardial contractile function when intervention is postponed. The significantly larger left ventricular dimension at end-diastole, despite the reduction in volume loading post surgery, may also demonstrate irreversible structural changes. Our data would suggest that recovery of left ventricular function is less likely when the left ventricular z-score has reached the value of 4, and that, ideally, intervention should be performed when the z-score approaches or exceeds 3.

Keywords: Aortic regurgitation; pulmonary autograft; ventricular function

THE OPTIMAL TIMING FOR INTERVENTION IN children with chronic aortic incompetence is important for preservation of myocardial function. In studies in adults, various pre-operative parameters have been suggested as useful predictors of favourable outcome.[1–6] Generally, predictors based on measurements in one dimension have proved relatively insensitive, with surrogates of the ratio of mass to volume being most robust. Gaasch et al.[6] proposed using the ratio of preoperative left ventricular end-diastolic radius to the thickness of the posterior wall in diastole. Those patients with a ratio of 4.0 or more failed to show significant reduction in left ventricular volume. These data, obtained in adults undergoing aortic valvar replacement with mechanical, xenograft or homograft prostheses, may not be applicable to the children where the Ross procedure[7] is increasingly preferred. While the outcome data for the Ross procedure in adults and children are generally excellent,[8–11] there are no systematic studies in children describing the relationship between functional recovery and preoperative characteristics. The aim of our study, therefore, was to determine which preoperative variables are associated with preservation of ventricular function following the Ross procedure in the young.

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Accepted for publication 22 January 2003

https://doi.org/10.1017/S1047951103000490 Published online by Cambridge University Press

Materials and methods

The research protocol was approved by the Hospital Ethics Research Committee. The case files of all patients who had undergone the Ross procedure at our institution were reviewed retrospectively. Patients undergoing surgery because of acute aortic incompetence, those with more than mild aortic incompetence at follow-up, and those with incomplete data were excluded from further analysis. Those patients with mixed aortic valvar disease, where aortic stenosis was considered the predominant lesion with a gradient of more than 50 mm of mercury or with haemodynamically significant additional defects such as a ventricular septal defect, coarctation of the aorta, and mitral stenosis, were also excluded. Times of cardiopulmonary bypass, and patient demographics at the time of operation, were obtained from the records of perfusion. The immediate preoperative, and the most recent follow-up, echocardiograms were analysed by a single observer. Left ventricular end-systolic dimension, end-diastolic dimension, and the thickness of the posterior wall at end-diastole were measured according to standard guidelines for M-mode assessment.[12] The gradient across the left ventricular outflow tract was assessed by continuous wave Doppler.

Left ventricular end-diastolic dimensions were converted to z-scores using predicted normal values based on the heights of the patients.[13] Z-scores were calculated using the formula (observed value-mean value)/standard deviation. The degree of compensatory hypertrophy was assessed using the ratio of the radius of the left ventricular cavity in diastole divided by the thickness of the posterior wall in diastole. This value remains relatively constant throughout childhood.[14] The population studied was divided using the preoperative left ventricular z-score and the ratio of left ventricular end-diastolic radius to the thickness of the posterior wall in diastole to establish the validity of these measurements as predictors of outcome.

Statistical analysis

Groups were compared using Student's t-test for independent samples. Calculations were performed using commercially available statistical software (Statistica®, Release 5.1, Statsoft, Inc.). A p-value of less than 0.05 was considered to be significant.

Results

From August 1993 to July 1999, we performed the Ross procedure in 42 patients at our institution. After applying our criterions for exclusion, 21 patients remained suitable for study. Of these patients, 18 had undergone previous intervention in the form of either surgical aortic valvotomy or balloon aortic valvoplasty. Of the remaining 3 patients, 2 had mixed aortic valvar disease, and 1 had isolated aortic regurgitation.

Table 1. Demographics at surgery.

