The fate of antibiotic sterilized aortic allografts in Fontan circulation: results of the long-term follow-up


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Received 19 October 1998; received in revised form 4 October 1999; accepted 27 October 1999

Abstract

Objective: Between 1977 and 1988, 27 patients, mean age 8.9 (range 4–22) received an antibiotic sterilised aortic allograft in the setting of the Fontan procedure. This study describes the long-term follow-up of these patients. Methods: Fifteen patients had tricuspid atresia, nine double inlet ventricles and three others. The connection with the allograft was made to the pulmonary artery on the right side of the aorta in ten and to a left-sided main pulmonary artery in eight. In nine patients the allograft was anastomosed between the right atrium and the right ventricle. Results: There were five early and five late deaths. One late death may have been allograft related. Survival was 81, 74 and 68% at 5, 10 and 15 years, respectively. Conduit calciﬁcation was universal. Twelve patients underwent reoperation, freedom from reoperation was 100, 88 and 54% at 5, 10 and 15 years following the initial Fontan procedure. At reoperation the gradient across the allograft was never more than 3 mmHg. The allograft was explanted with conversion to atriopulmonary or cavopulmonary connection in nine and a second allograft was inserted between the right atrium and right ventricle in two. No mortality occurred at reoperation. 41.1% of survivors still have their original allograft. Conclusions: Although there is a signiﬁcant attrition rate allograft inclusion in the Fontan circulation does not change survival, but results in an increased reoperation rate. Inclusion of a valved conduit between the right atrium and ventricle does not usually enhance the growth potential of the rudimentary ventricle. All patients are in a good functional class which may represent the strict original selection criteria. The inclusion of a valve in the Fontan circulation is not recommended. © 1999 Published by Elsevier Science B.V. All rights reserved.

Keywords: Fontan; Allograft; Survival; Reoperation

1. Introduction

Fontan and Baudet recommended the inclusion of allograft valves in the systemic venous pathway [1]. Kreutzer et al. [2] and Yacoub et al. [3] modiﬁed the surgical technique by abandoning the valve in the IVC and creating a valved communication to the pulmonary artery either anterior or posterior to the aorta. Laks et al., enjoyed favourable early and mid-term results with a similar operative technique [4]. The fate of allografts in the Fontan circulation has not been well documented. We have presented this cohort of patients previously [5]. The purpose of this paper is to summarise the results of the follow up to 21 years.

2. Patients and methods

Twenty-seven patients received antibiotic sterilised aortic allografts (diameters 17–22 mm) in the setting of a Fontan operation in Southampton between 1977 and 1988. The mean age at the time of the operation was 8.9 years (4–22 years). Three quarters of the patients were palliated with previous surgical procedures. The diagnoses were tricuspid atresia in 15, double inlet ventricle in nine, pulmonary atresia with intact ventricular septum in two and complex transposition of the great arteries in one. Four patients had dextrocardia.

The positioning of the conduit was dictated by the anatomy. Ten patients had their allografts connected between the right atrium and the pulmonary artery on the right side of the aorta. In eight patients the conduit coursed anterior and to the left of the aorta to reach the pulmonary artery. There were nine cases with tricuspid atresia and ventriculo-arterial concordance where the size of the rudimentary right ventricle was considered big enough to contribute to the pulmonary circulation and the valved conduit was therefore inserted between the right atrium and the right ventricle.
3. Results

There were five early deaths (Table 1). One of the eight patients with a right sided conduit died late of chronic heart failure and protein losing enteropathy. At the time of death the allograft had no significant gradient. Four patients in this group have the original allograft.

Two patients with left-sided allografts died late. One died in hospital and the second died suddenly eight years post-operatively. The latter patient was known to have ventricular hypertrophy and episodes of atrial arrhythmia. The post-mortem examination did not reveal the cause of death. Three patients still have the original allograft.

There were three late deaths in the group of nine patients with allografts implanted between the right atrium and right ventricle. One followed allograft explantation in another institution, the details of the post-mortem examination are not available. The other two died suddenly, both patients were treated for atrial arrhythmiae, in one case the post-mortem revealed mild allograft stenosis which might have contributed to death. All survivors have required reoperation. Two received allograft re-implantation as they had reasonable sized right ventricles, contributing to the circulation. The rudimentary right ventricular chamber did not contribute to the pulmonary circulation in the remaining two patients and the allografts were therefore explanted to allow right atrium-ventricle to pulmonary artery anastomosis.

<table>
<thead>
<tr>
<th></th>
<th>Early deaths</th>
<th>Late deaths</th>
<th>Alive</th>
<th>Alive with original allograft</th>
<th>Reoperations</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right connection</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>4 (57%)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Left connection</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>3 (50%)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>RA-RV connection</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>5 (18.5%)</td>
<td>5 (18.5%)</td>
<td>17 (62.9%)</td>
<td>7 (41.1%)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12</td>
<td>27</td>
</tr>
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<sup>a</sup> Percentage of the long-term survivors.

