Options for coronary translocation and other considerations in aortic root translocation (Bex-Nikaidoh procedure)

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ABSTRACT

Introduction : **The surgical options for patients with transposition of the great arteries (TGA), ventricular septal defect (VSD), and left ventricular outflow tract obstruction include intracardiac baffling with the right ventricle to pulmonary artery (PA) conduit (Rastelli procedure), "*reparation a l'etage ventriculaire*" or aortic root translocation (Bex-Nikaidoh procedure). The Bex-Nikaidoh procedure allows a more normal, anatomically aligned left ventricular outflow tract. However, the operation is technically demanding, and coronary translocation remains one of the major challenges for successful root translocation.**

Methods : **All patients who underwent aortic root translocation in a single institute over a period of 2 years from January 2015 to December 2017 were included in the study. Surgical technique and early outcomes are described with specific focus on the different observed coronary artery patterns and surgical strategies for translocation.**

Results : **Fourteen patients underwent aortic root translocation. The coronary artery patterns observed could be categorized into four different patterns based on the size of the pulmonary annulus and the relative position of the PA relative to the aorta. Successful translocation of the coronary arteries was achieved in every patient. Mean follow-up was 18.42 ± 9.22 months. There was no mortality and no reoperation during the follow-up period.**

Conclusion : **The Bex-Nikaidoh procedure is a promising surgical option for TGA, VSD, and pulmonary stenosis. Good outcomes are achievable despite wide variations in anatomy using a tailored approach for coronary translocation.**

Keywords : Aortic root translocation, Nikaidoh procedure, transposition of the great arteries, ventricular outflow tract obstruction, ventricular septal defect

INTRODUCTION

The presence of left ventricular outflow tract obstruction (LVOTO) in patients with transposition of the great arteries (TGA) and ventricular septal defect (VSD) precludes the performance of the arterial switch operation. LVOTO frequently occurs at multiple levels and is progressive.[1]

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The Rastelli procedure (baffling of the VSD directing blood from the Left Ventricle [LV] to the aorta through the VSD and insertion of a right ventricle [RV] to pulmonary artery [PA] conduit) is the oldest operation described for surgically repairing TGA/VSD/LVOTO.[2]

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Previous studies have identified a high incidence of reinterventions and reoperation due to degeneration of the RV-PA conduit and baffle obstruction with suboptimal mid- and long-term results.[3-5] The "*reparation a l'etage ventriculaire*" (REV) (resection of the conal septum, VSD enlargement, baffling of the VSD directing blood from the LV to the aorta, and direct implantation of the PA on the RV) was introduced in 1981 in an attempt to overcome the limitations of the Rastelli procedure.[6] Previous studies have reported lower reintervention rates for LVOTO in patients undergoing the REV as compared to the Rastelli procedure.[7,8] As an alternative to the Rastelli procedure and REV, Bex in 1980 and later, Nikaidoh in 1984, introduced the concept of aortic root translocation.[9,10] This procedure allows for a more anatomically aligned LVOT. However, the operation is technically demanding and coronary translocation remains one of the major technical challenges for successful root translocation.[11]

In this report, we highlight several anatomic variations in coronary patterns encountered during our experience with the Bex-Nikaidoh procedure and describe various techniques for coronary translocation.

METHODS

All patients who underwent the Bex-Nikaidoh procedure for TGA/VSD/LVOTO at our institution between January 2015 and December 2017 were identified. Demographics, morphological and operative details, complications, and follow-up information were obtained from patients' medical records, hospital databases, and outpatient records from the referring cardiologist. Early mortality was defined as death within 30 days of surgery or within the same hospital admission.

Surgical technique

The decision to perform an aortic translocation was based on the age of the patient and the details of the cardiac anatomy, including echocardiographic findings, location and size of the VSD, coronary anatomy, and *z*-score of the pulmonary annulus. All procedures were performed using cardiopulmonary bypass at 28°C with aorto-bicaval cannulation. Antegrade cold blood cardioplegia (CP) solution was delivered initially into the aortic root followed by ostial CP. The pulmonary arteries were mobilized and the Lecompte maneuver was performed in all patients. All the VSDs were closed with bovine pericardium. We prefer to close even shallow VSD using a patch as this ensures that both, the aortic and neo-pulmonary roots are in the same plane. Right ventricle to PA continuity was established using the bovine jugular vein conduit (Contegra®, Medtronic, Minneapolis, USA).

