Apex rotation as a risk factor for total anomalous pulmonary connection repair in single ventricle

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Abstract

Background: The high incidence of postoperative pulmonary venous obstruction (PVO) is a major mortality-associated concern in patients with right atrial isomerism and extracardiac total anomalous pulmonary venous connection (TAPVC). We evaluated new anatomical risk factors for reducing the space behind the heart after TAPVC repair. Methods: 18 patients who underwent TAPVC repair between 2014 and 2020 were enrolled. Sutureless technique was used in 12 patients and conventional repair in six patients. The angle between the line perpendicular to the vertebral body and that from the vertebral body to the apex was defined as the "vertebral-apex angle (V-A angle)." The ratio of post- and preoperative angles, indicating the apex's lateral rotation, was compared between patients with and without PVO. Results: The median (interquartile range) age and body weight at repair were 102 (79-176) days and 3.8 (2.6-4.8) kg, respectively. The 1-year survival rate was 83% (median follow-up, 29 [11-36] months). PVO occurred in seven patients (39%), who showed an obstruction of one or two branches in the apex side. The postoperative V-A angle (46° [45°-50°] vs. 36° [29°-38°], P = 0.001) and the ratio of post- and preoperative V-A angles (1.27 [1.24-1.42] vs. 1.03 [0.98-1.07], P = 0.001) were significantly higher in the PVO group than in the non-PVO group. The cut-off values of the postoperative V-A angle and ratio were 41° and 1.17, respectively. Conclusions: A postoperative rotation of the heart apex into the ipsilateral thorax was a risk factor for branch PVO after TAPVC repair.

Original article

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Running head: apex rotation is a risk for PVO

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Conclusions: A postoperative rotation of the heart apex into the ipsilateral thorax was a risk factor for branch PVO after TAPVC repair.

Keywords: functional single ventricle, total anomalous pulmonary venous connection, stent.

List of Abbreviations

TAPVC**:** total anomalous pulmonary venous connection

PVO: pulmonary venous obstruction

RAI: right atrial isomerism

PV: pulmonary vein

CT: computed tomography

V-A angle: Vertebral-apex angle

AUROC: area under the receiver operating characteristic

BTS: Blalock Taussig shunt

PAB: pulmonary artery banding

RV-PA: right ventricle-pulmonary artery

PA: pulmonary artery

AVVR: atrioventricular valve regurgitation

LAA: left aortic arch

RAA: right aortic arch

TCPC: total cavopulmonary connection

Introduction

The surgical outcomes are unsatisfactory for patients having single-ventricle with total anomalous pulmonary venous connection (TAPVC) and heterotaxy syndrome. A major concern is that the anatomical feature of extracardiac TAPVC in right atrial isomerism (RAI) frequently causes pulmonary venous obstruction (PVO) after surgery (1-3). The reported rates of hospital mortality and postoperative PVO are 43%-53% (1,2) and 42% (1), respectively. Thus, both mixed-type TAPVC and preoperative PVO have been reported as risk factors for PVO after TAPVC repair (1-3). Alterations in anatomical factors resulting from surgery may also affect the incidence of PVO. Therefore, the identification of such factors may help modify the surgical strategy and methods.

The purpose of this study was to evaluate the surgical outcomes of TAPVC repair and determine anatomical risk factors for postoperative PVO in neonates and infants with RAI, single ventricle, and extracardiac TAPVC. We hypothesized that 1) the anatomical relationship between the arch and apex and 2) the apex rotation into the thoracic cavity after surgery are both related to postoperative PVO, as they both indicate a narrowing of the posterior space from the caudal side of the pulmonary artery (PA) to the lower end of the lower pulmonary vein (PV) and the space between the left and right phrenic nerves.

Patients and Methods

Subjects

The subjects included 18 patients (11 boys and seven girls) with RAI, single ventricle, and extracardiac TAPVC who underwent a TAPVC repair using the sutureless technique (12 patients) or conventional repair (six patients) at Kanagawa Children's Medical Center in Yokohama, Japan, from April 2014 to December 2020. While the diagnostic criteria for right and left atrial isomerism remain controversial (4), the diagnosis of RAI in the present study was based on the intraoperative inspection of the morphology of the atrial appendages. This was a single-center retrospective study using medical records. This study was approved by our ethics committee including outside experts (18.09.2020; the number of IRB, 2005-17). The consent was waived because of the retrospective nature of the study.

