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Case Report

Modified Hand-Sewn Polytetrafluoroethylene Bicuspid Valved Conduit for the Reconstruction of Right Ventricle Outflow Tract in Truncus Arteriosus in Infancy: A Case Report

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Abstract

The reconstruction of the right ventricle outflow tract in truncus arteriosus remains challenging. The use of valved conduit based on polytetrafluoroethylene has been increasingly popular since the 1990s. Albeit with verified long-term durability, the previous techniques for manufacturing polytetrafluoroethylene valved conduit were relatively cumbersome and time-cost, which at least in part limited its further application. We reported the first successful truncus arteriosus case using a modified and simplified technique for hand-sewing the polytetrafluoroethylene pulmonary bicuspid valved conduit. Eventually, the patient completed the surgery successfully and showed a satisfactory outcome during the 17-month follow-up. Therefore, this technique is a time-saving, reproducible, and reliable approach in truncus arteriosus on the reconstruction of the right ventricle outflow tract.

Keywords

truncus arteriosus; right ventricle outflow tract reconstruction; polytetrafluoroethylene; valved conduit; technique

Introduction

Truncus arteriosus (TA), characterized by a single arterial trunk arising from the heart and supply of both systemic and pulmonary circulation, was a rare congenital heart malformation with a prevalence of 3–10 per 100,000 live births [1]. The surgical treatment involves the separation of the pulmonary arteries or pulmonary artery trunk from the common trunk, ventricular septal defect repair as well as the reconstruction of the right ventricle outflow tract (RVOT) continuity. Albeit with the technical advances over the past decades, the ideal method of RVOT reconstruction is yet to be defined. Direct right ventricle-to-pulmonary artery anastomosis with or without left atrial appendage interposition appeared to be beneficial and effective but was limited to the potential of early re-intervention due to pulmonary artery distortion and unclear long-term outcomes [2]. Valved conduits such as bioprosthetic conduit and homografts are also frequently used; however, no one is capable of fulfilling the clinical requirement due to limited availability and ease of infection or thrombosis [3].

Alternatively, Yamagishi *et al*. [4] first introduced the adoption of polytetrafluoroethylene (PTFE) to produce unicuspid valve and bicuspid valve for RVOT reconstruction. Since then, the PTFE valved conduit has become increasingly popular owing to its being immunologically inert, low cost, and ease of construction [5]. Additionally, previous studies have demonstrated similar comparable outcomes in terms of conduit explant, major reintervention, moderate stenosis, and severe conduit insufficiency between PTFE conduits and Homograft conduits [6]. Miyazaki *et al*. [7] fabricated an expanded PTFE conduit with bulging sinuses and used it in the RVOT reconstruction of a total of 902 patients, showing satisfactory long-term outcomes. It was reported that the 5-year and 10-year rate of freedom from PTFE conduit reintervention were 92.3% and 76.1%, respectively [7]. However, the surgical process for manufacturing PTFE valved conduit in the previous studies was relatively cumbersome and time-consuming, which might hinder its further application. Thus, we reported a TA patient undergoing ROVT reconstruction using a hand-sewn 0.1 mm-thick PTFE bicuspid valved conduit based on a modified and simplified technique. The CARE checklist was used when writing this case report (**Supplementary Table 1**).

