The right auricle tunnel as intercaval tunnel in total cavopulmonary connection may prevent atrial flutter

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Abstract

Objective: Total cavopulmonary connection (TCPC) is a routine operation for palliation of children with cardiac anomalies in whom biventricular repair is impossible. The original technique consists of the creation of a semi-prosthetic intercaval tunnel. A substantial proportion of these patients develop atrial flutter. We developed a technique for creating an intercaval tunnel that uses the tissue of the right auricle as intercaval tunnel. This technique avoids suture lines in the neighbourhood of the blood supply of the sinus node and leaves the terminal crest free. Since atrial flutter frequently occurs after Mustard and Senning operations in which suture lines are similar as for creating the lateral tunnel in TCPC we postulated that our technique for creating the intercaval tunnel without prosthetic material might prevent atrial flutter.

Methods: All the children that qualified for a TCPC were included. Whenever possible our operative technique was applied. In the other cases a semi-prosthetic conduit was used for creating the intercaval tunnel. Of 47 consecutive patients 30 (64%) had a tunnel of right auricle tissue, 12 (26%) had a tunnel of prosthetic material. Five patients did not need an intercaval tunnel and were omitted in this study. Only surviving patients were included in this study. Patients that needed more atrial surgery then necessary for TCPC were also omitted. Postoperative ECG’s and Holter monitorings were studied.

Results: Overall mortality was 7 of 47 patients (14.9% 70% CL 9.4–22.2%). There was no mortality due to rhythm disturbances. Atrial flutter occurred in 3 of 31 included patients (9.7, 70% CL 4.3–18.5%). In the right auricle group 1 of 22 patients (4.5, 70% CL 0.6–14.6%) had atrial flutter compared to 2 of 9 patients (22.2, 70% CL 7.5–45.0%) in the prosthesis group ($P = 0.13$).

Conclusion: The use of the right auricular technique for creating the intercaval tunnel is applicable in the majority of patients qualifying for a TCPC. Mortality and morbidity are equal comparing the two techniques. However, markedly less atrial flutter occurs in the group where the right auricle was used as intercaval tunnel. Therefore, we recommend the use of our technique for total cavopulmonary connection. © 1998 Elsevier Science B.V. All rights reserved

Keywords: Arrhythmias; Atrial flutter; Fontan procedure; Total Cavopulmonary Connection

1. Introduction

Arrhythmias are a major cause for morbidity and even for mortality after Fontan type operations [1]. In this respect the total cavopulmonary connection (TCPC) is associated with less arrhythmias than is the atropulmonary connection (APC) (or the so-called ‘classical Fontan operation’) [2–4]. In a comparative study Gelatt found atrial tachyarrhythmias in 29% of patients treated with APC and 14% atrial tachyarrhythmias in patients with a TCPC [4].

It is well recognized that suture lines in the neighbourhood of the sinus node or its blood supply can cause sinus node dysfunction [5,6] and subsequent arrhythmias, as is the case in atrial rerouting for transposition of the great arteries [7–10]. These arrhythmias may lead to pacemaker implantation or even may cause sudden death.

Since the introduction of the TCPC we developed an operative technique that uses the tissue of the right auricle to construct the intercaval tunnel, with the purpose to add growth potential to the lateral tunnel and to keep away from the sinus node. The leading thought was that in patients operated on with our method, less atrial arrhythmias would develop in comparison with patients oper-
ated with the original technique, with a prosthetic lateral tunnel.

This paper deals with the evaluation of this technique, focusing on the incidence and nature of arrhythmias.

2. Materials and methods

2.1. Operative technique

All operations were performed through a median sternotomy, using hypothermic cardiopulmonary bypass with aortic and bicaval cannulation. Cold crystalloid cardioplegia was used for myocardial protection. Previous aortopulmonary shunts were taken down on starting cardiopulmonary bypass.