Surgical procedures for total anomalous pulmonary venous connection repair using the sutureless technique and conventional procedure

Cardiopulmonary bypass with aortic and bicaval cannulation under moderate

hypothermia (28) was established. Before cardiac arrest, the common chamber and

PVs were dissected from the pericardium behind the heart through a right-side

approach. In the primary sutureless technique, the incision was initiated at the common chamber maintaining the PV confluence and was extended onto each PV. The incision was then carefully extended to the pleural-pericardial reflection without entering the thoracic cavity. In the conventional repair, the incision was made only in the common chamber. After creating an anastomotic leak on the PV side, cold antegrade cardioplegia was administered without circulatory arrest. An incision was made in the posterior atrial wall, which was partially resected to prepare for anastomosis. In sutureless technique with the heart elevated to the right, the atrial-pericardial suture was initiated from the left posterior to the left phrenic nerve. In conventional procedure, the anastomotic running suture was performed from the right side. To prevent the constriction of the anastomotic line, the running sutures were stopped and ligated four times on the left side, lower and upper edge, and on the right side. We did not change the operative procedure depending on the type of TAPVC. The anastomotic range was as follows: in sutureless technique, the anastomotic pericardial sites were dorsal to the phrenic nerve on the left and right, inferior to the pulmonary artery level on the cranial side, and above the inflow level of the inferior vena cava on the caudal side. In conventional procedure, the anastomotic site was only between common chamber and the posterior atrial wall. After cardiopulmonary bypass withdrawal, we confirmed the presence of sufficient anastomotic area through epicardial echocardiography.

Evaluation of pulmonary venous obstruction

Computed tomography (CT) of the chest and transthoracic echocardiography were performed pre- and postoperatively for all patients. PVO was comprehensively defined by the shape that is clearly narrower on the heart side than on the periphery on computed tomography, continuous flow pattern, and mean pressure gradient greater than 8 mmHg at the atrial entrance on echocardiography (5). We diagnosed seven patients with PVO (PVO group) and 11 patients without PVO (non-PVO group) according to these diagnostic criteria.

Vertebral-apex angle

The angle between the line perpendicular to the vertebral body and the line from the vertebral body to the apex was defined as the "vertebral-apex angle" (V-A angle) in end-diastolic phase of CT scan. The V-A angle was individually measured by two surgeons, and the average value was obtained. This angle reflected the rotation of the apex to the ipsilateral thorax (**Fig. 1**). Changes in the V-A angle before and after the operation were evaluated. Furthermore, the preoperative (α) and postoperative (β) V-A angles, and the ratio of the post- to preoperative angle (β/α) were compared between the PVO and non-PVO groups.

Statistical analysis

The data are expressed as median (interquartile range). Survival probabilities were evaluated using the Kaplan-Meier method. The Mann–Whitney U-test was used to compare continuous variables between the PVO and non-PVO groups; an effect size greater than 0.50 was considered a large difference. The $\chi 2$ test was used to compare the categorical data between the two groups. The overall accuracy of the potential variables in predicting postoperative PVO was summarized using the area under the receiver operating characteristic (AUROC) curves. The optimal cut-off values of the postoperative V-A angle and ratio to predict postoperative PVO were determined by the Youden index. Differences were considered statistically significant if the P-value was <0.05. All data were analyzed using IBM SPSS Statistics, Version 24.0 (IBM Corp, Armonk, NY).

Results

Patient characteristics

Table 1 shows the patient characteristics. The fetal diagnosis of TAPVC was conducted for all patients. Stent dilation was performed as the first palliative procedure for an obstructive vertical vein in seven patients. The median age and bodyweight of the patients at TAPVC repair were 102 days and 3.8 kg, respectively. The type of TAPVC was supracardiac in 14 patients, infracardiac in two, and mixed type in two. Seven patients had dextrocardia, while 11 had levocardia. The aortic arch position was left in seven patients and right in 11 patients. Concomitant procedures performed with TAPVC repair were Blalock Taussig shunt (BTS) in two patients, PA banding (PAB) in four patients, Glenn procedure in 11 patients, and right ventricle-PA (RV-PA) conduit placement in one patient. There were no significant differences in patient background and surgical procedures between the groups.

