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Comparison for Long-Term Results of the Modified Réparation à l´étage Ventriculaire and Rastelli Repair

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Abstract

Background: This study aimed to compare the long-term outcomes of a modified réparation à l'étage ventriculaire (REV) and the Rastelli repair for ventricular septal defect (VSD) and pulmonary outflow tract obstruction without ventriculoarterial concordance. **Methods**: The study included 100 consecutive patients who underwent a modified REV ($n = 50$) or Rastelli repair ($n = 50$) for transposition of the great arteries, double outlet right ventricle, or double outlet left ventricle with VSD and pulmonary outflow tract obstruction. The mean ages of the patients who underwent the modified REV and Rastelli repair were 2.50 years (range: 0.30-12.48) and 5.91 years (range: 0.36-46.15), respectively ($P < .05$). **Results**: Actuarial survival and arrhythmia-free survival rates were 83.4% ± 4.0% ($P > .05$) and 72.4% ± 5.0%, respectively at 37.25 years ($P > .05$). The reoperation-free survival was 18.7% ± 4.6% at 31.82 years ($P < .05$). The freedom from the first, second, third, and fourth reoperations after the modified REV versus the Rastelli repair was 35.9% ± 8.3% at 29.8 years versus 6.7% ± 4.3% at 31.8 years ($P < .05$); 83.2%±6.3% at 29.8 years versus 21.2% ± 15.6% at 35.8 years ($P < .05$); 94.1% ± 4.1% at 29.8 years versus 56.1% ± 10.9% at 37.3 years ($P < .05$); and 97.0% ± 3.0% at 29.8 years versus 74.3% ± 10.2% at 37.3 years ($P < .05$), respectively. The most common causes of reoperation after the Rastelli repair were pulmonary stenosis, left ventricular outflow tract obstruction, and arrhythmia. However, the most common cause of reoperation after the modified REV was pulmonary regurgitation. **Conclusion**: Modified REV and Rastelli repair have shown satisfactory results in long-term follow-up. However, the Rastelli repair could not avoid repeated reoperations, especially for biventricular outflow tract obstruction and arrhythmia.

Keywords

ventriculoarterial discordance, ventricular septal defect, pulmonary stenosis, modified REV (réparation à l'étage ventriculaire), Rastelli repair

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Introduction

Surgical treatments for ventricular septal defect (VSD) with pulmonary stenosis (PS) or pulmonary atresia (PA) without ventriculoarterial (VA) concordance, including transposition of the great arteries (TGA), double-outlet right ventricle (DORV), double-outlet left ventricle (DOLV), and Taussig-Bing anomaly, have advanced dramatically over the past 50 years.[1,2]

The Rastelli operation, which involves baffling the VSD to the aorta and connecting the right ventricle (RV) to the pulmonary arteries via a valved conduit, has historically been considered the procedure of choice.[1] However, a small or remote VSD and the presence of tricuspid valve straddling or abnormal attachment of the tricuspid chordae to the conal septum are limiting factors and risk factors for mortality. For RV–pulmonary artery connections, the availability of homografts is limited, and the durability of xenografts is disappointing, especially in small infants. The timing of surgery is usually delayed due to the desire for a larger conduit with enhanced durability, and multiple reoperations for conduit changes are inevitable.[1,3–5]

To overcome these limitations, the REV procedure creates a connection from the left ventricle (LV) to the aorta with greater freedom from residual obstruction due to resection of the outlet septum, which avoids the spiral shaped LV-to-aorta tunnel. With this surgical approach, the size of the VSD and the abnormal attachment of the tricuspid chordae to the conal septum are not limiting factors. The pulmonary trunk is reimplanted directly into the RV instead of using anextracardiac valved conduit.[2] We modified the REV procedure by not using the Lecompte maneuver, and reported the results for this modified réparation à l'étage ventriculaire (REV).[6–9]

Currently, to our knowledge, no clear evidence of the superiority of one operation over the other based on long-term

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outcomes has been reported. Therefore, this study aimed to compare the long-term outcomes of the modified REV and Rastelli repair in VSD with PS or PA without ventriculoarterial concordance.

Patients and Methods

Patients' Profile

We collected the clinical data of patients with VSD, and PS without ventriculoarterial concordance who underwent our modification of the REV procedure ($n = 50$) or the Rastelli repair ($n = 50$) from July 1979 to February 2016 at our center.

Data on patient demographics, perioperative information, and associated outcomes were obtained from electronic medical records. The present study was approved by the Institutional Review Board of Seoul National University Hospital (2102-175-1200), and the need for patient consent was waived due to its retrospective nature.