The different anatomical subsets noted and the method of coronary translocation in each subset is given below:

Subset 1

Aorta situated anterior to main pulmonary artery, pulmonary valve annulus z-score ≤−2 moderate-severe hypoplasia of the PV annulus [Figure 1a].

In this subset, the patients were diagnosed with d-TGA, VSD, and severe PS with an anteroposterior relationship of the great arteries. The z-score of the pulmonary valve (PV) was $z = -2$ or less. These patients have minimal posterior displacement of the aortic root and only partial mobilization of aortic root was performed leaving a pedicle of myocardium under the left main coronary artery. This simplifies the operative steps and minimizes the risk of bleeding. The right coronary artery (RCA) was harvested and successfully re-implanted in the same location. One other option is mobilization of the coronary arteries without detachment, especially when the conal tissue between aortic and pulmonary root is thin.

Subset 2

Aorta situated anterior to the main pulmonary artery, pulmonary valve annulus z-score >−2 (mild hypoplasia of the pulmonary valve annulus) [Figure 1b].

This subset comprises those patients who were diagnosed with d-TGA, VSD, and severe PS with an anteroposterior relationship of the great arteries. The PV annulus is moderately hypoplastic but not amenable to ASO and LVOT resection. In this subset, more posterior displacement of the aortic root is required. Both the coronary buttons were harvested. The aortic root was rotated 180° during posterior translocation to facilitate more anatomical coronary reimplantation.

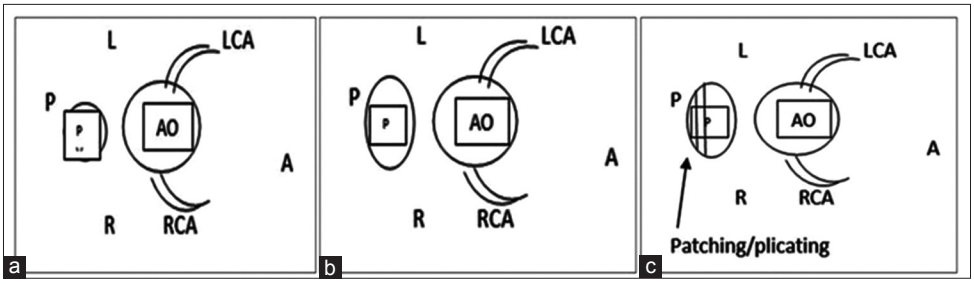

Figure 1: (a-c) Representation of operative modifications in patients with D Transposition Of Great Arteries (DTGA) ventricular septal defect Pulmonary Stenosis (PS). A: Anterior, AO: Aorta, L: Left, LCA: Left circumflex artery, P: Posterior, R: Right, RCA: Right circumflex artery

One option to avoid significant post displacement of aortic root due to the large pulmonary annulus is to plicate the posterior wall of the pulmonary annulus valve effectively reducing it to a hypoplastic PV [Figure 1c]. This converts the anatomy to subset 1 and obviates the need for 180° rotation of the aortic root and coronary button harvesting/reimplantation.

These subsets may be suitable for a half-turned truncal switch or double root translocation, especially if the PV cusps are not dysplastic.

Subset 3

Aorta situated anterior and to the left of the main pulmonary artery, pulmonary valve annulus z-score >−2) (mild hypoplasia of the pulmonary valve annulus) [Figure 2a].

In this subset, the patients were diagnosed with Double outlet right ventricle, VSD, and severe PS with L-transposition of the aorta and a hypoplastic PV. In order to translocate the aorta posteriorly, harvesting of both coronary buttons are required. Aortic translocation is not technically possible with only coronary mobilization as the aortic root not only has to be translocated posteriorly but also shifted to the right at the same time. Depending on the anatomy, one or both coronary may need to be reimplanted into a new position in the sinus after closing the original coronary button harvest site with bovine pericardium. The left coronary artery often requires extensive mobilization to facilitate reimplantation without tension, as the aortic root moves posteriorly and rightward.

