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Nikaidoh Procedure for a Beating Heart: A Technical Note

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What is known on this subject?
The Nikaidoh procedure is a complicated surgery that has only been performed for 100 patients to date.

What this techinical reports adds?
Performing the Nikaidoh procedure on a beating heart provides advantages.

ABSTRACT

Aortic root translocation is a surgical choice offering potential advantages for combinations of transposition of the great arteries (TGA), pulmonary stenosis (PS), and ventricular septal defect (VSD). Six patients were included in this analysis. All of them were diagnosed with TGA, PS, and VSD and all of them underwent the Nikaidoh procedure. In 2 of these 6 cases (33.3%), aortic translocation was performed on a beating heart. Performing aortic root translocation on a beating heart is probably useful in reducing the cross-clamp time and the mortality rate, as well as preventing coronary malposition.

Keywords: Aortic translocation, pediatric cardiovascular surgery, beating heart, Nikaidoh procedure

Introduction

The cases of six patients are addressed in this report. Their mean age was 25.5±8.73 months and mean body weight was 11.5±2.42 kg. They were all diagnosed with simultaneous transposition of the great arteries (TGA), pulmonary stenosis (PS), and ventricular septal defect (VSD) and all of them underwent the Nikaidoh procedure. Half of the patients (n=3) had a history of right modified Blalock-Taussig shunt (m-BT shunt) and underwent shunt take-down and right pulmonary artery (PA) reconstruction simultaneously. Aortic translocation was performed on a beating heart in 33.3% of the cases (n=2). The mean cross-clamp time was 124 (range: 82-167) min while mean cardiopulmonary bypass time was 228.16 (range: 220-234) min. Of these patients, 16.6% (n=1) needed support in the form of extracorporeal membrane oxygenation. Aortic insufficiency was not observed in any case during the early or middle period. The early mortality rate was 16.6% (n=1). The body weight of that patient was less than 10 kg and he had the longest cross-clamp time. While 66.7% of patients underwent right ventricular outflow tract (RVOT) reconstruction with a transannular patch, 33.3% (n=1) underwent a conduit replacement procedure performed between the right ventricle (RV) and PA. The mean hospital stay was 10.33±1.86 days, mean duration of intensive care was 3.67±1.86 days, and these values were significantly shorter for patients for whom the Nikaidoh procedure was applied to a beating heart. Neurological complications were not observed in any cases.

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The mean duration of follow-up was 58.4±24.75 months. The rate of reoperation among patients who survived was 20%. The patient who underwent RV-PA conduit replacement needed surgery again 4 years later due to conduit degeneration. No reoperation occurred during follow-up for patients who underwent reconstruction with a transannular patch.

There are three main groups of surgical procedures for the complex forms of these cases. These are the réparation à l'étage ventriculaire (REV), Rastelli, and Nikaidoh procedures (1).

The Nikaidoh procedure entails aortic translocation with a biventricular outflow tract. It has gained popularity recently (2,3). The Nikaidoh procedure originally consisted of translocating the aortic root in a direct posterior fashion, involving the resectioning of the infundibular septum while leaving the coronary arteries in place. The RVOT is reconstructed with the largest possible quantity of autologous tissue to ensure some extent of growth potential. Conduit replacement may be required in cases where this procedure is impossible (4). Nikaidoh (3) subsequently described surgical modifications to the approach.

The most important advantage offered using the Nikaidoh procedure is that it provides a correction closer to normal anatomy. This reduces any risks of left ventricular outflow tract (LVOT) or RVOT obstruction and minimizes the rate of reoperation (5). This report was drafted to share our experiences with patients operated on with the Nikaidoh procedure because of the combination of TGA, PS, and VSD.

Technical Report

Before beginning these operations, it is of the utmost importance to establish a clear picture of the patient's cardiac anatomy, including full information about the following:

- Spatial relationships of great vessels,
- Location and size of the VSDs,
- Coronary anatomy,
- Pulmonary annulus size,
- Presence of any abnormal atrioventricular valve attachments,
- Size of the right ventricle (6).