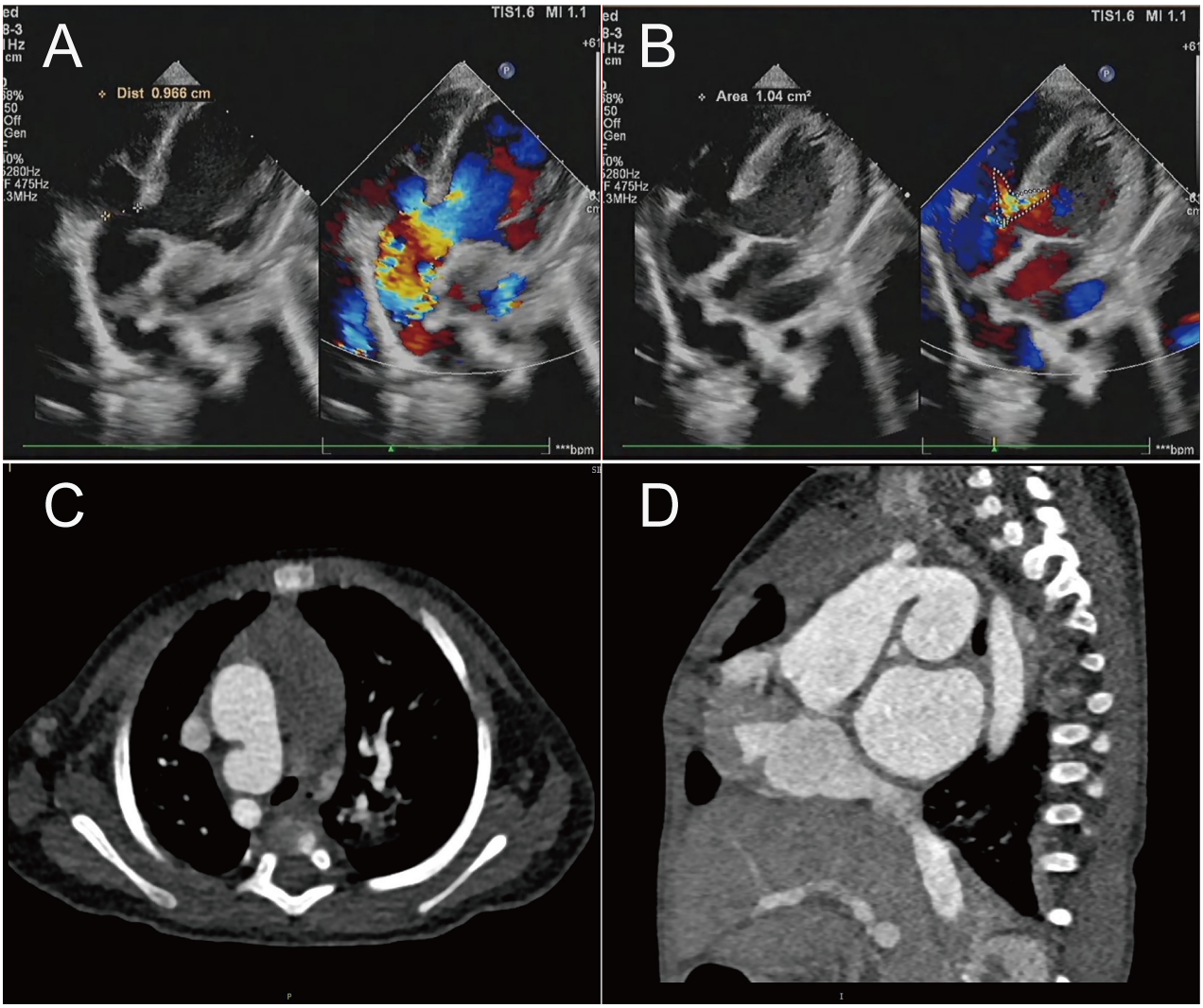

Fig. 1. The preoperative transthoracic echocardiogram and computed tomography findings. (A) The main pulmonary artery was derived from the left posterior wall of the common trunk 14 mm above the level of the truncus valve with a 9.0 mm opening. (B) The ventricular septal defect was 10 mm in size with a bi-directional shunt. (C) The right aortic arch with the right descending aorta was revealed on computed tomography. There was a 7 mm connection between the aortic arch and the main pulmonary artery. (D) The main pulmonary artery arose from the posterior wall of the common trunk.

Case Report

A one-year-old female infant was referred to our hospital owing to a one-year history of recurrent shortness of breath and cyanosis and a 20-day history of recurrent cough. She was previously diagnosed with congenital heart disease combined with bronchopneumonia and received antibiotics treatment to control infection in another hospital. She presented to our hospital for further repair of congenital heart disease. On referral, she had severe malnutrition and cyanosis with low saturation of pulse oxygen (82%). On physical examination, a loud single second heart sound and a systolic ejection murmur at the left sternal border were heard. The electrocardiogram revealed sinus tachycardia and a T-wave change. A chest X-ray film showed cardiomegaly and pneumonia. Echocardiogram demonstrated a type I TA, ventricle septal defect with 10 mm in size, mild truncus valve insufficiency as well as severe pulmonary artery pressure. Fig. 1A showed the main pulmonary artery arose from the left posterior wall of the common trunk with a 9.0 mm opening at the supravalvular level. Fig. 1B revealed a 10 mm ventricular septal defect with a bi-directional shunt. The main pulmonary artery arose from the left posterior wall of the common trunk 14 mm above the level of the truncus valve. A cardiac computed tomography confirmed the TA, common trunk overriding, and right-sided aortic arch. As shown in Fig. 1C,D, the main pulmonary artery originated from the posterior wall of the right aortic arch with a 7 mm connection. She was thereby diagnosed with type I TA and concurrent heart failure.

