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Early results and factors affecting arterial switch operation in provincial medical center

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Transposition of the great arteries (TGA) is a serious and complicated congenital heart disease, accounting for 5% to 7% of all congenital heart malformations. Most fetuses with TGA can survive stably to delivery. After birth, their survival depends on the associated ventricular septal defect (VSD), atrial septal defect (ASD) or patent ductus arteriosus (PDA). Without treatment, approximately 30% of these infants die in the first week after birth and 90% die within the first year.[1] Arterial switch operation is now recognized worldwide as an effective treatment for TGA and good results have been achieved with this approach. ASO was performed late at our center, with a few patients and high mortality rates in the early stage. In recent years, both the number of patients and the survival rate have increased with the gradual improvement of the skills of the surgical team. More patients have been diagnosed prenatally with the development and promotion of fetal echocardiography. From pregnancy to delivery to surgery, children with TGA require monitoring with close cooperation among medical staff from multiple disciplines. In this study, the data of 87 patients who underwent ASO from January 2014 to December 2019 at our center were retrospectively summarized to analyze the major nonsurgical factors affecting patient prognosis [Table 1]. The study was approved by the Ethics Committee of Shandong Provincial Hospital.

The patients were mainly from the local area and three southern neighboring regions. The proportion of rural patients was high, and the proportion of prenatal diagnosis was low. The proportion of vaginal delivery and cesarean section was similar. The proportion of affected patients who were the second child of the family was higher than the sum of the number of first and third children affected. The proportion of males was high, which was consistent with the overall incidence of TGA.[1] The mortality rates associated with urban residence, prenatal diagnosis, cesarean section, the first child of the family, and female sex were higher than those of the patients in the corresponding groups, but the differences were not statistically significant. Many studies have shown that prenatal diagnosis can improve survival rate. However, our results revealed the opposite, similar to the findings (18%) of Qu *et al*.[2] This may be because some patients diagnosed after birth stopped treatment or died before surgery, which could also explain why the mortality of rural patients was lower than that of urban patients. It is interesting to note that the mortality rate of the second child of the family was significantly lower than that of the first or the third child. Although the difference was not statistically significant, this finding may be worthy of further study.

Before ASO, all patients were reviewed by the same senior echocardiography expert in detail. The coronary artery pattern could not be accurately described, and other diagnoses were consistent with intraoperative exploration. The proportion of TGA with a VSD (TGA-VSD) was 35.6% (31/87) which was consistent with the overall incidence (40%).[1] Eighty-four patients had ASD or patent foramen ovale (PFO) and 69 patients had PDA. Four patients had pulmonary stenosis (PS), three had double outlet right ventricle (DORV) and three had coarctation of the aorta (CoA). The main coronary artery pattern was conventional pattern (The left coronary artery [LCA] originates from sinus 1, which then gives rise to left anterior descending branch[LAD] and circumflexbranch [CX], and the right coronary artery [RCA] originates from sinus 2; 1LAD,Cx;2R) defined according to the Leiden classification. The mortality of the TGA with an intact ventricular septum (TGA-IVS) group and the unconven-

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Table 1: Data of patients who underwent ASO ($n = 87$).

Characteristics	Group	*n*	Survived	Died	*P*
Residence	Urban	31	25	6	0.063
	Rural	56	53	3	
Diagnosis	Prenatal	23	19	4	0.236
	After birth	64	59	5	
Gender	Male	64	60	4	0.051
	Female	23	18	5	
Delivery time	Premature	7	4	3	0.022
	Full-term	80	74	6	
Delivery method	Vaginal	41	39	2	0.163
	Cesarean	46	39	7	
Parity	First	27	22	5	0.206
	Second	52	49	3	
	Third	8	7	1	
VSD	TGA-VSD	31	29	2	0.481
	TGA-IVS	56	49	7	
Coronary artery pattern	Conventional	63	57	6	0.702
	Abnormal	24	21	3	
ICU before ASO	Yes	14	9	5	0.005
	No	73	69	4	
MV before ASO	Yes	19	12	7	< 0.001
	No	68	66	2	
Be rescued before ASO or Emergency ASO	Yes	7	3	4	0.002
	No	80	75	5	
Weight at ASO	< 3 kg	11	5	6	< 0.001
	≥ 3 kg	76	73	3	
Age at ASO	< 7 days	13	8	5	0.004
	7–14 days	34	30	4	
	> 14 days	40	40	0	

ASO: Arterial switch operation; ICU: Intensive care unit; MV: Mechanical ventilation; TGA-VSD: Transposition of the great arteries-ventricular septal defect; TGA-IVS: TGA with an intact ventricular septum; VSD: Ventricular septal defect.

tional coronary artery pattern group was higher than that of the corresponding groups, but the difference was not statistically significant, similar to the findings of Fricke *et al*'s study.[3] Therefore, VSD complications and coronary artery patterns were not the key factors affecting mortality at our center.

Before ASO, prostaglandin E was used to prevent PDA healing, while appropriate intervention was used to improve cardiac and respiratory functions. Most patients were delivered at full-term, and there were only seven patients born prematurely between 34 and 36 weeks. Nineteen patients required mechanical ventilation (MV), fourteen patients required intensive care in the intensive care unit (ICU) because of their critical condition, and seven patients had undergone rescue or emergency surgery. The mortality rates associated with premature birth, preoperative MV or being in the ICU, and rescue or emergency surgery were significantly higher than those of patients in the corresponding groups. These were important risk factors for postoperative death at our center. The last 6 weeks of pregnancy is a critical period of growth and development, and premature newborns have low biological reserves, poor lung function, and low weight, which increases the risk of postoperative death.[4] Therefore, it is best to give birth at 39 to 40 weeks of gestation unless there are obstetric indications.