The chest is entered via standard median sternotomy, and a large section of the pericardium is extracted to used to close the VSD and reconstruct the RVOT. The coronary anatomy is examined to ensure safe removal of the aortic root from the right ventricle, and the main PA and its branches are mobilized. Arterial cannulation is applied to all patients at the level of the proximal aortic arch to permit more effective aortic mobilization and bicaval cannulation is used to initiate cardiopulmonary bypass at 32 °C. The proximal right coronary artery and left main coronary arteries are released in the beating heart (Figure 1). To begin, a curvilinear incision is made in the anterior wall of the right ventricle, parallel to the aortic annulus, to facilitate proper visualization of the valve (Figure 2). Subsequently, the aortic root is dissected from the RV circumferentially. The size and location of the VSD are evaluated (Figure 3). The main PA is proximally transected while ensuring that its length is preserved. The posterior aspect of the aortic root is then sutured to the pulmonary annulus in the beating heart (Figure 4). Cross-clamping is applied to the aorta and antegrade custodial cardioplegia is induced. Via the right pulmonary vein, a left ventricular vent is inserted. The aorta was transected for the Le Compte maneuver (Figure 5).

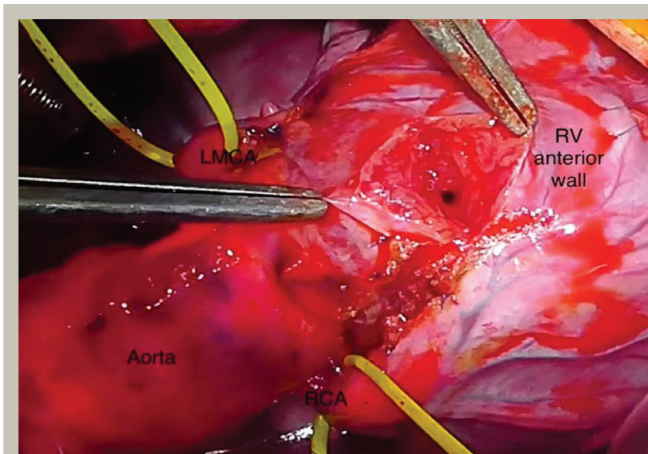

Figure 1. Proximal RCA and LMCA are released in the beating heart

LMCA: Left main coronary artery, RCA: Right coronary artery, RV: Right ventricle

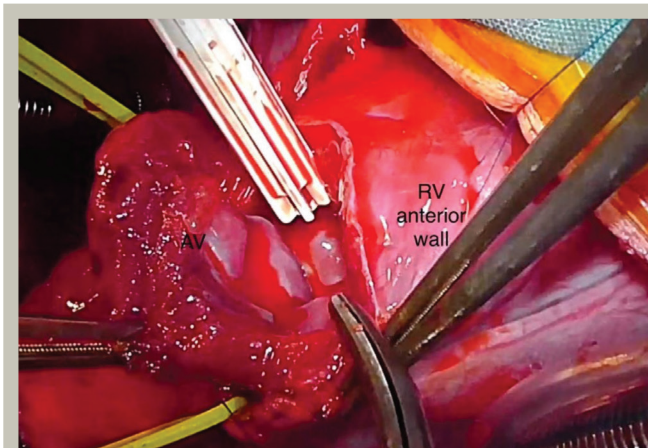

Figure 2. A curvilinear incision in the anterior wall of the RV was created to visualize the aortic valve

AV: Aortic valve, RV: Right ventricle

Figure 3. The size and location of the VSD is evaluated
VSD: Ventricular septal defect

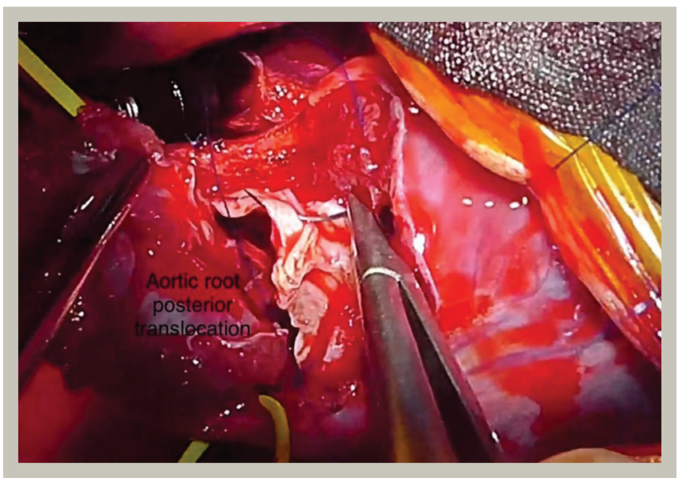

Figure 4. The posterior aspect of the aortic root is sutured to the pulmonary annulus in the beating heart