The male-to-female ratios were 27:23 and 32:18 in the REV and Rastelli groups, respectively ($P > .05$). The age at operation ranged from 0.30 to 12.48 years (mean 2.50 ± 2.06 years) in the REV group, and from 0.36 to 46.15 years (mean 5.91 ± 8.28 years) in the Rastelli group. The patients in the REV group were younger than those in the Rastelli group ($P < .05$). Body weight at operation ranged from 5.7 to 35 kg (mean 11.22 ± 4.80 kg) in the REV group and from 5.9 to 55 kg (mean 16.53 ± 11.73 kg) in the Rastelli group. The weight of the patients in the REV group was lower than those of the patients in the Rastelli group ($P < .05$). The follow-up duration was 19.22 ± 10.03 years (range 0.15-29.81) in the REV group, and 16.41 ± 9.58 years (range 0.72-37.25) in the Rastelli group ($P > .05$) (Table 1).

Preoperative diagnoses included TGA, VSD with PS or PA in 33 (66%) in the REV group, and 23 (46%) in the Rastelli group, double outlet RV, VSD with PS or PA in 15 (30%) in the REV group, and 25 (50%) in the Rastelli group, double outlet LV, VSD with PS in 1 (2%) in the REV group, and 1 (2%) in the Rastelli group, TGA, atrioventricular septal defect (AVSD) with PS in 1 (2%) in the REV group, and double outlet RV, AVSD with PS in 1 (2%) in the Rastelli group) (Table 2).

Previous palliations were performed in 26 and 37 patients in the REV and Rastelli groups, respectively. A Blalock-Taussig-Thomas shunt or central shunt was performed in 24 and 29 patients in the REV and Rastelli groups, respectively. Atrial septostomy or septectomy was performed in 4 patients in the REV group and 5 in the Rastelli group. Palliative RV-to-pulmonary artery connection was performed in 5 patients in the Rastelli group. Infundibulectomy was performed in 2 patients in the Rastelli group. Palliative Mustard operation was performed in 1 patient in the Rastelli group. The mean time interval from the first palliation to definitive repair was 1.98 ± 1.06 years (0.01 to 4.54 years) in the REV group and 4.09 ± 7.47 years (0.40 to 39.11 years) in the Rastelli group ($P < .05$) (Table 3).

Table 1. Patient Profile.

	REV ($n = 50$)	Rastelli ($n = 50$)
Male:female	27:23	32:18
Age at operation	2.50 ± 2.06 years (range: 0.30-12.48)	5.91 ± 8.28 years (range: 0.36-46.15)
Body weight at operation	11.22 ± 4.80 kg (range: 5.7-35)	16.53 ± 11.73 kg (range: 5.9-55)
Follow-up duration	19.22 ± 10.03 years (range: 0.15-29.81)	16.41 ± 9.58 years (range: 0.72-37.25)

REV, réparation à l'étage ventriculaire.

Table 2. Disease Entities.

	REV ($n = 50$)	Rastelli ($n = 50$)
TGA, VSD with PS or PA	33 (66%)	23 (46%)
TGA, AVSD with PS	1 (2%)	0 (0%)
DORV, VSD with PS or PA	15 (30%)	25 (50%)
DORV, AVSD with PS	0 (0%)	1 (2%)
DOLV, VSD with PS	1 (2%)	1 (2%)

Abbreviations: AVSD, atrioventricular septal defect; DOLV, double outlet left ventricle; DORV, double outlet right ventricle; PA, pulmonary atresia; PS, pulmonary stenosis; REV, réparation à l'étage ventriculaire; TGA, transposition of the great arteries; VSD, ventricular septal defect;

Table 3. Previous Palliations.

Previous palliation	REV	Rastelli
BTT shunt or central shunt	24	29
Atrial septostomy or septectomy	4	5
RV–PA connection		5
Infundibulectomy		2
Palliative Mustard operation		1
Total	26/50	37/50
Interval from the first palliation to complete repair	1.98 ± 1.06 years (range: 0.01-4.54)	4.09 ± 7.47 years (range: 0.40-39.11)

Abbreviations: BTT, Blalock-Taussig-Thomas; PA, pulmonary artery; REV, réparation à l'étage ventriculaire; RV, right ventricle

Surgical Procedures

Fifty patients underwent complete repair with ourmodification of the REV procedure, whereas 50 patients underwent the Rastelli operation.