3.1. Reoperations

There were 12 reoperations, freedom from reoperation was 100, 88, and 54% at 5, 10 and 15 years, respectively (Fig. 1). Mean time from initial Fontan to reoperation was 11.25 years (range 7.5–19). Two early reoperations had new allografts reimplanted between the right atrium and right ventricle. Conversion from right atrium right ventricle allograft to a valveless conduit was performed in two because of the small size of the rudimentary right ventricle.

Seven patients had their allograft explanted: four were converted to atriopulmonary, three to cavopulmonary connection. In the remaining patient the reoperation was indicated to close a residual right atrium-left ventricle communication.

No mortality was associated with reoperations. Two reoperated patients have died late at 5 and 8 years.

3.2. Follow-up

Survival totals 271 patients years, and at 5, 10 and 15 years was 81, 74 and 68%, respectively (Fig. 2). Twelve have had recent cardiac catheter studies. 13 of the 17 survivors are in sinus rhythm. Two patients accomplished a full Bruce protocol for 12 min; of the remaining 15, all but two with or without reoperation are in NYHA functional class I. Two of the three pregnancies in the series were successful including twins delivered by normal vaginal delivery.

Heavy calcification of the allograft conduit was universally observed, however, in no case was the mean gradient

![Fig. 1. Freedom from reoperation.](image1)

![Fig. 2. Survival.](image2)
more than 3 mmHg. One patient exhibited a peak (‘a’) gradient of 5 mmHg and in five no gradient was found. Trivial regurgitation was present in nine patients.

One patient who was on oral contraceptive but anticoagulated at that time has had atrial thrombus and one other a pulmonary embolism. All survivors are anticoagulated. Three patients are awaiting reoperation with mild obstruction of their original allograft.

4. Discussion

It is well illustrated by its numerous modifications how the Fontan concept has evolved over the years. In the recent years the total cavopulmonary connection with lateral tunnel provides the surgical uniformity for the follow-up data comparison [6]. It has been clearly demonstrated that a valve is unnecessary in right atrium to pulmonary artery situation [7]. However, it remains controversial whether a fair sized rudimentary right ventricle should be included into right atrium-pulmonary artery connection but if it is, a homograft is necessary to prevent regurgitation. Pulsatile flow was shown to be beneficial in providing better functional state [8,9] and lower CVP [10,11]. There is some evidence that the right ventricle might retain some growth potential [5,8], although it is disappointing that only two of the initial nine patients in this group ended up with a ‘biventricular’ circulation. A valve between the right atrium and the rudimentary ventricle would not encourage ventricular growth per se.

It is obvious that all allografts in the Fontan circulation will inevitably require explantation. Allograft survival in these patients is comparable to that in the other patient groups receiving allografts at the same institution [11]. The age at implantation did not exhibit an effect on the conduit survival. The earlier date of operation did fare better in the series.

The indication and timing of reoperation is a difficult and complex issue. Impairment in the clinical state and newly occurring atrial arrhythmiae warrant reoperation even without a gradient. Asymptomatic patients with a gradient probably merit reoperation, at least post-mortem findings of a stenosed allograft in a patient without clinical symptoms supports this.

Reoperation technique varies, when the allograft aligns across the sternum to the left side we expose and cannulate the femoral artery before opening the sternum. The systemic venous pathway can be reconstructed with either atriopulmonary or cavopulmonary connection. One possible disadvantage of the atriopulmonary method is that the coronary sinus remains on the right side. This has been associated with higher incidence of ventricular dysfunction [12]. Our data does not support this finding, probably because no patients had CVP higher than 20 cm H2O. Preoperative atrial flutter/arrhythmia is the indication for a lateral tunnel cavopulmonary connection. Explantation of the allograft and creation of an atriopulmonary connection was coupled with significantly shorter cardiopulmonary bypass time (mean: 55.3, 40–63 min) usually without the need to cross-clamp the aorta.

In contrast creation of a lateral tunnel in which coronary sinus blood was diverted to the left side by creation of an ASD is associated with significantly longer cardiopulmonary bypass times (mean: 103, 66–151; P = 0.01) and the use of cardioplegia. All lateral tunnels were fenestrated.

In conclusion patients with Fontan circulation exhibited a significant attrition rate [13]. No early and one late death was possibly related to the allograft. Allograft inclusion results in a significantly increased reoperation rate. Late survivors with or without their original allografts are in a good NYHA functional class. The inclusion of a valve in the Fontan circulation is not recommended.

References