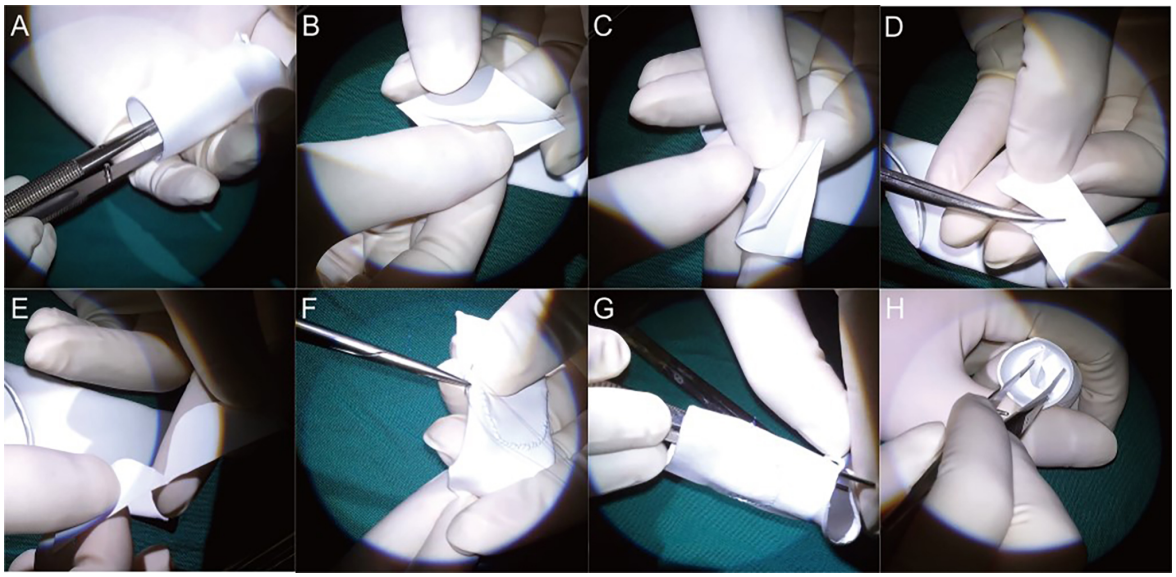

Fig. 2. Procedures of hand-sewing the expanded polytetrafluoroethylene bicuspid valved conduit. (A) Turn the conduit inside out. (B) Fold the 0.1 mm-thick polytetrafluoroethylene membrane in half. (C) Refold the membrane in half. (D) Tailor the bicuspid valve based on the folded membrane according to the formula as follows: valve width = diameter of the conduit × π × 0.5; valve height = valve width × 0.9. (E) Expand the folded bicuspid valve. (F) Sew the bicuspid valve to the inner wall of the conduit. (G) Turn the conduit outside in. (H) Adjust the valve position.