Cavopulmonary anastomoses were performed in the usual manner by direct anastomosis of the superior caval vein and right pulmonary artery using absorbable monofilament polydioxanone sutures (PDS, Ethicon, Somerville, NJ) and making as wide an anastomosis as possible. In patients with a left sided superior caval vein a left sided cavopulmonary anastomosis with the left pulmonary artery was made in the same manner.

The inferior caval venous blood was routed to the superior caval vein through a tunnel that was created by using the tissue of the right auricle. The superior caval vein was enlarged, if the diameter was much less than that of the inferior caval vein. The right auricle was separated from the rest of the atrium by an incision in an antero-posterior direction into the terminal crest which was left undisturbed (Fig. 1). The incision was then continued at a right angle to the previous one, parallel and anterior to the terminal crest (Figs. 2 and 3). By incising the top of the right auricle and removing prominent trabeculae inside the auricle, a tissue flap was created. This tissue flap was then folded towards the inferior caval vein (Fig. 4) and was sutured to the junction of the inferior caval vein and the right atrium using the tissue of the Eustachian valve (Fig. 5). Most of the atrial septum was excised and a medial and lateral suture line in the cranial direction completed the tunnel. All the sutures are done with PDS®. The remaining part of the lateral wall of the right atrium was sutured down onto the created tunnel to close the atrium. The coronary sinus drained purposely into the functional left atrium causing a small non-significant right-to-left shunt, but creating a low pressure area for the coronary sinus blood to drain in. If appropriate a fenestration could be made from the tunnel to the functional left atrium. The completed operation is depicted in Fig. 6.

In those cases where our right auricle tunnel could not be applied a prosthetic lateral tunnel was constructed using the technique described by DeLeval et al.[11].

2.2. Patients

Since 1987, 47 patients underwent a TCPC in our hospital. All patients that qualified for a TCPC were included.
The closing date for this study was January 1st, 1997. In this period no atriopulmonary connection operations were performed. Whenever possible our operative technique was applied \((n = 30)\). In those cases \((n = 12)\) where our technique could not be applied due to prior Fontan operation \((n = 2)\), left atrial isomerism \((n = 2)\), abnormal pulmonary venous connection \((n = 1)\) or non-specified \((n = 5)\) an intercaval tunnel was constructed with the aid of prosthetic material (expanded polytetrafluoroethylene, PTFE, Gore-Tex, WL Gore and Associates, Flagstaff, AZ) [11]. In five patients no intercaval tunnel needed to be constructed since there was (hemi)azygos continuation, and the hepatic veins were left to drain into the atrium.

### 2.3. Excluded patients

Patients who died in hospital were excluded in this arrhythmia study. No hospital mortality was due to atrial rhythm disturbances. Two patients operated on in the beginning of our series of TCPC had total cavopulmonary connections without an intercaval tunnel constructed (but with closing their ASD) and these two were re-operated on later to construct the intercaval tunnel. These two patients were also excluded in this study. Also patients \((n = 2)\) that had total abnormal pulmonary venous drainage that was corrected during operation were excluded. Finally, the five patients that had no intercaval tunnel constructed were excluded.

### 2.4. Included patients

In this arrhythmia study 31 patients were included. They were divided into two groups: one in which we could apply

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Total number</th>
<th>Right auricle tunnel</th>
<th>Prosthetic tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tricuspid atresia (with or without TGA)</td>
<td>13</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>PA:IVS</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Hypoplastic LV or RV</td>
<td>10</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Double inlet ventricle</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Complete AVSD</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>DORV, TAPVD</td>
<td>31</td>
<td>22</td>
<td>9</td>
</tr>
</tbody>
</table>

AVSD, atrioventricular septal defect; DORV, double outlet right ventricle; LV, left ventricle; PA:IVS, pulmonary atresia with intact septum; RV, right ventricle; TAPVD, total abnormal pulmonary venous drainage; TGA, transposition of the great arteries.
our right auricle tunnel and one in which we had to use a semi-prosthetic tunnel. The diagnoses of these patients are summarized in Table 1.