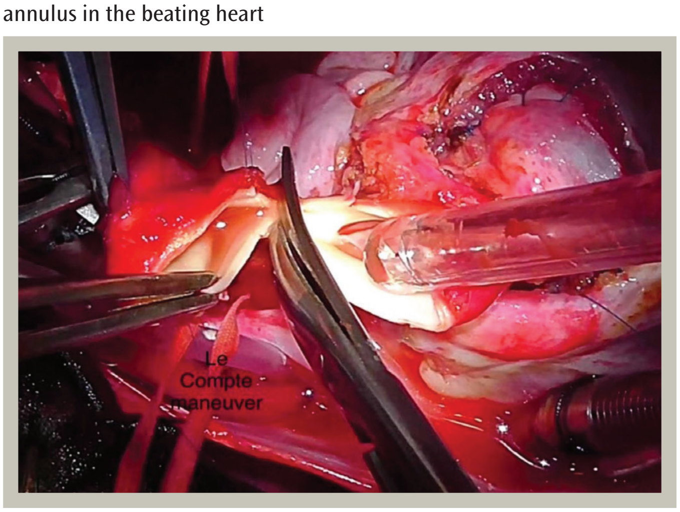

Figure 5. The aorta was transected for the Le Compte maneuver

The anterior aspect of the LVOT is subsequently repaired a running suture and a patch extending from the crest of the VSD to the aortic root (Figure 6). A segment of the ascending aorta of approximately 3-5 mm undergoes resectioning to avoid the posterior compression of the pulmonary arteries, and aortic anastomosis is performed, again with the application of a running suture. The anterior and posterior walls of the main PA are then reconstructed with autologous pericardium similar to the transannular patch approach used in cases of tetralogy of Fallot. RVOT reconstruction can be performed using an RV-PA conduit when a transannular patch is not suitable (Figure 7). When atrial septal defects are found to be present, they are closed via right atriotomy.The appearance at the end of the surgical procedure is shown in Figure 8.

Discussion

There is no consensus regarding the best surgical technique to be applied in cases of simultaneous TGA, PS, and VSD. Honjo et al. (7) defined the LVOT complexity score to standardize

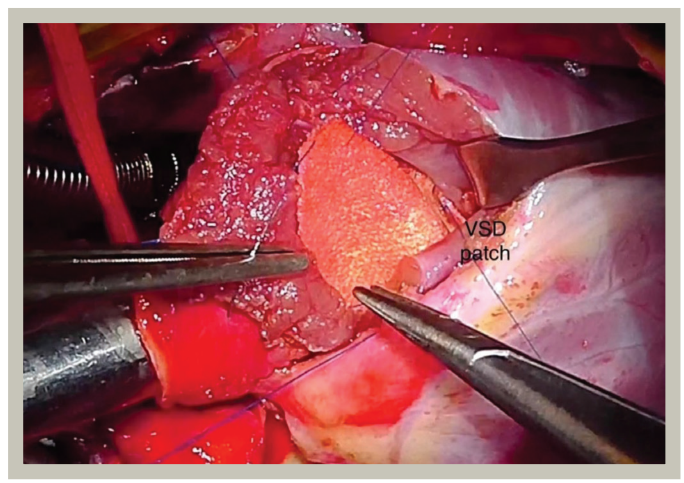

Figure 6. The anterior aspect of the LVOT is rebuilt with a patch that extends from the crest of the VSD up to the aortic root using running suture
VSD: Ventricular septal defect, LVOT: Left ventricular outflow tract