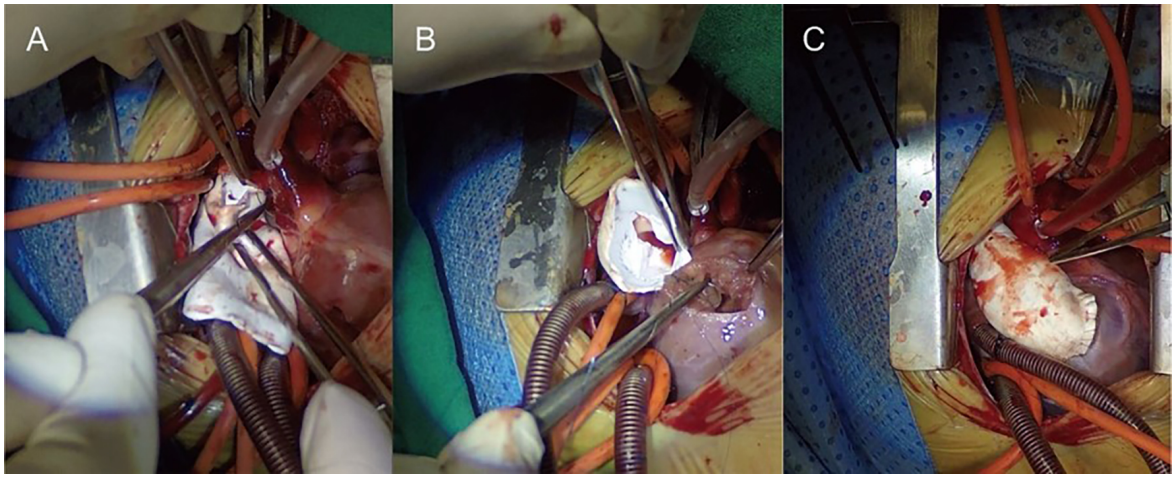

Fig. 3. Reconstruction of right ventricle outflow tract with the valved conduit. (A) The valved conduit was connected distally to the main pulmonary artery by end-to-end anastomosis with 6-0 prolene. (B) The proximal end of the valved conduit was also anastomosed to the right ventricle opening with 6-0 prolene. (C) The valved conduit was placed in a heterotopic anatomic position to achieve right ventricle outflow tract reconstruction.

The surgery was performed by a median sternotomy. After cardiopulmonary bypass establishment, cross-clamping of ascending aorta and cardiac arrest were obtained. The main pulmonary artery was first cut from the common trunk, followed by a repair of a new aorta incision. The ventricle septal defect was then repaired with an autologous pericardium via the right ventricle incision approach. As shown in Fig. 2, a 16 mm expanded polytetrafluoroethylene bicuspid valved conduit was hand-sewn determined by the size of the main pulmonary artery. Briefly, the 16 mm conduit was first turned inside out. Subsequently, the bicuspid valve based on 0.1 mm-thick polytetrafluoroethylene membrane was manufactured according to the following formula: valve width = diameter of the conduit × π × 0.5; valve height = valve width × 0.9. The bicuspid valve was then sutured to the inside wall of the conduit by running suture with 6-0 prolene. The valved conduit was turned outside in, with the proximal end left Fan shaped to match the right ventricle opening. The distal end of the valved conduit was anastomosed to the main pulmonary artery by 6-

Table 1. The patient's recovery process after surgical repair of TA.

Time	Events
2022.01.18.08:00	The surgical repair of TA started.
2022.01.18.14:15	The surgery was completed successfully. The patient was transferred to the pediatric intensive care unit.
2022.01.27.08:52	The chest tube was removed.
2022.01.28.09:45	The mechanical ventilation was withdrawn. The endobronchial tube was removed.
2022.02.01	The patient was transferred to the general ward.
2022.02.03	The patient was discharged with significantly relieved symptoms and improved saturation of pulse oxygenation.
2022.02.18	The echocardiogram showed unobstructed RVOT and PA (flow velocity through pulmonary valve: 1.4 m/s), no pulmonary regurgitation, no residual shunt, mild aortic regurgitation (0.8 cm^2), and well LVEF (63%) at the postoperative one-month follow-up.
2022.03.23	The echocardiogram showed unobstructed RVOT and PA (flow velocity through pulmonary valve: 0.5 m/s), no pulmonary regurgitation, no residual shunt, mild aortic regurgitation (0.4 cm^2), and normal LVEF (60%) at the postoperative two-month follow-up.
2023.06.19	The echocardiogram showed unobstructed RVOT and PA (flow velocity through pulmonary valve: 0.5 m/s), no pulmonary regurgitation, no residual shunt, mild aortic regurgitation (0.4 cm^2), and normal LVEF (61%) at the postoperative 17-month follow-up.

TA, truncus arteriosus; RVOT, right ventricle outflow tract; PA, pulmonary artery; LVEF, left ventricular ejection fraction.

