Modification Of The Extracardiac Total Cavopulmonary Connection - Placement Of A Graft Antero-Medially Rather Than Laterally

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Citation

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Abstract

In the conventional extracardiac total cavopulmonary connection (TCPC), a graft is placed lateral to the atrium. To prevent pulmonary venous obstruction, a thorough dissection around the pulmonary veins is required. The cause of sinus node dysfunction after extracardiac TCPC is still unknown. One possibility may be a compression of the sinus node from the outside by the graft. In this report, we proposed to modify TCPC by implanting a graft antero-medially rather than laterally to prevent the aforementioned complications. Six patients underwent this modified technique of TCPC. There was no death. The average pulmonary arterial pressure was 11 mmHg. The average follow-up was 24 months. No pulmonary venous stenosis or sinus node dysfunction was observed. In the conventional TCPC, the flow from the superior vena cava directly collides with the flow from the inferior vena cava at the central pulmonary artery (PA) resulting in energy loss. The central PA slightly curves anteriorly to posteriorly. In this modified technique, the flow from the graft enters the central PA from the front and may smoothly advance backwards into the distal PA along its naturally curved line. Thus, this modified technique may produce less energy loss compared to the conventional extracardiac TCPC.

INTRODUCTION

The configuration of the extracardiac total cavopulmonary connection (TCPC) has been discussed in several publications from the hydrodynamic perspective [1, 2]. To obtain a good surgical result of TCPC, several other conditions, such as preservation of the pulmonary venous return, a proportionate pulmonary arterial flow into both lungs, and prevention of sinus node dysfunction, are required besides keeping the hydrodynamic energy loss to minimum. In the conventional extracardiac TCPC, a polytetrafluoroethylene (PTFE) tube is usually placed lateral to the atrium (Figure 1A). In this report, we proposed to modify TCPC by implanting a convex-shaped PFTE tube antero-medially rather than laterally to meet the aforementioned requirements (Figure 1B).

TECHNIQUE

Seven patients underwent this modified technique of extracardiac TCPC. The diagnoses of these 7 patients were, tricuspid atresia in 3 patients, single right ventricle in 3 patients (2 with asplenia), and hypoplastic left heart syndrome in 1 patient. Median age at this modified TCPC was 2.3 years. All patients previously underwent bidirectional Glenn shunt as a usual procedure. During the TCPC operation, the inferior vena cava (IVC) was divided with the posterior area being slightly longer than the anterior area, and the end of the PTFE tube was anastomosed to the IVC, thereby placing the graft antero-medially. The central pulmonary artery (PA) was incised at its anterior surface instead of the inferior surface as in the conventional TCPC procedure. Then, the other side of the PTFE graft was anastomosed to the central PA. This convex-shaped extracardiac TCPC allows the graft to pass anteriorly and medially rather than laterally (Figure 1B). In all but one adult patient, 18 mm diameter Gore-tex tube was used for extracardiac conduit. In one adult patient, 20mm Gore-tex tube was used. In one patient with hypoplastic left heart syndrome, 4mm fenestration was placed.

There was no early or late death. The average pulmonary arterial pressure at the intensive care unit was 11 ± 1 mmHg. The average follow-up was 27 months. Thus far, no pulmonary venous stenosis or sinus node dysfunction was

observed.

DISCUSSION

We propose that this modification of convex-shaped extracardiac TCPC may have the following advantages compared to the conventional TCPC:

Prevention of pulmonary venous obstruction and less phrenic nerve paralysis

Pulmonary venous obstruction is easy to avoid with this modified TCPC compared to conventional TCPC. To prevent pulmonary venous obstruction in the conventional TCPC, a thorough dissection around the right pulmonary vein is required. This dissection sometimes causes phrenic nerve paralysis. This modification usually does not need a thorough dissection around the right pulmonary vein and thus may reduce the occurrence of the phrenic nerve paralysis.

Prevention of sinus node dysfunction

The cause of sinus node dysfunction after extracardiac TCPC is still unknown [3]. One of the reasons may be the division of the SVC or veno-atrial junction. However, hemi-Fontan procedure which keeps the connection veno-atrial junction failed to reduce sinus node dysfunction [4]. Other possibility is surgical dissection around sinus node. Another possibility is that the extracardiac graft may compress the sinus node from the outside. In our previous experience, the usual laterally placed extracardiac PTFE graft oppressed the sinus node form the outside resulting in sinus node dysfunction. Then, spatial separation of the graft from the sinus node resulted in recovery of the sinus node function at the operation. Thus, this modification can prevent direct oppression of the sinus node from the outside and can avoid the dissection around the sinus node.

Reduction of flow energy loss

Many recent publications on computational fluid dynamics have advocated the importance of the TCPC route [1, 2]. But, many of them presupposed the central PA as a straight line. However, the real central PA slightly curves anteriorly to posteriorly with a peak at the insertion of the main PA (Fig 2). In the conventional TCPC, the flow from the superior vena cava directly collides with the flow from the IVC at the anastomosis in the central PA resulting in very large energy loss. It was reported that an offset model demonstrated less energy loss [5]. However, this model may lead to late pulmonary arterial venous malformation because of the unbalanced pulmonary arterial flow distribution. In this modified technique, the flow from the PTFE graft enters the central PA from the front and may smoothly advance backwards into the distal PA along its naturally curved line of the native PA. Thus, this convex-shaped graft may produce less energy loss compared to the conventional extracardiac TCPC. We are concerned about energy loss at the IVC level configuration. A computational fluid dynamics study should be conducted to verify this hypothesis. In addition, we should follow a future convex shaped configuration of this conduit during the patient growth.