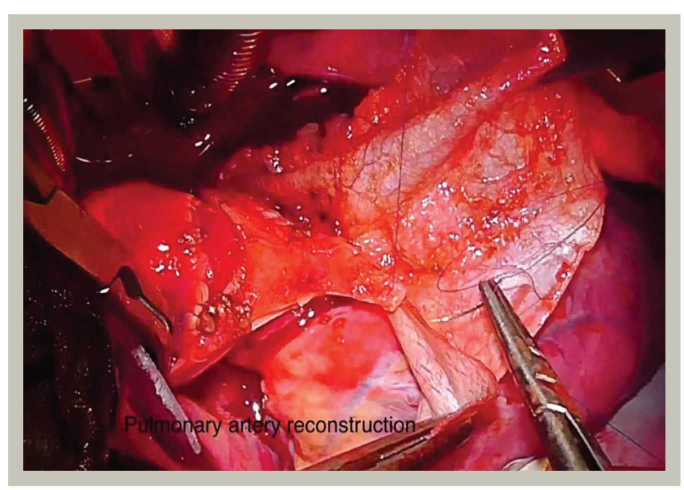

Figure 7. Pulmonary artery reconstruction with transannular patch

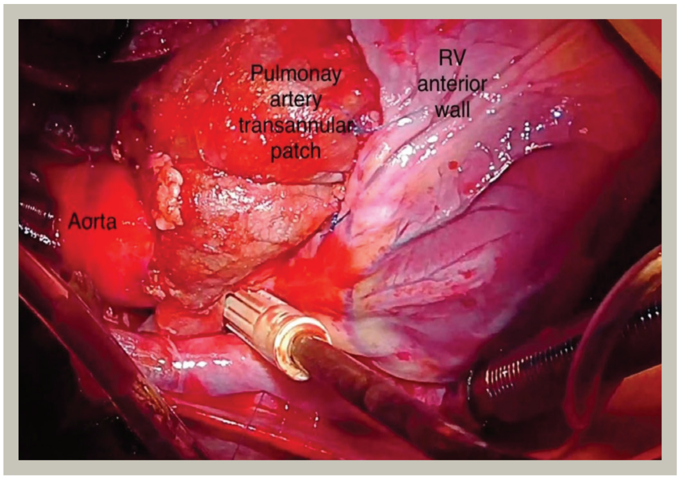

Figure 8. Appearance at the end of the surgical procedure

RV: Right ventricle

patient selection. With this scoring system, surgical decisions are made on the basis of echocardiography results and depending on the anatomical characteristics of the case. The absence of a double-outlet right ventricle, pulmonary valve dysplasia/hypoplasia, posterior infundibular septal deviations and degree of left ventricular infundibular fold obstruction, fibromuscular ridges, presence of septal hypertrophy, and atrioventricular valve overriding/straddling were all carefully evaluated. The Z-scores of the pulmonary valve and LVOT and the peak gradients are also considered. Each component is scored considering the extent of its contribution to the LVOT obstruction. Accordingly, it has been reported that the Nikaidoh procedure is probably a better choice for patients with LVOT complexity scores of >3 (7). In our clinic, we decide on surgical interventions by considering the patient's age, echocardiographic findings, aorta-PA relationship, structure of the VSD, and the expected anatomy after the formation of the intracardiac conduit.

Although the Nikaidoh procedure was first described in 1984, it had been performed for only 100 patients as of 2011 (8). One of the reasons why this surgical procedure is performed less commonly is its complexity. As their main theoretical advantages, the Nikaidoh procedure and its modified versions allow for the achievement of a more natural intracardiac geometry and RVOT reconstruction. An appropriate LVOT configuration reduces the risk of LVOT obstruction. Regardless of the VSD location and morphology, the Nikaidoh procedure can also be performed for patients with additional intracardiac malformations who have contraindications to the Rastelli procedure.

Furthermore, it is obvious that the Nikaidoh technique is superior in cases with smaller right ventricles. In the event of right ventricular hypoplasia, it may be possible to achieve a 1.5 ventricular repair by performing the Nikaidoh procedure in conjunction with the placement of a bidirectional Glenn shunt. If the aorta is seen to be remote from the left ventricle, the Rastelli procedure would necessitate a long intracardiac conduit but the Nikaidoh procedure would not. However, if the VSD is seen to be remote from the left ventricle or it is non-committed or insignificant, the Rastelli procedure becomes impossible, but biventricular repair can be performed using the Nikaidoh procedure (3). The Nikaidoh procedure can also be performed in cases of straddling mitral valves or straddling tricuspid valves (9).

In 2020, Agarwal and Vaidyanathan (10) described the prerequisites for performing the Nikaidoh procedure. The size of the pulmonary annulus and the translocation distance of the aorta are directly related to each other. Therefore, pulmonary atresia is a contraindication to the Nikaidoh procedure. Generally, the Nikaidoh procedure should be performed for patients with a pulmonary annulus diameter of 5 mm and above (10).

Another important point to consider is whether these operations are more appropriate at younger ages or in later years. Cyanosis is most often moderate and the surgical operation can be delayed. If cyanosis needs to be treated, a modified Blalock shunt might be the best choice (11). In our study, we performed m-BT shunt operations for 50% of the patients before applying the Nikaidoh procedure due to desaturation and PA hypoplasia.