2.5. ECG’s

All ECG’s were studied. Holter monitoring was performed in 20 cases (65%). Atrial flutter was defined as the presence of a characteristic electrocardiographic pattern consisting of a sawtooth appearance of the atrial depolarization (in leads II, III, aVF and V1) [12].

2.6. Statistical analysis

Statistical analysis was performed using SPSS for Windows Release 7.5 software. Data were analyzed by applying the chi-square test.

3. Results

From the total of 47 TCPC patients, in 30 (64%) an intercaval tunnel of right atrial tissue was constructed, in 12 (26%) a semi-synthetic tunnel was used and in 5 (10%) no tunnel was constructed. Mean age at time of TCPC was 5.5 years (range 1.1 to 15.0 years). Hospital mortality (≤30 days) was 14.9% (7 of 47 patients; 70% CL 9.4–22.2%). These patients all died of elevated pulmonary vascular resistance. Hospital mortality between the groups was similar, 5 of 30 (16.7, 70% CF 9.5–26.7%) in the right auricle group and 1 of 12 (8.3, 70% CF 1.1–25.5%) in the prosthesis group and 1 of 5 (20, 70% CF 2.6–53.1%) in the group where no tunnel had to be constructed. Late mortality was 1 of 40 surviving patients.

From the 31 patients included in this study in 22 (71%) patients an intercaval tunnel of right atrial tissue was constructed and in 9 (29%) patients a semi-synthetic tunnel. Atrial flutter occurred in 3 of the 31 patients (9.7, 70% CF 4.3–18.5%). In the right auricular group 1 of 22 patients had atrial flutter (4.5, 70% CF 0.6–14.6%) compared with two of nine patients in the prosthesis group (22.2, 70% CF 7.5–45.0%) (P = 0.13, chi-square test) (Table 2).

Immediately after operation 27 of 31 patients were in sinus rhythm. Four others had a sick sinus syndrome. There was no difference in the occurrence of sick sinus syndrome between the two groups.

Mean follow-up time after TCPC was 4.7 years (range 1.2 to 8.4 years) with no difference between the two groups. All patients are in functional class I except two patients in the prosthetic tunnel group, of which one has cyanosis caused by intrapulmonary fistulae and one has protein loosing enteropathy. Four patients have a pacemaker implanted.

4. Discussion

There is good evidence that TCPC is currently the best available palliation for patients with only one functional ventricle. This operation is done mainly within the right atrium and therefore, complications involving the right atrium may be expected. Atrial rhythm disturbances like atrial flutter are more common after heart operations involving extensive surgery of the right atrium like Mustard and Senning operations for transposition of the great arteries. It has become clear that this complication is a result of surgical manipulations, surgical incisions and/or damage to the sinus node or its blood supply [5–10]. In the original technique by DeLeval [11] the superior suture line of the atrial baffle runs in about the same area as is the case in Mustard and Senning operations. Furthermore, there is evidence that anchoring the lateral tunnel to the terminal crest promotes the development of flutter [13,14]. Leaving the terminal crest free appears to be of importance for the perpetuation of sinus rhythm. A totally different consequence of a TCPC is an increase of central venous pressure, thus stretching the atrial myocardial fibres, which in turn can also lead to atrial rhythm disturbances, just as in mitral valve regurgitation.

Since we applied our technical modification, where no suture line is made in the neighbourhood of the sinus node, and which leaves the terminal crest free, we found atrial flutter in 4.5% of patients that were operated with our technique. This was markedly less than the 22.2% found in the prosthesis group. The probability, however, that this result is due to chance is 13% (P = 0.13).

Gelatt [4] found 13.2% (70% CL 9.1–18.4%) of atrial tachyarrhythmias in their lateral tunnel group (lateral tunnel partial or complete with prosthesis; n = 76). When compared with this study we had 22.2% (70% CL 7.5–45.0%). These confidence limits overlap almost totally so the data from our relatively small prosthesis group are similar to those of Gelatt.