Before ASO, balloon atrial septostomy (BAS) is not a routine intervention at our center, even though it can effectively extend the waiting time before surgery. BAS is an invasive treatment with risks including femoral or umbilical vein trauma, atrial arrhythmia, complete cardiac block, and pulmonary vein or inferior vena cava avulsion, and increases the risk of thromboembolic events in the brain.[1] Most of our patients had VSD, ASD, PFO, or PDA. During preoperative conversation, guardians are more inclined to choose emergency surgery instead of palliative treatment. Additionally, they prefer an emergency radical operation to dual-stage surgery. Therefore, only one male baby underwent dual-stage surgery. He had TGA-IVS concurrent with ASD approximately 0.80 cm in size. He underwent a modified B-T shunt and banding operation first, a second banding operation 4 days later, and ultimately underwent ASO 6 days later.

All surgeries were performed by the same surgical team, and the concurrent VSD, PDA, PS, and CoA were repaired. One special case was a patient who was 28 years old when she underwent ASO. This patient had TGA concurrent with DORV, the diameter of the VSD was 3 cm, and the pulmonary artery pressure was greater than the systemic pressure. She underwent Switch + VSD repair operation. Except for this particular patient, the age at surgery and weight at surgery ranged from 1 to 423 days (median

13 days) and 2.25 to 8.00 kg (median 3.58 kg), respectively. There have been many studies on the timing of ASO, but opinions are not uniform. Most groups have suggested that once the diagnosis is confirmed, ASO should be performed as soon as possible within 2 weeks after birth.[4] Waiting several days after birth before ASO allows the effective transition from the fetal to neonatal circulation, reduces pulmonary vascular resistance, and allows for the functional development of the newborn.[1,4] Low body weight is still a risk factor for death after major cardiac surgery in children. Low-weight babies are usually born prematurely and may have related complications that affect various systems. The mortality rates of patients aged <7 days and weighing <3 kg were significantly higher than those of patients in the corresponding groups. Age and weight were important risk factors for postoperative death at our center.

During surgery, the PFO of 57 patients was preserved, which means that for children with concurrent PFO only, PFO was not intervened with to avoid surgery-related heart injury; in some patients with ASD, part of the ASD was retained. Residual defects that maintain a small shunt of blood flow in the heart improve the postoperative recovery process, especially in patients whose pulmonary circulatory resistance may fluctuate and prompt a hemodynamic crisis. Sixty-three patients had delayed sternal closure (DSC). DSC is not recommended as a routine method but is widely used as a simple and effective technique for patients with long and complicated operations or heavy postoperative bleeding to prevent heart compression in a hemodynamically unstable state after pediatric heart surgery.[1]

The mean cardiopulmonary bypass (CPB) time and aortic clamp (AC) time during surgery were 135.9 ± 18.9 min and 81.2 ± 12.9 min, respectively. VSD needs to be repaired, and it is more complicated to correct unconventional patterns of the coronary artery, so the CPB time and AC time were significantly longer in patients with VSD or unconventional coronary artery. The AC time was also longer in patients aged >14 days. The mean DSC time was 2.1 ± 1.5 days, and patients aged <7 days had significantly longer DSC times. After ASO, all patients were transferred to the ICU for close monitoring and underwent MV. The mean MV and ICU duration times were 103.0 ± 45.8 h and 8.8 ± 3.3 days, respectively. Patients who had been managed in the ICU before surgery had significantly longer postoperative MV and ICU stay durations. The mean length of hospital stay (LOS) was 21.8 ± 7.0 days, and was significantly longer among patients with VSD. The LOS of the second child of the family was the shortest with statistical significance.

Overall, under the premise of stable technical progress of the surgical team, the main factors affecting mortality at our center were comprehensive characteristics of the child before surgery, such as premature birth, low weight, young age, preoperative requirement for MV and intensive care, or emergency surgery. These factors are closely related to the maternal-fetal environment (MFE).[5] Damage of MFE can lead to immature functions and abnormal development of multiple organ systems, which decrease the biological reserves, increase the mortality rate of newborns after cardiac surgery, and prolong the LOS. MFE is considered impaired if one or more of the following conditions occur: gestational hypertension, preeclampsia, small for gestational age, or premature delivery. All of the nine patients who died had different impairments of the MFE—three were born prematurely, two were one of a set of twins, one was test-tube baby, and the mothers of four patients had obesity, hypertension, anemia, liver dysfunction, or thyroid problems during pregnancy. These conditions were rare in the patients who survived.

In summary, the number of patients was small, the mortality rate was still high at our center, and we will carry out further studies in the future. Clinicians should continue to promote prenatal diagnostics and provide sound advice for pregnant women. For those with other serious problems and poor prognosis, selective induction of labor should be recommended to alleviate physical injury and financial burden. For those who continue the pregnancy, intensive perinatal monitoring is required to improve the prognosis, and it is best to give birth at 39 to 40 weeks of gestation unless there are obstetric indications. VSD and coronary artery pattern have no significant effect on surgery-associated mortality rates, while the overall physical characteristics of the patients before ASO are particularly important. If the baby is generally stable, delaying surgery to 14 days of age may reduce the mortality rate. Meanwhile, for children diagnosed 14 days or more after birth, ASO should be performed aggressively.

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Conflicts of interest

None.

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