Figure 1

Figure 1A. - Schema of the conventional extracardiac total cavopulmonary connection. A PTFE tube is placed lateral to the atrium. Figure 1B. - Schema of the convex-shaped extracardiac total cavopulmonary connection. A PTFE tube is placed anterior and medial to the atrium. Sinus node (a red spot) and pulmonary veins are located away from the extracardiac PTFE graft.

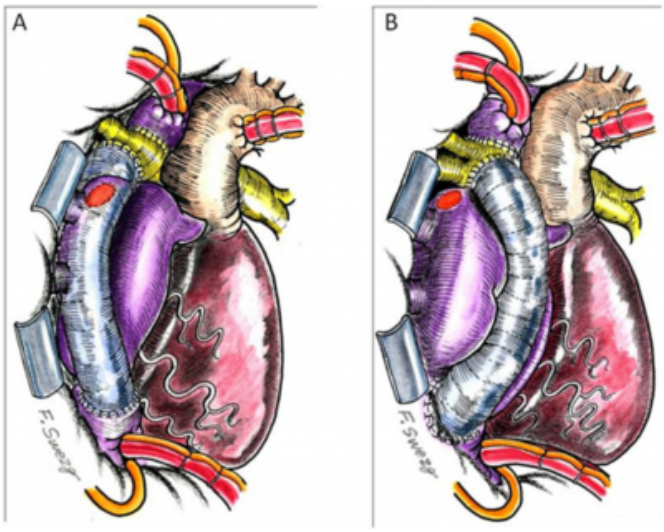
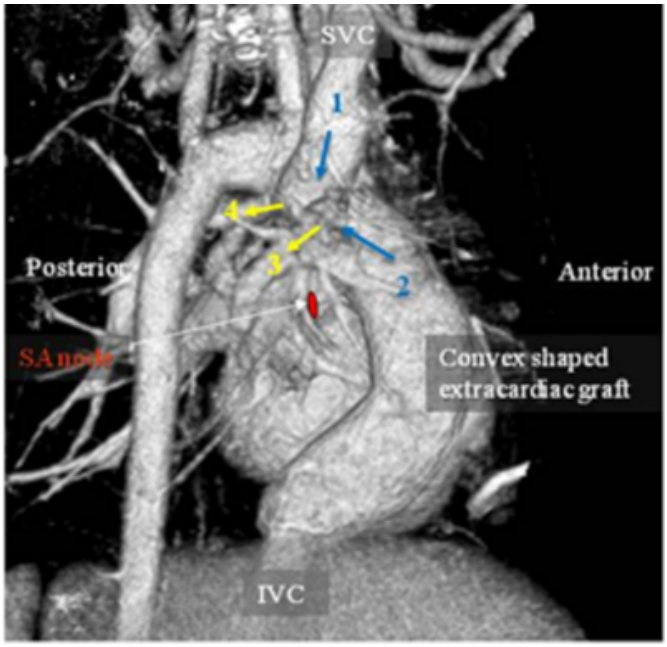


Figure 2

Figure 2: Right lateral view of the 3D computed tomography scans show that the convex-shaped extracardiac polytetrafluoroethylene (PTFE) tube was implanted between the inferior vena cava (IVC) and central pulmonary artery (PA) in a patient with hypoplastic left heart syndrome. The sinus node (a red spot) was located posteriorly to the PTFE tube presumably indicating a low risk of sinus node dysfunction due to oppression from the outside. The flow from the superior vena cava (SVC) and from the IVC via the PTFE tube did not collide directly at the central PA. The central to peripheral PA curves anteriorly to posteriorly and superiorly to inferiorly.



Blue arrow 1 indicates the flow from the SVC, blue arrow 2 indicates the flow from the IVC via the convex-shaped PTFE, yellow arrow 3 indicates the flow to the right PA, and yellow arrow 4 indicates the flow to the left PA.

References

1. Wang C, Pekkan K, de Zélicourt D, Horner M, Parihar A, Kulkarni A, and et.al. Progress in the CFD modeling of flow instabilities in anatomical totalcavopulmonary connections. Ann Biomed Eng 2007;35:1840-56.
2. Marsden AL, Bernstein AJ, Reddy VM, Shadden SC, Spilker RL, Chan FP, and et.al. Evaluation of a novel Y-shaped extracardiac Fontan baffle using computational fluid dynamics. J Thorac Cardiovasc Surg 2009;137:394-403.
3. Dilawar M, Bradley SM, Saul JP, Stroud MR, Balaji S. Sinus node dysfunction after intraatrial lateral tunnel and extracardiac conduit Fontan procedures: a study of 24-hour Holter recordings. Pediatr Cardiol 2003;24:284-88.
4. Cohen MI, Bridges ND, Gaynor JW, Hoffman TM, Wernovsky G, Vetter VL, and et.al. Modifications to the cavopulmonary anastomosis do not eliminate early sinus node dysfunction. J Thorac Cardiovasc Surg. 2000;120:891-900.
5. Soerensen DD, Pekkan K, de Zélicourt D, Sharma S, Kanter K, Fogel M, and et.al. Introduction of a new optimized total cavopulmonary connection. Ann Thorac Surg. 2007;83:2182-90.

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