Surgical outcomes

Follow-up was completed for all patients (median follow-up, 29 [11-36] months). Postoperative PVO occurred in seven of 18 patients (39%). Nine patients had preoperative PVO that necessitated intervention for TAPVC in the neonatal period confirmed by preoperative CT of the chest and transthoracic echocardiography. There were 14 survivors: six patients underwent the Fontan procedure, six patients were awaiting the Fontan procedure, and two patients were awaiting the Glenn procedure (**Table 1**). The overall survival rates at 6 months, 1 year, and 2 years were 89%, 83%, and 75%, respectively (**Fig. 2**). There were three hospital deaths and one post-discharge death: Patients who died in hospital were a 134-day-old boy, a 122-day-old girl and a 93-day-old girl with supracardiac type TAPVC and pulmonary atresia, while the patient who died after discharge was a 91-day-old girl with supracardiac type TAPVC and mild pulmonary stenosis. In two of three patients who died in hospital, a stent was inserted into the obstructive vertical vein on day 0 and 28 respectively. Bilateral PAB with patent flow of the ductus artery was performed on day 8 and 34 to regulate the PA flow respectively, and TAPVC repair using the sutureless technique in one patient, conventional procedure in the other patient and modified BTS were performed on day 134, 122 respectively. They died of heart failure 48 days and 80 days after the last operation owing to a high-flow status. In the other patient of the three, a stent was inserted into the obstructive vertical vein on day 0, PAB was performed on day 17, and TAPVC repair using the sutureless technique and the Glenn procedure were performed on day 91. She died of uncontrollable chylothorax 206 days after the last operation.

The patient who died after discharge did not have preoperative PVO and stent insertion was not necessary. She was performed TAPVC repair using the conventional procedure, Glenn and implantation of pacemaker because of congenital bradycardia on day 93. While she had postoperative branch PVOs in the apex side, postoperative course was good and she was discharged on day 110. Fontan procedure was performed on day 478 and she was discharged on 239 postoperative days. She died of refractory heart failure on 295 days after Fontan procedure. Of the four dead patients, the two patients of sutureless technique had no PVO, but the other two of conventional procedure had PVOs.

Relationship between arch-apex position and postoperative branch pulmonary venous obstruction

All branch PVOs were on the apex side. The aortic arch and apex were on the same side in eight patients and on opposite sides in 10 patients. Among patients with the aortic arch and apex on the same side, four (4/8 = 50%) had branch PVOs. Among patients with these on opposite sides, three (3/10 = 30%) had branch PVO (P =0.35). PVO occurred 4/7 in dextrocardia and 3/11 in levocardia (P=0.33) (**Table 1**). In all PVO patients except one who was performed TAPVC repair using conventional procedure, they had an obstruction of one branch in the lower portion of the apex, while the exceptional one had an obstruction of two branches in the apex side.

Vertebral-apex angle and postoperative pulmonary venous obstruction

Figure 3 shows the V-A angle before and after the operation. The V-A angle increased after the operation in all patients except one (from 35° [32°-38°] to 39° [33°-46°], P = 0.018; **Fig. 3A**). Although no significant differences were noted in the preoperative V-A angles between the non-PVO and PVO groups (35° [27°-38°] vs. 34° [33°-38°], P = 0.78, **Fig. 3B**), the postoperative V-A angle (36° [29°-38°] vs. 46° [45°-50°], P = 0.001, effect size = 0.83;**Fig. 3C**) and the ratio (1.03 [0.98-1.07] vs. 1.27 [1.24-1.42], P = 0.001, effect size = 0.83; **Fig. 3D**) were significantly larger in the PVO than those in the non-PVO group. The cut off values of the postoperative V-A angle and the ratio were 41° and 1.17, respectively (AUROC curve, 1.0; P=0.001 for each).

Discussion

Here, we demonstrated that the rotation of the heart apex into the ipsilateral thorax after surgery was evident in patients with PVO after TAPVC repair. Furthermore, although it was independent of the anatomical relationship between the apex and the arch, PVOs were all in the apex side.