	Median (range)
Age (years)	13.8 (5.6–26)
Weight (kg)	53 (14.9–81)
Body surface area (m^2)	1.56 (0.65–2.0)
Cross-clamp (min)	101 (43–121)
Bypass (min)	147 (91–168)

Table 2. Mean values of postoperative ventricular function in groups divided using a preoperative left ventricular end-diastolic z-score greater than 3.

	z-score less than 3	z-score greater than 3	p value (Student's t-test)
Left ventricular end-diastolic z-score	–0.3	1.8	0.06
Ratio of left ventricular end-diastolic radius to the thickness of the posterior wall in diastole	2.2	2.8	0.1
Fractional shortening (%)	35	34	0.9

The perioperative demographics of the population are shown in Table 1. All patients were asymptomatic, and in Class I of the grading system of the New York Heart Association. The median age at the time of surgery was 13.8 years, with a range from 5.6 to 26 years. The median length of follow-up was 2.4 years, with a range from 0.5 to 6.8 years.

A preoperative left ventricular z-score of greater than 3 was used to divide the population in order to compare the postoperative measures of left ventricular function. There was no significant difference in either fractional shortening, or the ratio of left ventricular end-diastolic radius to the thickness of the posterior wall in diastole for the two groups (Table 2). The mean postoperative left ventricular z-score for the 2 groups tended to be lower in those with a preoperative left ventricular z-score less than 3, but this just failed to reach statistical significance ($p = 0.06$). There were no significant differences in the perioperative demographics of the two groups (Table 3).

When we further analysed the population using a threshold preoperative left ventricular end-diastolic z-score of greater than 4 to divide the population, there were significant differences in postoperative left

https://doi.org/10.1017/S1047951103000490 Published online by Cambridge University Press

Table 3. Mean values of perioperative parameters and duration of follow-up of groups divided using a preoperative left ventricular z-score greater than 3.

	z-score less than 3	z-score greater than 3	p value (Student's t-test)
Age at repair (years)	10.6	14.4	0.14
Weight at repair (kg)	29.7	48	0.09
Height at repair (cm)	131	157	0.05
Body surface area (m^2)	1.0	1.4	0.07
Cross-clamp (min)	106	100	0.6
Bypass (min)	146	143	0.8
Duration of follow-up (years)	2.8	2.5	0.7

Table 4. Mean values of postoperative ventricular function in groups divided using a preoperative left ventricular end-diastolic z-score greater than 4.

	z-score less than 4	z-score greater than 4	p value (Student's t-test)
Left ventricular end-diastolic z-score	0.22	2.2	0.02
Ratio of left ventricular end-diastolic radius to thickness of the posterior wall in diastole	2.3	2.8	0.01
Fractional shortening (%)	35	34	0.8

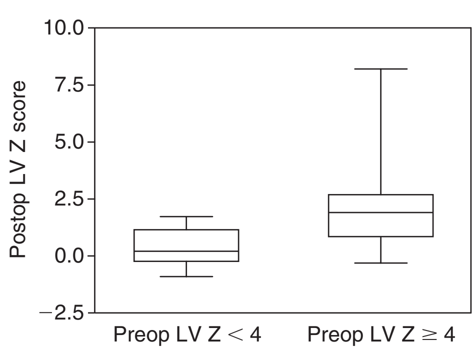

Figure 1.
Relationship between pre and post operative left ventricular diastolic size. Data are presented as box plots demonstrating median and inter quartile ranges (p = 0.02).

ventricular end-diastolic z-score, and also in the ratio of left ventricular end-diastolic radius to the thickness of the posterior wall in diastole ($p = 0.02$ and 0.01 respectively) (Table 4, Fig. 1). There was no difference in fractional shortening. There were no significant differences in the perioperative variables or duration of follow-up between these two groups (data not shown).

We were unable to show any significant difference between the groups of patients when different threshold values for the preoperative ratio of left ventricular end-diastolic radius to the thickness of the posterior wall in diastole were used to divide the population.

