Establishment of total cavopulmonary connection without use of cardiopulmonary bypass

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Abstract

Objective: To minimize deleterious postoperative influences of cardiopulmonary bypass on the pulmonary circulation immediately after the Fontan type procedure, total cavopulmonary connection was achieved without use of cardiopulmonary bypass. Methods: Since April 1996, 15 patients including five patients with visceral heterotaxy, in whom no intracardiac procedure was needed, have undergone this operative maneuver. Age at operation ranged from 1.2 to 44.6 years. Construction of a systemic to pulmonary shunt had been previously employed in seven patients, banding of the pulmonary trunk in two patients, and the Norwood procedure in one patient. The superior caval vein was initially anastomosed to the pulmonary arteries in bidirectional fashion under temporary bypass from the superior caval vein to the atrium. The channel for draining the inferior caval vein was subsequently constructed with the aid of temporary bypass from the inferior caval vein to the atrium, using a Goretex tube in ten patients, using a pedicled autologous pericardial roll in four patients, and directly anastomosing the pulmonary trunk to the orifice of the inferior caval vein in one patient. In patients with visceral heterotaxy and an independent hepatic venous drainage, redirection of the blood flow via the caval vein as well as the hepatic vein could be successfully achieved by placing dual temporary bypasses into these veins. Results: Postoperative courses were excellent in all patients. Superior caval venous pressure was 11–2 mmHg at 12 h after the operation. No blood transfusion was needed in nine patients (60%). Conclusion: This alternative operative procedure is undoubtedly attractive when establishing the Fontan circulation in patients undergoing no intracardiac maneuvers. © 1998 Elsevier Science B.V. All rights reserved

Keywords: The Fontan type procedure; Total cavopulmonary connection; Pulmonary circulation; Cardiopulmonary bypass; Extracardiac conduit

1. Introduction

The Fontan type procedure has been increasingly employed in patients with cardiac malformations unsuitable for biventricular repair. Improving surgical results and extending indications of the procedure, quite a few reports have been published concerning operative modifications and devices [1–8]. Our previous preference for achieving the Fontan circulation had been total cavopulmonary connection by either intraatrial rerouting using a baffle or intraatrial grafting using a Goretex tube, placing the sinus node as well as all the cardiac venous drainages into the low-pressured atrial chamber [9]. Although this sort of operative procedure remains useful in patients in whom intracardiac maneuvers, such as plasty to the atroventricular valves or repair of totally anomalous pulmonary venous connection, are needed, our alternative approach is to achieve total cavopulmonary connection without use of cardiopulmonary bypass by constructing an extracardiac channel from the inferior caval vein to the pulmonary arteries combined with bidirectional cavopulmonary anastomosis of the superior caval vein. With this modification, the deleterious influence of cardiopulmonary bypass on pulmonary circulation [10] and other systemic organs [11], as well as the disadvantageous effect of aortic cross-clamp on ventri-
ular function [12], could be minimized. This also results in a better pulmonary circulation and a better cardiac function which is of great importance immediately after the Fontan type procedure and makes the surgical intervention safer and more successful. This modification is herein described.

2. Materials and methods

Between April 1996 and September 1997, 26 patients underwent the Fontan type procedure, all by total cavopulmonary connection. In 11 patients, cardiopulmonary bypass was used because plasty to the atrophicventricular valve was needed in four patients, either atrial or ventricular septal defect was enlarged in three patients, pulmonary venous obstruction was repaired in one patient, extensive plasty to peripheral pulmonary stenosis was carried out in one patient, and possibility of biventricular repair was sought, although in vain, in the remaining two patients.

In the other 15 patients, in contrast, no intracardiac maneuver was considered to be necessary, and total cavopulmonary connection could be established without cardiopulmonary bypass. Five patients had visceral heterotaxy, four patients with isomeric right appendages and one patient with isomeric left appendages. In these patients, independent hepatic venous drainages were identified. Of the other ten patients, atrial arrangement was of usual pattern in eight patients, and mirror imaged in two patients. Biventricular atrophicventricular connections with the balanced ventricles were seen in four patients combined with double outlet right ventricle, one patient with separate atrophicventricular valves and three patients with a common atrophicventricular valve. In five patients, a dominant morphologically left ventricle was present, with classical tricuspid atresia in one patient, double inlet atrophicventricular connection in two patients, and common inlet atrophicventricular connection in two patients. In the other six patients, the dominant ventricle was of the morphologically right ventricle, with mitral atresia in three patients, hypoplastic left heart syndrome in one patient, and double inlet right ventricle with separate atrophicventricular valves in two patients.

Of all the 15 patients, ten patients had previously undergone palliative surgical procedures. A systemic to pulmonary artery bypass was used because plasty to the atrophicventricular valve was needed in four patients, either atrial or ventricular septal defect was enlarged in three patients, pulmonary venous obstruction was repaired in one patient, extensive plasty to peripheral pulmonary stenosis was carried out in one patient, and possibility of biventricular repair was sought, although in vain, in the remaining two patients.