Sutureless technique and conventional procedure for total anomalous pulmonary venous connection

Although the “sutureless technique” is a common surgical procedure for postoperative PVO after TAPVC repair (6), the indication of this technique versus the conventional procedure for the primary repair of TAPVC is controversial (7-9). Yamashita and colleagues reported that the sutureless technique for postoperative PVO does not improve prognosis; however, it is effective in PVO release (10). The sutureless technique theoretically avoids intimal proliferation in repaired native PVs and prevents the kinking or distortion of the anastomotic site. Several institutions primarily apply this technique (11,12). However, no significant difference in mortality between the primary sutureless technique and conventional repair for simple TAPVC and single ventricle with TAPVC has been observed (10,13). In our experience, while there were no significant difference between the sutureless and conventional groups (P=0.43), there was only one branch PVO in sutureless technique and one or more branch PVOs in conventional procedure which might have caused death from heart failure after Fontan. Our early results may not suggest the more usefulness of the primary sutureless technique than conventional procedure for RAI with TAPVC, including preoperative PVO (7 of 12 patients). Although both procedures were useful for TAPVC repair, PVO can still occur and strategies to prevent it are necessary.

Pathology of pulmonary venous obstruction after total anomalous pulmonary venous connection repair

Some authors indicate the following pathologies as the causes of PVO after conventional TAPVC repair: 1) thickened pulmonary vessel walls, 2) pulmonary lymphangiectasia, and 3) surgical anastomotic stricture (14,15). Although PVO is usually a serious condition that directly leads to death (1,2), our five patients of seven patients with postoperative PVO survived. All PVOs were local branch PVOs and did not show severe stenosis. The overall PV function was therefore maintained sufficiently for Fontan candidates except one patient who died after Fontan. The sutureless technique, using a large circular anastomosis, may have prevented the three abovementioned pathologies after conventional TAPVC repair. Although a single PVO is usually well tolerated, any minor PVOs may affect the long-term results of congenital heart disease.

In the present study, we hypothesized that the following two anatomical factors that narrow the space behind the heart were associated with postoperative PVO: 1) the anatomical relationship between the arch and apex, i.e., whether they are present on the same side or not, and 2) apex rotation into the thoracic cavity. Both factors may exaggerate the compression of PVs. Although our hypothesis 1) i.e., the anatomical relationship between the arch and apex, was denied, the relationship between heart apex and PVO was very likely. Furthermore, a change in the V-A angle, indicating apex rotation, was evident in the PVO group. We speculate the mechanism of apex rotation into the ipsilateral thorax and the relationship between apex rotation and postoperative PVO as follows: the apex rotation would be attributed to the fact that the pericardium was left open after surgery. Furthermore, the amount of the tissue surrounding the suture line may have affected PVO: especially, since sutureless technique needs a large anastomotic site, the area in contact with the surrounding tissue is also large. Thus, the suture line would be easily affected by surrounding tissue. In all six PVO cases, the lower PV branch in the apex side was diffusely stenotic as indicated in Fig. 1B.

Any modifications of the currently available techniques, e.g., more reduction of the surrounding tissue by resecting posterior wall of the atrium might decrease the incidence of postoperative PVO. Although we attempted to prevent the rotation of the apex into the thoracic cavity by fixing or closing the pericardium, we had to reopen the pericardium in all patients due to low cardiac function during or early after the surgery. We, therefore, could not prove the effectiveness of this strategy.

Limitations

The study had several limitations that need to be considered while interpreting the results. First, this was a single institution study of a small group of patients over a short period of time. The number of cases who are diagnosed heterotaxy with extracardiac TAPVC in our hospital is decreasing; we performed the last case of this procedure in April 2020. Further studies are required to investigate the long-term outcomes in a larger number of patients. Second, we only evaluated the effect of the V-A angle and the anatomical relationship between the arch and apex on surgical outcomes. Thus, we cannot exclude the possibility of an incidental focal change in the PVs along the suture line as a cause of postoperative branch PVO.

Conclusions

Our early survival outcome and the incidence of the PVO for RAI with TAPVC were satisfactory. Postoperative branch PVOs occurred in 39% of all patients. The PVOs were all in the apex side. Furthermore, the rotation of the apex into the ipsilateral thorax after surgery was evident in those with postoperative branch PVOs. The cut-off values of the postoperative V-A angle and ratio for the PVO prediction were 41° and 1.17, respectively. Further studies are necessary to examine whether strategies to reduce the rotation of the apex ameliorate PVO after TAPVC repair.

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Figure legends

Figure 1. Pre- (A) and post-operative (B) computed tomography images in end-diastolic phase of patient 3. The vertebral-apex angle (preoperative: α· postoperative: β) is defined as the angle between the line perpendicular to the vertebral body and that from the vertebral body to the apex. The arrows indicate the left lower pulmonary veins; it is normal in (A) and diffusely stenotic in (B).

