

The Ross Operation for Aortic Valve Disease: Previous Sternotomy Results in Improved Long-Term Outcome

Christopher J. Knott-Craig¹, Steven P. Goldberg², Peter Pastuszko¹, Marvin D. Peyton¹, James K. Kirklin²

¹University of Oklahoma Health Sciences Center, Department of Thoracic and Cardiovascular Surgery, Oklahoma,

²University of Alabama at Birmingham, Division of Cardiothoracic Surgery, Birmingham, Alabama, USA

Background and aim of the study: Progressive pulmonary autograft dilatation and failure following a Ross operation continues to be of major concern. It is hypothesized that the pulmonary autograft may perform better over the longer follow up period if the Ross operation is performed as a reoperation rather than a primary operation. The basis for this hypothesis is that the epicardial and mediastinal fibrosis encountered at reoperation may inadvertently provide additional support for the pulmonary autograft during the follow up period.

Methods: To test this hypothesis, 281 patients (mean age 24 ± 9 years) who underwent a Ross operation over a 16-year period were retrospectively analyzed. The patient population was divided into two subgroups in whom the Ross operation was performed: (i) as the first cardiac operation, through a sternotomy incision (primary-Ross; $n = 180$); and (ii) after the patient had undergone a previous sternotomy (prior-sternotomy; $n = 101$). A recent follow up examination was achieved in 93% of patients.

Since its introduction in 1967 (1), the Ross operation has become the standard method for replacing the aortic valve in children and young adults (2,3). The favorable hemodynamics, non-requirement for post-operative anticoagulation, resistance to infection and endocarditis, and very low incidence of valve-related complications has fuelled enthusiasm for this surgery. In the pediatric population, the Ross operation has become an attractive option because the autograft has been shown to have the potential to grow with the patient, thus obviating the need for further surgery (4).

However, as follow up data became available for longer periods, it became evident that the pulmonary

Results: Early and overall mortality was 2.1% and 6.4%, respectively, and there was no significant difference between the subgroups. At 12-year follow up, freedom from reoperation on the autograft, or valve-related death was $87 \pm 6\%$ versus $71 \pm 9\%$ in favor of the prior-sternotomy subgroup ($p = 0.06$). At 12-year follow up, freedom from valve-related death, or reoperation on the pulmonary autograft, or severe aortic regurgitation was $87 \pm 5\%$ versus $71 \pm 7\%$ ($p = 0.03$) in favor of the prior-sternotomy subgroup.

Conclusion: The results of a preliminary analysis suggest that additional benefit is accrued when the Ross operation is performed during re-sternotomy. This should encourage surgeons to attempt repair of the aortic valve during the initial surgery, with the knowledge that - if needed - the Ross operation can be performed safely at later surgery, and with possible additional benefit to the patient during the follow up period.

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autograft in the Ross operation was increasingly susceptible to dilatation and progressive regurgitation, particularly if the underlying pathology was aortic regurgitation, or if surgery was performed in the presence of a dilated ascending aorta (5). This problem was addressed by Elkins, who used various modifications of the technique, including annular fixation and replacement of the ascending aorta (6). Alternatively, these unexpected data spurred a resurgence in aortic valve repair (7) and alternative aortic valve replacement using mechanical and bioprosthetic valves (8).

During interactions with a large population of patients followed up after the Ross operation, it was observed that those patients in whom surgery was performed as a reoperation after a prior cardiac operation, seemed less likely to develop progressive aortic regurgitation, irrespective of whether their primary pathology was aortic regurgitation at the time of the Ross operation. It was hypothesized that the fibrous scar tis-

Address for correspondence:

Christopher J. Knott-Craig MD, University of Alabama at Birmingham, 716 Ziegler Research Building, 703 19th Street South, Birmingham, Alabama 35294, USA
e-mail: ckc@uab.edu

sue which forms around the right ventricular outflow tract and main pulmonary artery after a median sternotomy might provide additional support for the pulmonary autograft in its transplanted position. It was also supposed that the fibrous, less-distensible mediastinum and pericardium, which is evident in reoperative surgery, might itself support the autograft better and prevent its dilatation and failure.

The study aim was to assess whether patients who underwent the Ross operation during a re-sternotomy fared better during the follow up period in terms of pulmonary autograft function than those in whom the Ross operation was performed as first surgery.