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Fig. 1. Scheme of the operative procedures. (a) Bidirectional cavopulmonary anastomosis is to be achieved using a temporary bypass from the superior caval vein to the atrial appendage. The pulmonary blood flow is maintained unilaterally via either the native pulmonary stenosis or the shunt previously constructed. (b) With the unilateral Glenn circulation, one end of the Goretx tube graft or the pedicled autologous pericardial roll is to be anastomosed to the pulmonary arteries. If a shunt is present on the other side, both of the lungs are perfused at this stage. (c) Under the bilateral Glenn circulation with or without additional systemic to pulmonary forward flow, the opposite end of the extracardiac conduit is to be anastomosed to the stump of the inferior caval vein using a temporary bypass. (d) Partially clamping the extracardiac conduit as well as a part of the atrial wall, a fenestration can be constructed, if needed, after completion of the Fontan circulation by means of interposition of a small Goretx tube graft.
means of plasty. In the remaining one patient, the pulmonary trunk with a sufficient size for the inferior caval venous channel could be directly anastomosed to the orifice of the inferior caval vein because of its particular morphologic orientation.

In four patients, a fenestration was placed by interposing a small and short Goretex tube graft between the extracardiac channel for the inferior caval vein and the atrium (Fig. 1). A 4-mm diameter prosthesis was used in two patients with body weight of less than 15 kg, a 5-mm tube in a 12-year-old patient with 21 kg body weight, and an 8-mm tube in a 44-year-old patient with 54 kg body weight.

3. Results

No operative death was seen after this surgical procedure. Pressures within the superior and the inferior caval veins during temporary bypass were less than 20 mmHg in all the patients, mean values being 17 ± 2 and 13 ± 4 mmHg, respectively (Fig. 2). Immediately after the procedure, no pressure gradient was present between the pulmonary arteries and either the superior or the inferior caval vein. No blood transfusion was needed in nine patients (60%). Seven patients were extubated within 12 h after the operation, and six patients between 12 and 24 h after the operation. Postoperative pressure of the superior caval vein was from 8 to 16 mmHg with a mean of 11 ± 2 at 12 h after achieving the Fontan circulation (Fig. 2). Arterial oxygen saturation was 93.0 ± 1.4% in the four patients in whom fenestration was constructed.

By postoperative echocardiography, no obstruction has been demonstrated from the caval veins to the pulmonary arteries in any patient. Postoperative catheterization has been carried out 1 year after the procedure in six patients thus far. No pressure gradient was detected between the pulmonary arteries and either the superior or the inferior caval vein. The channel for the inferior caval vein made of a pedicled autologous pericardial roll was smooth and in good shape, as had been designed, with no obstruction or dilatation (Fig. 3).

4. Discussion

To minimize deleterious effects of cardiopulmonary bypass, one important surgical approach is undoubtedly to strive to devise extracorporeal circulation with a small priming volume [13]. Currently, overall priming volumes of the machine for cardiopulmonary bypass can be less than 250 ml at smallest. Using such a low priming volume circuit, operations with no blood transfusion could be achieved even in babies with body weights less than 5 kg if intracardiac malformations are less complicated. Another crucial aspect to minimize unfavorable influence of cardiopulmonary bypass is to shorten the duration on cardiopulmonary bypass as much as possible. As was demonstrated clearly by Dr. Hanley [14], shorter time for cardiopulmonary bypass was related to better outcomes after the extracardiac Fontan procedure. When extending this concept to its extreme, no use of cardiopulmonary bypass should be the best. Particularly in patients with some risks and at the borderline for surgical indication of the Fontan type procedure, even mild insufficiency of the pulmonary circulation could militate against successful establishment of the Fontan circulation in the early postoperative stage. It is justifiably considered that the surgical procedure is safer when less invasive.

In order to put the idea of total cavopulmonary connection without use of cardiopulmonary bypass into practice, technical aspects are of unequivocal importance. It is necessary to cannulate the tube for temporary bypass into the superior and the inferior caval veins as distal as possible. It is almost always an easy matter to place the tube at the high position of the superior caval vein. The superior caval vein is to be dissected until the right cervical vein as well as the innominate vein are clearly identified. The cannulation is adjacent to the connection between these major branches.
As for the inferior caval vein, in contrast, extensive dissection is much more difficult. The surgeon has to avoid injury to the parenchyma of the liver. Usually, the site for cannulation is at the exact level of the diaphragm. To perform readily the anastomosis between the stump of the inferior caval vein and the extracardiac conduit, the inferior caval vein could be transected slightly above the junction between the inferior caval vein and the atrium. We prefer an oblique division of the venoatrial junction, rather than a square one, leaving a small sleeve of the atrial musculature around the inferior caval vein. By this maneuver, the surgeon can get an adequate orifice for anastomosing a relatively large size of the prosthesis even in patients under 2 years. In addition, heparin was administered, not only for anticoagulation during temporary bypass, but also for use of auto-transfusion. This is because a certain amount of bleeding necessarily occurs when introducing the cannula for the temporary bypass into the caval veins and the atrial cavity. To establish the operative procedure with no or minimal blood transfusion, auto-transfusion was considered essential.