Aortic translocation is a high-tech operation, and its most important part of it is the stabilization of the aortic valve and coronary arteries. Based on experience from Toronto, it was recommended to apply the Rastelli procedure in the presence of coronary anomalies (7). In a study conducted in 2018, Olds et al. (12) reported that coronary anomalies are not contraindications but require special maneuvers. For patients with posterior looping, it was recommended to mobilize the coronary arteries more and anastomose them more medially than otherwise expected using the trap-door technique. For patients with anterior looping, kinking is expected to be more prominent during reimplantation and the arteries should be anastomosed more distally. Partial reimplantation and rotation of the aortic root have been presented as other options (12). Chernogrivov et al. (13) recommended aortic translocation following the complete mobilization of the coronary arteries and the aortic root. In the first years of our clinical experience, the classical Nikaidoh technique was used. As our experience increased over the years, we began to prefer to perform coronary artery exploration and aortic root posterior translocation on beating hearts. In this way, posterior aortic anastomosis is performed in the beating heart, as well. This is intended to shorten the cross-clamp time and prevent coronary malpositioning. In this study, this technique was performed for 33.3% of patients. Cross-clamp times of these patients were significantly shorter than those of the others. None of them were found to have coronary malpositioning or aortic valve dysfunction. Although one of them had atrioventricular valve straddling, the technique could still be used successfully.

Early results of the Nikaidoh procedure are promising. It has a low early mortality rate that is reported to be 0%-5% (5,14). Its mortality rates in the late period were also found to be lower than those of the Rastelli or REV procedures. In the study by Kramer et al. (5), prolonged durations of aortic cross-clamping and cardiopulmonary bypass were reported to be associated with early mortality. The Rastelli procedure has been reported to be less risky for patients of advanced age with coronary anomalies, severe LV hypertrophy, and dysfunction (15).

In our study, one patient died in the early stage (16.6%). This patient was the one with the lowest body weight and the longest cross-clamp time in this study, weighing 8 kg and needing an RV-PA conduit. Hazelkamp et al. (1) reported that children weighing less than 10 kg are at higher surgical risk and that their reoperation rate is higher. Although this prevailing opinion in the literature is also dominant in our clinic, a surgical operation was planned due to desaturation and growth retardation for the patient who had a history of m-BT shunt operation. In our study, the cause of the higher mortality rate was thought to be associated with the small number of included patients.

It has been demonstrated in the literature that small PA diameters homografting, and body weight are critical determinants of the need for conduit replacement. If the standard deviation of the homograft from the Z-score is higher than 3, it is defined as excessively large, and placing an inappropriately large homograft increases the likelihood of duct bending and sternal compression (16). While this consideration is important for patients who have undergone anatomical repairs with Rastelli-type procedures, it is also relevant in the event of Bex-Nikaidoh procedures. Fiore et al. (16) indicated that the optimal Z-scores for pulmonary conduits in Rastelli-type/non-Ross operations range from +1 to +3. For some anatomical subtypes, the diameter of the implanted conduit is probably vital (17). According to another opinion, the use of an oversized conduit in the Nikaidoh procedure does not cause sternal decompression and can reduce the risk of reoperation (13). Raju et al. (17), in their study investigating the effect of the type of RVOT reconstruction, reported RV-PA conduit operations to be a risk factor for reoperation. In our study, the rate of reoperation was 20%. Reoperation was not required for any patient who underwent reconstruction with a transannular patch. One patient who underwent RV-PA conduit replacement needed reoperation 4 years later due to conduit degeneration. In our clinic, we think that the use of conduits should be avoided unless absolutely necessary.

Conclusion

The Nikaidoh procedure has been shown to be a good option in cases of complex TGA. It provides better anatomical correction. compared with the Rastelli and REV procedures, no difference was found in terms of early and mid-term mortality or reoperation. Coronary anomaly and AV valve straddling are not contraindications to the Nikaidoh procedure. Performing the aortic translocation procedure on a beating heart provides advantages both in terms of shortening the cross-clamp time and ensuring a proper configuration of the coronary arteries. These operations should preferably be performed with transannular patches for patients with body weights of more than 10 kg. RV-PA conduits are risk factors for reoperation.

Ethics

Informed Consent: Informed consent was obtained.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: B.Z.T.R., A.C.H., Concept: B.Z.T.R., A.C.H., Design: B.Z.T.R., A.C.H., Data Collection or Processing: B.Z.T.R., Analysis or Interpretation: B.Z.T.R., Literature Search: B.Z.T.R., Writing: B.Z.T.R.

Conflict of Interest: No conflict of interest was declared by the authors.

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