We developed a substantially different operative technique that not only avoids the use of prosthetic material but more importantly avoids the above described hazardous suture lines. This technique can be applied in the majority of patients that need a TCPC. Whenever possible we apply our auricular tunnel technique. In cases with a normal atrial situs or in right atrial isomerism it is possible to apply our operative technique. This is not only the case in tricuspid atresia but also in many complex cardiac anomalies, even if there are positional anomalies of the heart. Also previously performed cardiac operations, like bidirectional Glenn ana-
stomosis, do not interfere with the application of this technique. Only in those cases with left atrial isomerism and in some specific morphologic conditions like abnormal pulmonary venous drainage our operative technique is not applicable. Also because of previous operations, like a previously performed APC operation (classical Fontan), it is sometimes impossible to apply our operative technique. It is mostly judged intraoperatively whether our right auricle technique is applicable or not. Fenestration can be done if thought appropriate in the same way as described for PTFE tunnels using a 4 mm punch. Although not adequately studied, it is our observation that these fenestrations often close spontaneously. In our series, no fenestration had to be closed by either catheter devices or by operation. Since the atrial tissue is elastic there is a theoretical advantage because in circumstances where the pressure in the tunnel is relatively high the fenestration opens more and more blood is vented to the functional left atrium adding to the preload of the ventricle and causing better cardiac output. We leave the coronary sinus draining into the functional left atrium as we think this causes better haemodynamics for the coronary blood flow, although Ward [15] suggests the contrary.

The results of our series of TCPC operations are comparable to other series when mortality and morbidity other than atrial flutter are considered. There are many reasons not to use prosthetic material while correcting congenital heart defects in children. The lack of growth potential may be the one the most obvious, especially while these operations tend to be performed at younger age.

5. Conclusions

In our results of total cavopulmonary connection we found markedly less atrial flutter in the group where our right auricle tunnel was used compared with the group where the classical lateral tunnel technique was applied. Although our series is relatively small our results suggest that this difference is no coincidence. Furthermore, our technique is easily applicable in the majority of patients and has the advantage of avoiding the use of prosthetic material.

Acknowledgements

We like to thank Mr H.J. Waterbolk for his artwork.

References


Appendix A. Conference discussion

Dr M. Hazekamp (Leiden, The Netherlands): Was there any difference in age group between the lateral, the autologous tissue technique and the prosthetic patch technique? Was there a difference in age? Did you match these patients?

Dr Waterbolk: There was a difference in age. The lateral tunnel group was slightly older than our auricular tunnel group.

Dr Hazekamp: So doesn’t that influence your conclusion, as we do not see atrial flutter very often in young patients even when prosthetic patch.

Dr Waterbolk: Well, this is a small group, and I think this is a difficult question to answer here.
Dr M. Elliott (London, UK): One of the hypotheses that Marc de Leval proposed when defining that the use of a prosthetic internal patch might prevent later atrial distension. We all know that a number of traditional atrio-pulmonary connections have ended up with dilated atria which have required conversion to TCPC. While I accept this is a relatively short follow-up, don’t you consider that this might be a terminal complication if this particular procedure?

Dr Waterbolk: Well, as far as now, we did not see this as a complication, but I think I take your point that this will probably be the case. We will follow up our patients and maybe this will be a problem or may not be a problem.

Dr S. Conte (Leuven, Belgium): This study, as others on alternative methods to improve the outcome of Fontan patients, is very interesting. As you mentioned that in the presented series a fenestration was added to the TCPC just occasionally, I presume that due to the absence of prosthetic material in your intercaval tunnel it may be more difficult to obtain a controlled shunt through the fenestration.

I would like to know: what have been your criteria for adding a fenestration to the intercaval tunnel? Did you notice any relation between non-use of fenestrated TCPC and mortality in your series of patients?

Dr Waterbolk: Almost all of our patients are fenestrated. We do this routinely.