0 prolene running sutures with regular and appropriate suture spacing to avoid anastomotic leakage (Fig. 3A). Similar end-to-end anastomosis was also applied to connect the proximal end of the valved conduit and the right ventricular opening (Fig. 3B). Consequently, the conduit was placed in a heterotopic anatomic position to reduce the tension of anastomosis (Fig. 3C). The transesophageal echocardiogram was performed immediately after the surgery to confirm no conduit stenosis and insufficiency.

The patient's recovery process is summarized in Table 1. The patient was transferred to the intensive care unit after completing the surgery. Routine mechanical ventilation, electrocardiogram monitoring, and positive inotropic drugs were given. Beside echocardiogram and chest radiography were also regularly performed to assess the cardiopulmonary function. Blood gas analysis and central venous pressure were monitored to maintain the balance of body fluids and electrolytes. The patient was discharged on the 16th day after the surgery with significantly improved saturation of pulse oxygen (99–100%) and received the antithrombotic administration by aspirin (0.3–0.5 mg/kg qd) for half of one year. Echocardiography at a 17-month follow-up after 17 months showed a satisfactory valved conduit performance. Fig. 4A showed no residual shunt, mild aortic regurgitation with 0.4 cm^2, and unobstructed right ventricular outflow and pulmonary artery. The flow velocity through the pulmonary valve was 0.5 m/s, suggesting no stenosis (Fig. 4B).

Comments

The surgical repair of TA remains challenging, particularly in RVOT reconstruction. We thereby reported and described a successfully modified and simplified technique for manufacturing handmade pulmonary bicuspid valved conduit with the utilization of PTFE, which was eventually applied in the RVOT reconstruction in a female infant with TA and showed a good conduit performance during the follow-up.

The application of the valved conduit in addition to direct anastomosis of the right ventricle to the pulmonary artery has been the most common choice in RVOT reconstruction in TA. Either bioprosthetic conduits or homografts appeared to show a sub-optimal conduit performance due to limited availability, the potential for obstruction, and disappointing durability [8,9]. To circumvent these issues, Yamagishi *et al.* [4] first designed a pulmonary unicuspid/bicuspid valve base on a 0.6 mm-thick PTFE membrane for RVOT reconstruction in the 1990s on account of its ease of availability, low cost, and being immunologically inert. Since then, tremendous efforts have been made to design and manufacture an ideal conduit with appropriate fluid dynamics and improved outcomes [10,11]. However, the techniques described in the previous studies were relatively time-cost and complex, which might compromise the conduit performance. In contrast, we modified and simplified the technique proposed by Quintessenza *et al.* [12] for manufacturing the PTFE bicuspid valve. It took only 15 minutes to complete the entire manufacturing process, which is easily reproducible and appears not to significantly augment the surgery period.