Subset 4

Aorta situated anterior and to the right of the main pulmonary artery, pulmonary valve annulus z-score >−2 (mild hypoplasia of the pulmonary valve annulus) [Figure 2b].

In this subset, patients were diagnosed with DORV, VSD, severe PS and a hypoplastic PV. There was a side-by-side arrangement of the great arteries with the aorta situated to the right and PV to the left. The surgical principles used are similar to subset 3, but in these patients, it is the RCA that requires extensive mobilization.

In any of the subsets described above, if there appears to be excessive tension on the coronary anastomosis, we proceed with detachment of the coronary button. The defect in the sinus is closed with a redundant patch of autologous pericardium, thereby extending the sinus. An aortic punch is used to create an opening in the patch to which the coronary button is reimplanted without tension.

RESULTS

A total of 14 patients underwent posterior aortic root translocation at our institute. There was no early mortality. Baseline characteristics, perioperative details, and complications are given in Tables 1-3. Thirteen patients had normal sinus rhythm postoperatively. One patient had complete heart block in the immediate postoperative period and a permanent pacemaker was inserted. At 1-year follow-up, the child was noted to have normal sinus rhythm. The mean follow-up was 18.42 ± 9.22 months (range 10–46 months). Recurrence of mild Right ventricular outflow tract obstruction (peak echocardiographic gradient of ≥25 mm Hg and mild aortic regurgitation was observed in 2 out of 14 (14.3%) patients. LVOTO and left ventricular (LV) dysfunction was not observed in any patient. All patients were alive at last follow-up.

Table 1: Baseline characteristics of the patients undergoing the Bex-Nikaidoh procedure

Variable	Description	*n* (%)
Gender	Females	10 (71.42)
	Males	4 (28.58)
Type of VSD	Inlet (including perimembranous and subaortic types)	12 (85.71)
	Muscular	2 (14.28)
Rhythm	CHB	1 (7.14)
	NSR	13 (92.86)
Variable		**Mean±SD**
Age (months)		57.92±48.74
Height (cm)		99.71±30.25
Weight (kg)		15.07±10.95

CHB: Complete heart block, NSR: Normal sinus rhythm, VSD: Ventricular septal defect, SD: Standard deviation

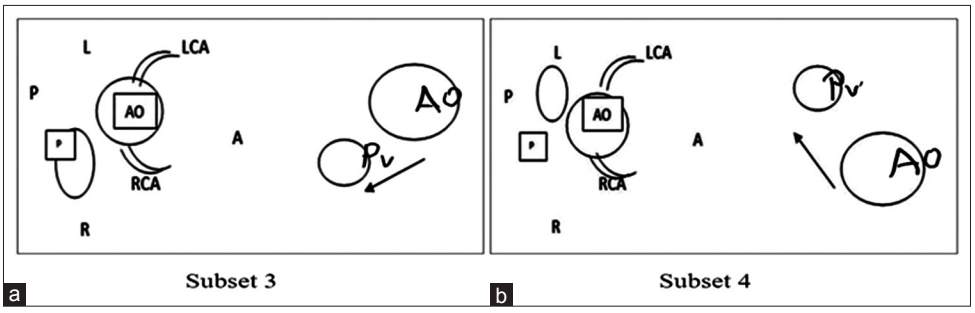

Figure 2: (a and b) Representation of operative modifications in patients with Double outlet right ventricle (DORV) ventricular septal defect Pulmonary stenosis (PS). A: Anterior, AO: Aorta, L: Left, LCA: Left circumflex artery, P: Posterior, R: Right, RCA: Right circumflex artery, PV: Pulmonary value

DISCUSSION

Aortic root translocation (Bex-Nikaidoh procedure) was introduced in 1980 by Bex and popularized by Nikaidoh in 1984 as an alternative to the REV and Rastelli procedures.[9,10] The advantages of the Nikaidoh procedure include a straight-line connection between the LV and aorta, much less reduction in RV volume and the placement of an RV-PA conduit in an orthotopic position.[12] However, the procedure is technically demanding, with risks of destabilizing the aortic valve and/or kinking/compressing the proximal coronary arteries.[13]