Figure 2. Cumulative survival rate after TAPVC repair. TAPVC, total anomalous pulmonary venous connection.

Figure 3. V-A angles before and after the operation. (A) The change in V-A angle after the operation. (B) Differences in the preoperative V-A angles (α) between the non-PVO and PVO groups. (C) Differences in the postoperative V-A angles (β) between the non-PVO and PVO groups. The V-A angles of the patients in the PVO group were 42° or more, while those in the non-PVO group were 40° or less. The dotted line presented the cut off value of 41°. (D) The ratio of post- and preoperative V-A angles (β/α). The ratios of the patients in the PVO group were 1.18 or more, while those in the non-PVO group were 1.15 or less. The dotted line presented the cut off value of 1.17. Values are median and interquartile range. PVO, pulmonary venous obstruction; V-A, vertebral-apex.

References

1. Hoashi T, Kagisaki K, Oda T, Kitano M, *et al* . Long-term results of treatments for functional single ventricle associated with extracardiac type total anomalous pulmonary venous connection. Eur J Cardiothorac Surg. 2013;43:965–70.

2. Khan MS, Bryant III R, Kim SH, *et al* . Contemporary outcomes of surgical repair of total anomalous pulmonary venous connection in patients with heterotaxy syndrome. Ann Thorac Surg. 2015;99:2134–40.

3. Alsoufi B, McCracken C, Schlosser B, *et al* . Outcomes of multistage palliation of infants with functional single ventricle and heterotaxy syndrome. J Thorac Cardiovasc Surg. 2016;151:1369–77.

4. Hashmi A, Abu-Sulaiman R, McCrindle BW, Smallhorn JF, Williams WG, Freedom RM. Management and outcomes of right atrial isomerism: a 26-year experience. J Am Coll Cardiol. 1998;31:1120–6.

5. Minich LL, Tani LY, Breinholt JP, Tuohy AM, Shaddy RE. Complete follow-up echocardiograms are needed to detect stenosis of normally connecting pulmonary veins. Echocardiography. 2001;18:589–92.

6. Najm HK, Caldarone CA, Smallhorn J, Coles JG. A sutureless technique for the relief of pulmonary vein stenosis with the use of in situ pericardium. J Thorac Cardiovasc Surg. 1998;115:468–70.

7. Honjo O, Atlin CR, Hamilton BC, *et al* . Primary Sutureless repair for infants with mixed Total anomalous pulmonary venous drainage. Ann Thorac Surg. 2010;90:862–8.

8. Yanagawa B, Alghamdi AA, Dragulescu A, *et al* . Primary sutureless repair for “simple” total anomalous pulmonary venous connection: midterm results in a single institution. J Thorac Cardiovasc Surg. 2011;141:1346–54.

9. Zhu Y, Qi H, Jin Y. Comparison of conventional and primary sutureless surgery for repairing supracardiac total anomalous pulmonary venous drainage. J Cardiothorac Surg. 2019;14:34.

10. Yamashita K, Hoashi T, Kagisaki K, *et al* . Midterm outcomes of sutureless technique for postoperative pulmonary venous stenosis. Gen Thorac Cardiovasc Surg. 2014;62:48–52.

11. Azakie A, Lavrsen MJ, Johnson NC, Sapru A. Early outcomes of primary sutureless repair of the pulmonary veins. Ann Thorac Surg. 2011;92:666–71.

12. Mueller C, Dave H, Prêtre R. Primary correction of total anomalous pulmonary venous return with a modified sutureless technique. Eur J Cardiothorac Surg. 2013;43:635–40.

13. Yun TJ, Coles JG, Konstantinov IE, Al-Radi OO, Wald RM, Guerra V. Conventional and sutureless techniques for management of the pulmonary veins: evolution of indications from postrepair pulmonary vein stenosis to primary pulmonary vein anomalies. J Thorac Cardiovasc Surg. 2005;129:167–74.

14. Yong MS, d’Udekem Y, Robertson T, *et al* . Outcomes of surgery for simple total anomalous pulmonary venous drainage in neonates. Ann Thorac Surg. 2011;91:1921–7.

15. Kelle AM, Backer CL, Gossett JG, Kaushal S, Mavroudis C. Total anomalous pulmonary venous connection: results of surgical repair of 100 patients at a single institution. J Thorac Cardiovasc Surg. 2010;139:1387–94.

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