Clinical material and methods

Patients

A group of young adults was selected from a continuously updated database of patients undergoing the Ross operation at the Oklahoma University Medical Center. Permission to undertake the analysis was obtained from the appropriate Institutional Review Boards.

A total of 281 consecutive patients (202 males, 79 females; mean age 24 ± 9 years; range: 10 to 40 years) was operated on at a single institution between August 1986 and June 2002. The underlying cardiac pathology was isolated aortic stenosis ($n = 83$), isolated aortic insufficiency ($n = 109$), or a combination of stenosis and regurgitation ($n = 89$). The patient population was divided into two subgroups: (i) those in whom this was the first cardiac operation performed through a sternotomy incision (primary-Ross; $n = 180$); and (ii) those in whom the Ross operation was performed after the patient had undergone a previous sternotomy (prior-sternotomy; $n = 101$).

Follow up and surgical technique

A recent follow up examination was achieved in 93% of patients, and consisted of patient contact and/or recent echocardiography. The median follow up period was 6.1 years (range: 4 to 17 years). Valve-related complications and death were defined according to established guidelines (9). On a scale of 1 to 4, significant aortic regurgitation was defined as aortic regurgitation grade ≥ 3 .

The surgical technique, which has been previously well documented, consisted predominantly of a free-standing root replacement with various modifications of annular support (10). The technique and risk factors were similar in both subgroups.

Statistical analysis

In this preliminary analysis, the decision was taken to analyze the subgroups independent of technique

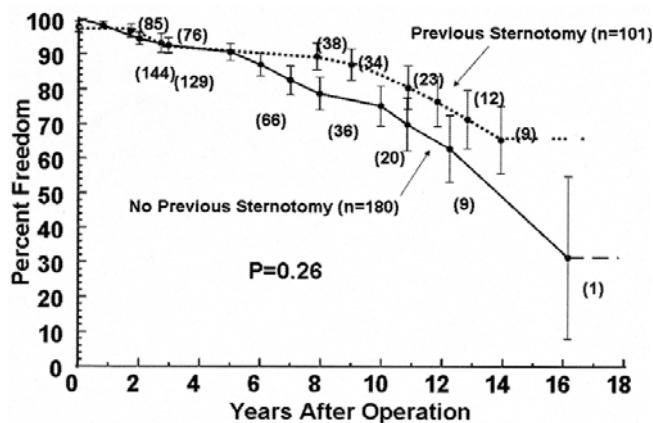


Figure 1: Freedom from reoperation on aortic or pulmonary valve, or valve-related death, or severe autograft regurgitation.

and other previously published risk factors for late aortic regurgitation from the authors' institution (11). Dichotomous variables were analyzed using Fischer's exact test, and Kaplan-Meier survival graphs were analyzed using the Wilcoxon log-rank analysis. A p-value < 0.05 was considered to be statistically significant. Early deaths were excluded from the actuarial comparisons

Results

The early mortality was 2.1% (6/281) and overall mortality 6.4% (18/281). There was no significant difference in early or late mortality between the subgroups (Table I). Although the freedom from all reoperations or valve-related deaths or valve degeneration (severe autograft regurgitation) at 12-year follow up suggested that patients who had the Ross operation as a reoperation had a better outcome than those who had the operation as primary surgery, the data were not convincing ($78 \pm 6\%$ versus $65 \pm 10\%$; $p = 0.26$) (Fig. 1). However, when reoperations on the right ventricular outflow tract (which are not relevant to the question under review) were excluded and only freedom from

Table I: Comparison of early and late mortality between patients undergoing the Ross procedure as a primary versus secondary sternotomy.

Mortality	Primary sternotomy (n = 180)	Secondary sternotomy (n = 101)	p-value
Early (%)	1.1	3.9	NS
Late (%)	5.6	2.0	NS
Overall (%)	6.6 (n = 12)	5.9 (n = 6)	NS

NS: Not significant.