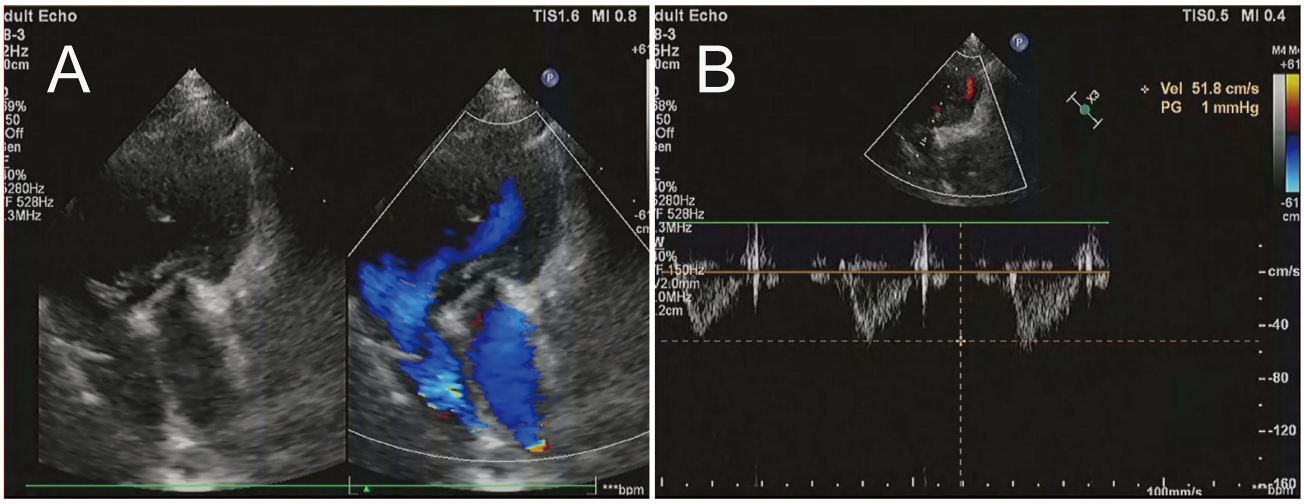

Fig. 4. The postoperative echocardiographic findings at a 17-month follow-up. (A) Unobstructed right ventricular outflow and pulmonary artery, mild aortic regurgitation with 0.4 cm^2, and no residual shunt were shown. (B) The flow velocity through the pulmonary valve was 0.5 m/s, indicating no stenosis and satisfactory conduit performance.

Table 2. Comparison of RVOT reconstruction strategies.

RVOT reconstruction strategies	Advantages	Disadvantages	Reference
Bioprosthetic conduits	Longer freedom from reoperation, larger conduit sizes	Earlier conduit stenosis and insufficiency, higher risk of reintervention and endocarditis	[3,14,15]
Homografts	Increased longevity, better hemodynamic properties	Potential for obstruction, limited availability, smaller sizes	[16,17]
Direct RV-PA anastomosis	Long-term freedom from conduit reoperation	No favorable anatomy, potential for severe pulmonary regurgitation	[1,2]
Conventional PTFE conduit	Ease of availability, low cost, being immunologically inert	Relatively cumbersome, time-costing	[5,6]
Modified PTFE conduit	Ease of availability, low cost, being immunologically inert, time-saving	Undefined indication and contraindication, lack of evidence on safety and efficacy	[6,18]

RVOT, right ventricle outflow tract; RV-PA, right ventricle to pulmonary artery; PTFE, polytetrafluoroethylene.

In the postoperative 17-month follow-up, the patient showed great outcomes as no stenosis or insufficiency within the bicuspid valved conduit occurred. The short-term and long-term safety and efficacy of PTFE-based RVOT reconstruction have been verified. Miyazaki *et al.* [7] enrolled a total of 902 patients undergoing ROVT reconstruction with the utilization of PTFE valved conduit showing that the freedom from the intervention was 96.3%, 87.4%, and 84.2% at 5 years, 10 years, and 15 years, respectively. Of note, the pulmonary artery and right ventricle were connected by the valved conduit in a heterotopic anatomic position. It is acceptable as the anatomic position of the conduit has been demonstrated to not impact its durability and further risk of reintervention [13]. Overall, the comparison between our modified technique and conventional strategies of RVOT reconstruction was summarized in Table 2 (Ref. [1–3,5,6,14–18]).

There were several limitations. First, the present study was limited to the nature design of the case report and thereby low representativeness. However, it is anticipated that the accumulative adoption of this modified and simplified technique on more patients in the future would be beneficial for the definition of its indication and contraindication in RVOT reconstruction of TA patients and even other congenital heart disease patients. Secondly, the period of postoperative follow-up was relatively short. It is unclear whether this technique is associated with some potential complications such as conduit thrombosis, infection, and pulmonary valve dysfunction in a longer period of follow-up. Hence, future studies should focus on its long-term outcomes in terms of safety and efficacy.

Therefore, the modified and simplified technique for manufacturing the PTFE pulmonary bicuspid valve is a safe and efficient alternative to reconstruct RVOT in patients with TA, which has the potential to extend its application in the future due to reproducible and time-saving properties.

Availability of Data and Materials

The data and materials of this case can be shared on reasonable request by the corresponding author.

Author Contributions

XL and HY designed the study and performed the surgery. JM also designed the study, wrote the first draft of the manuscript, and completed the revision. HQ , MT, WX, YL, ZTJ, TT, LH, and ZZ were in charge of data collection and video recording. SW, JC, and JZ provided professional suggestions and discussion on the surgery and supervised the research. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study was approved by Guangdong Provincial People's Hospital Ethics Committee (No. GDREC2019338H(R2)) on 17th September 2019. The written informed consent was obtained from the patient's parents.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.59958/hsf.6383.

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