The right ventricular outflow tract can be reconstructed using a conduit or transannular patch. Raju *et al.* from Boston reported their outcomes comparing the two options in 2015 and suggested that the use of a transannular patch had early outcomes comparable to valved conduits, with a trend for fewer late reoperations during follow-up.[13] Other studies have shown a similar incidence of reoperation with both options, either for conduit failure or progressive pulmonary regurgitation.[14,15]

The Bex-Nikaidoh procedure was modified by Hu *et al.* to address potential limitations of a RV-PA conduit or a transannular patch.[16] The modification involved preserving the native PV to minimize postoperative pulmonary insufficiency. This could potentially allow growth of the pulmonary root and therefore decrease the need for reoperation. Other modifications include the Ross-switch-Konno procedure as described by Bautista-Hernandez *et al.*[17]

As the Bex-Nikaidoh procedure gains further acceptance, the results have continued to improve. Table 4 gives a brief description of the larger series reported more recently.

Similar to other studies our mid-term results demonstrated no recurrence of LVOTO.[19] Left ventricular function was preserved in all patients. Mild aortic regurgitation occurred in one patient which is similar to previous reports.[15] This is at variance with a report from Villalba *et al.* in which aortic regurgitation was reported as a nonsignificant event.[19]

The survival in our series is similar to the report from Bautista-Hernandez *et al.* who demonstrated 100% survival with a modified Nikaidoh procedure in 11 patients thought the follow up in our series is shorter (mean 18.4 months vs. mean 59 months).[17]

Honjo *et al.* in their analysis of 28 patients who underwent the Nikaidoh procedure at their institute noted the importance of the arrangement of the coronary arteries in the decision-making between the Nikaidoh procedure and the Rastelli operation.[20] We agree with their assessment that anterior looping of a coronary artery makes mobilization of the aortic root difficult and poses a significant risk of tension on the coronary artery after translocation. We would perform the Nikaidoh procedure when faced with this type of coronary distribution. In their opinion, the presence of a single coronary system represented a relative contraindication for the Nikaidoh procedure. In our opinion, it may be possible to translocate a single coronary artery using one of the techniques we have described though other factors such as the size of the PV annulus and the relationship of the great arteries must also be taken into consideration before deciding on the final surgical strategy.

Table 2: Intraoperative characteristics

Variable	Types	*n* (%)
Coronary harvested	Both	7 (50)
	Single	7 (50)
Position of aorta relative to PA	Towards left	2 (14.28)
	Towards right	12 (85.71)
Chest open	No	8 (57.14)
	Yes	6 (42.85)
Variable		**Mean±SD**
CPB time (min)		235.07±42.51
Cross clamp time (min)		176.50±42.67
Minimum temperature on CPB (degrees Celsius)		27.25±2.36
Duration of intubation (h)		39.14±19.43
ICU stay (days)		5.35±1.27

CPB: Cardiopulmonary bypass, ICU: Intensive care unit, SD: Standard deviation, PA: Pulmonary artery

Table 3: Postoperative complications

Complications	*n* (%)
Reintubation	1 (7.1)
Bleeding	4 (28.6)
Pleural effusion	4 (28.6)

CONCLUSION

The modified Nikaidoh procedure is a promising surgical option for TGA, VSD, and pulmonary stenosis. Good

Table 4: Recent series describing outcomes after aortic root translocation

Author	Year	Number of patients	Median follow-up (months)	Median age (years)	Mean weight	Early mortality	Late mortality	Reintervention
Morell *et al.*[14]	2005	12	33	2	NA	1	0	4 (on 3 patients)
Yeh *et al.*[15]	2007	19	136	3.3	16.1	1	0	7 (on 5 patients)
Hu *et al.*[16]	2007	4	5.5	6	NA	0	0	0
Kramer *et al.*[18]	2014	21	27.6	0.8	9.6	2	1	2
Raju *et al.*[13]	2015	32	20.8	0.6	7.7	1	0	14

NA: Not available

outcomes are achievable despite wide variations in anatomy using a tailored approach for coronary translocation. Further evaluation of these approaches is necessary in larger number of patients with longer follow-up.

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Conflicts of interest

There are no conflicts of interest.

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