Discussion

The timing of intervention in patients with chronic aortic incompetence is difficult. In adults, clinical[15] and echocardiographic[5] indexes have been used to predict functional left ventricular recovery. Few, if any, are universally accepted as definitive. Decision-making is even more difficult in children. The advantages of delaying replacement with a prosthetic valve in growing children are obvious. While there are fewer concerns regarding the need for early replacement of the aortic valve after the Ross procedure,[16] prediction of left ventricular remodelling remains central to decision-making in terms of timing of the initial intervention. The guidelines provided by the task force of the American College of Cardiology and the American Heart Association[17] for replacement of the aortic valve in the adolescent or young adult with chronic aortic regurgitation were published in 1998. This report proposes onset of symptoms, asymptomatic left ventricular systolic dysfunction, or asymptomatic progressive left ventricular enlargement with a left ventricular z-score greater than 4 as so-called "class I" indications for surgery. It would appear that this recommendation is an extrapolation from data obtained in adults.

We aimed to determine whether any echocardiographic parameters might predict left ventricular recovery after the Ross procedure for chronic aortic incompetence in childhood. Interestingly, despite the promising reports from Gaasch[6] and Kasegawa[18] and their co-workers, showing that the ratio of left ventricular end-diastolic radius to the thickness of the posterior wall in diastole is one of the most robust predictors of left ventricular recovery in adults, this was not the case in our patients. Using a value for this ratio of 4, as proposed by Gaasch and colleagues, we found no difference in postoperative left ventricular z-score in the children undergoing the Ross procedure in our population. While there are conflicting reports regarding the utility of left ventricular dimensional parameters, such as a left ventricular end-systolic dimension greater than 5.5 cm, and a fractional shortening of less than 25%,[1,2,5] the z-score of the preoperative left ventricular end-diastolic dimension was the most sensitive predictor of subsequent left ventricular performance.

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Using a cutoff of preoperative left ventricular end-diastolic z-score of greater than 4, there was a significantly higher postoperative left ventricular z-score. This difference in left ventricular dimension at follow-up, despite the achieved reduction in volume loading, would suggest irreversible changes in myocardial structure. Furthermore, there was also a significant difference in the ratio of left ventricular end-diastolic radius to the thickness of the posterior wall in diastole. This index, based on the ratio of mass to volume, has been proposed as a useful measure of ventricular function.[14,19] It remains relatively constant throughout childhood.[14,20] With chronic volume loading of the ventricle there is compensatory concentric hypertrophy, which initially normalises the wall stress and preserves contractile function.[21] An increase in this ratio, therefore, indicates increasing wall stress and deteriorating contractility. The changes seen in our population suggest that there is a disturbance of left ventricular short axis architecture which does not recover when repair is left to a later stage of the disease.

Our data would suggest, therefore, that replacement of the aortic valve be anticipated when the left ventricular end-diastolic z-score approaches or exceeds 3. Clearly, with the relatively small size of our sample, individual characteristics need to be taken into account. It would be naive to assume that a single threshold for the z-score may predict a universal pattern of recovery. It is also worthy of note that patients with mixed aortic valvar disease, specifically those with a coexisting systolic gradient of greater than 50 mmHg, were excluded from our study. The current data should not be extrapolated to those with more complex haemodynamic problems, or indeed, to those undergoing other forms of aortic valvar replacement. It is well known, for example, that prosthetic valves are less haemodynamically efficient than tissue valves.[22] This difference may well influence the extent and rate of postoperative left ventricular remodelling. The issue of previous aortic stenosis, and the effect it has on ventricular remodeling, is also an important consideration. The majority of our population had undergone previous interventions to relieve valvar aortic stenosis. At the time of the Ross procedure, they had mixed aortic valvar disease. Indeed, only one of our patients had isolated new aortic incompetence. It has been reported that recovery of ventricular function occurs more rapidly in patients undergoing valvar replacement for aortic stenosis as compared to aortic incompetence, due to the major changes in afterload occurring in those with initial stenosis.[23] The authors, however, also recognised that, although the two groups of patients had similar ejection fractions, the use of this index in patients with aortic incompetence underestimates the degree of ventricular dysfunction.

We conclude from the study of our children that postponing intervention to a later stage of the disease is more likely to be associated with a more dilated ventricle, and disruption of short axis architecture, despite "successful surgical repair".

Acknowledgements

We thank Faith Hanstater for assistance in preparation of the manuscript. Research at the Institute of Child Health and Great Ormond Street Hospital for Children NHS Trust benefits from Research and Development funding received from the NHS Executive.

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