Obviously, use of a prosthetic tube graft as an extracardiac conduit [15] remains controversial [16]. It is probable that a Goretex tube graft with its size greater than 20 mm could provide an adequate channel for the inferior cava-pulmonary pathway even in adolescents and adults with the Fontan circulation. To implant such a prosthesis of relatively large size, optimal timing for the Fontan type procedure would be 3 years of age or older. Our preference has been, however, earlier definitive repair even for the Fontan type procedure [9]. In patients younger than 2 years, it would be feasible to construct the inferior venous channel using a 16- or 18-mm Goretex tube. Although our experience of intraatrial grafting has shown that the channel constructed by a 16- or 18-mm Goretx tube could provide an excellent result even at the time of catheterization more than 5 years after total cavopulmonary connection [17], replacement of the prosthetic tube graft will be almost certainly needed for up-sizing in the future. An alternative approach to promote earlier establishment of the Fontan circulation is probably use of autologous tissue for the channel [18]. It remains unclear, however, whether the roll made of pedicled autologous pericardium grows or not. At least, nonetheless, no unfavorable obstruction nor dilatation of the constructed channel was seen at the time of postoperative catheterization, but also for use of auto-transfusion. This is because a certain amount of bleeding necessarily occurs when introducing the cannula for the temporary bypass into the caval veins and the atrial cavity. To establish the operative procedure with no or minimal blood transfusion, auto-transfusion was considered essential.

In conclusion, this alternative operative procedure is obviously, use of a prosthetic tube graft as an extracardiac conduit [15] remains controversial [16]. It is probable that a Goretx tube graft with its size greater than 20 mm could provide an adequate channel for the inferior cava-pulmonary pathway even in adolescents and adults with the Fontan circulation. To implant such a prosthesis of relatively large size, optimal timing for the Fontan type procedure would be 3 years of age or older. Our preference has been, however, earlier definitive repair even for the Fontan type procedure [9]. In patients younger than 2 years, it would be feasible to construct the inferior venous channel using a 16- or 18-mm Goretex tube. Although our experience of intraatrial grafting has shown that the channel constructed by a 16- or 18-mm Goretx tube could provide an excellent result even at the time of catheterization more than 5 years after total cavopulmonary connection [17], replacement of the prosthetic tube graft will be almost certainly needed for up-sizing in the future. An alternative approach to promote earlier establishment of the Fontan circulation is probably use of autologous tissue for the channel [18]. It remains unclear, however, whether the roll made of pedicled autologous pericardium grows or not. At least, nonetheless, no unfavorable obstruction nor dilatation of the constructed channel was seen at the time of postoperative catheterization, but also for use of auto-transfusion. This is because a certain amount of bleeding necessarily occurs when introducing the cannula for the temporary bypass into the caval veins and the atrial cavity. To establish the operative procedure with no or minimal blood transfusion, auto-transfusion was considered essential.

In conclusion, this alternative operative procedure is undoubtedly attractive when establishing total cavopulmonary connection in patients undergoing no intracardiac surgical interventions, and can be achieved even in those with abnormal venoatrial connections in the setting of visceral heterotaxy.

References

Appendix A. Conference discussion

Dr J.S. Stark (London, UK): Can you tell us from the various techniques you describe, pericardial roll or the tube, which is your favorite technique? Which one would you prefer today?

Dr Uemura: Nowadays, of course, thinking about the potential growth of the channel, the pedicled autologous roll is the first choice. But at the beginning of our introduction of this technique, the Goretex tube interposition was much easier for constructing the IVC channel. That is why we used the Goretex tube.

Dr M.A. Navabi (Shiraz, Iran): Have you measured and compared transpulmonary gradient in these two groups, because that should show the benefit of not using cardiopulmonary bypass.

Dr Uemura: I showed the SVC pressure immediately after the operation. I think that is a good marker for the pulmonary circulation. But actually if we subtract the atrial pressure from the pulmonary artery pressure, then the value was also relatively small compared with that in the patients undergoing cardiopulmonary bypass.

Dr L. Von Segesser (Lausanne, Switzerland): I have seen that you have used tube sizes up to 24 mm, and in grown-ups we have used similar sizes of tubes but with external support. Unfortunately there is no big external supported tube graft available anymore. What are you using now if you have a grown-up redo case, for instance?

Dr Uemura: The maximal size was 24 mm, and that was used in a male patient 44 years of age.

Dr L. Von Segesser: Was it supported or unsupported externally?

Dr Uemura: With no support.