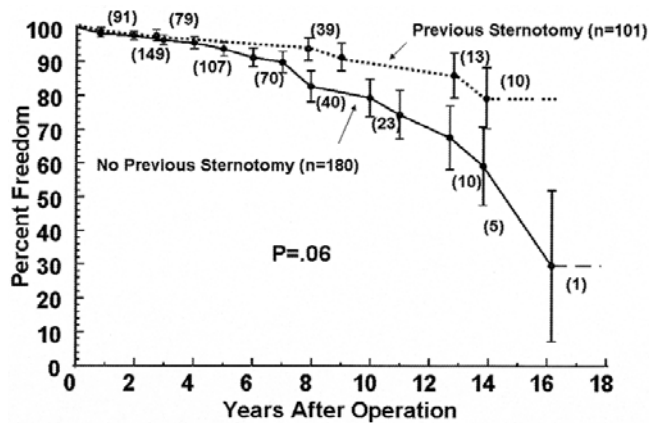


Figure 2: Freedom from reoperation on the aortic (autograft) only, or valve-related death.

reoperation on the aortic valve (autograft) or valve-related death at 12 years' follow up (Fig. 2) were examined, the differences in the two subgroups become more striking ($87 \pm 6\%$ versus $71 \pm 9\%$; $p = 0.06$).

Freedom from valve-related death, reoperations on the aortic valve, or severe aortic regurgitation at 12-year follow up suggested that the prior-sternotomy subgroup had a significant outcome advantage over the primary-Ross subgroup ($87 \pm 5\%$ versus $71 \pm 7\%$; $p = 0.03$) (Fig. 3).

Discussion

The Ross operation gained favor in the arenas of surgery and cardiology because it represented a method of dealing with aortic valve disease which would not require reoperation. Indeed, Ross and colleagues reported an 80% freedom from reoperation at 20 years' follow up (12). However, as the Ross operation became more widely offered as a definitive aortic valve replacement, it became clear that these results could not be reproduced (13). The measurable 'growth' of the pulmonary autograft which seemed to parallel somatic growth in the child was subsequently offset by later reports which suggested that the pulmonary homograft in the pulmonary position was not only subject to earlier replacement than anticipated, but was also more prone to dilatation and progressive regurgitation, thereby creating a potential for reoperation on two valves (14). This led to a resurgence in aortic valve repair, and of replacements with alternative mechanical and bioprostheses (15).

Despite these drawbacks, the Ross operation is still arguably the best aortic valve replacement procedure currently available for infants, children, and active young adults (6). It also remained a particularly attractive option if conservative methods of repairing the

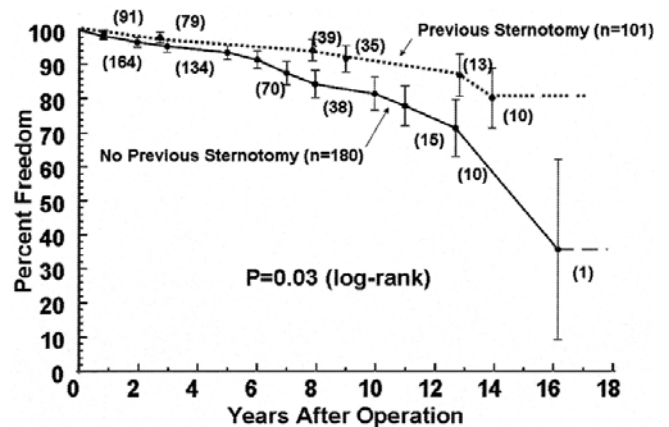


Figure 3: Freedom from reoperation on the aortic (autograft) only, or valve-related death, or severe autograft regurgitation.

diseased aortic valve were unsuccessful, provided that the surgery could be performed without incremental risk to the patient, and that the pulmonary autograft performed at least as well over the long term as when surgery was performed as an initial operation on the aortic valve. The present authors' clinical observations with a large number of young patients who underwent the Ross operation both as primary surgery and as a reoperation, indeed suggested that this was the case. In addition, the results of this simple analysis suggested not only that these observations were correct, but also that there might indeed be an improved longer-term durability of the pulmonary autograft when surgery was performed as a reoperation as opposed to a primary operation. Although these data must be substantiated by a more detailed analysis, they suggest that there is an advantage both in terms of survival and freedom from reoperation on the autograft or significant progressive regurgitation.

It has been postulated that the post-surgical adhesions present following prior sternotomy may provide an additional extrinsic support for the autograft, thereby constraining its ability to dilate and subsequently fail due to regurgitation during the follow up period. The present study was limited, however, by the nature of its simple comparison between two groups (primary versus secondary sternotomy) and, although the data obtained were impressive in this regard, future detailed multivariate analyses are required. If rigorous statistical methods corroborate these results, however, the cardiothoracic surgeon - when presented with a young patient with aortic valve disease - should give serious consideration before proceeding with a primary aortic valve repair, knowing that setting the stage for a Ross operation as a second procedure will confer a better outcome in terms of valve longevity and overall patient survival.

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