The choice between these two options was dictated by anatomic conditions. We preferred the Rastelli procedure for pulmonary artery distortion, multiple pulmonary artery stenosis, hypoplastic pulmonary artery, or elevated pulmonary vascular resistance, and the REV for favorable anatomy or early age. The presence of branch pulmonary artery stenosis, in combination with free pulmonary regurgitation (PR), may lead to severe postoperative right ventricular failure. Therefore, the REV is preferred for patients with a relatively sizable pulmonary artery in dextro-TGA, or for patients with side-by-side great vessels.

Modified Réparation à l'étage Ventriculaire (REV). We have previously detailed the technical aspects of the modified REV in detail for different anatomical variations in VA discordance, VSD, and PS.[6,7,9] The VSD was baffled from the LV to the aorta after the conal septum was resected, and the VSD was also extended, which enlarged even a small restrictive VSD and constructed a wider and straighter left ventricular outflow tract (LVOT). In cases involving abnormal insertion of the tricuspid tensor apparatus, we transferred them to the right side of the patch after division. The branches of the pulmonary artery were dissected and mobilized sufficiently beyond the pericardial reflection for a tension-free anastomosis between the RV and pulmonary artery. The Lecompte maneuver[10] was not applied by sufficient dissection until the hilar portion of the pulmonary artery since the pulmonary bifurcation was located orthotopically posterior to the ascending aorta. We simplified the procedure and reduced the risk of bleeding by avoiding transection of the aorta and reanastomosis. Right translocation of the main pulmonary trunk was performed in 9 patients, depending on the initial position of the great arteries. The right ventricular outflow tract (RVOT) was reconstructed using an anterior patch after the monocusp valve was inserted along the margin of the ventriculotomy. The mean cardiopulmonary bypass time for these patients was 189.6 ± 75.4 min and mean aortic crossclamp time was 93.3 ± 36.3 min.

Rastelli Procedure. All the procedures were performed using conventional extracorporeal circulation techniques. The mean cardiopulmonary bypass time was 225.8 ± 84.1 min and mean aortic crossclamp time was 105.6 ± 42.6 min. In cases involving abnormal insertion of the tricuspid tensor apparatus, we transferred them to the right side of the patch after division. Heterograft valved conduits were used in 36 patients, artificial valved conduits in 10, and homograft valved conduits in 4 to reconstruct the pulmonary ventricular outflow tracts. Proximal anastomosis was supplemented in some patients with a patch to make the conduit curvature smooth.

Statistical Analysis

Statistical analyses were performed using the SPSS software (version 29.0; SPSS, Inc., Chicago, IL). All descriptive data are expressed as means ± standard deviations, and significance was set at $P < .05$. The significance of differences between 2 groups was assessed using the unpaired Student's t-test, x-square test, or Fisher's exact test. Estimated survival and freedom from events, including arrhythmia and reoperation, were determined using the Kaplan-Meier method. Differences between the groups were evaluated using the log-rank test. Variables were evaluated by using the likelihood ratio test in the Cox proportional hazards regression model. The follow-up status of patients was determined by retrospective review of hospital records or by telephone interviews.

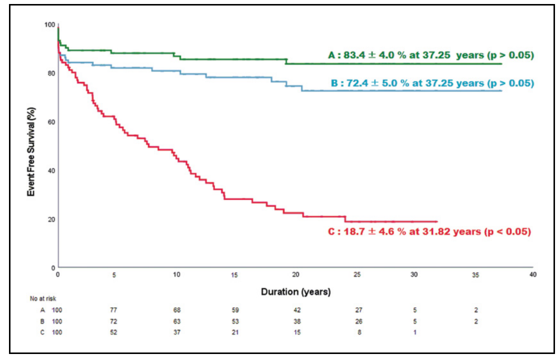

Figure 1. Probability of survival for all patients (n=100): (A), arrhythmia-free survival (B), reoperation-free survival (C) in all (n = 100). The actuarial survival and arrhythmia-free survival rates were 83.4% ± 4.0% ($P > .05$) and 72.4% ± 5.0%, respectively at 37.25 years ($P > .05$). The reoperation-free survival was 18.7% ± 4.6% at 31.82 years ($P < .05$).

Results

The actuarial survival was 83.4% ± 4.0% ($P > .05$) (Figure 1). In the REV group, 2 early and 4 late deaths occurred. The cause of death included low cardiac output syndrome in 3 patients, infection in 2, and unknown etiology in 1. Five early deaths and 4 late deaths were recorded in the Rastelli group. The cause of death included low cardiac output syndrome in 6 patients, infection in 1, intracranial hemorrhage in 1, and unknown etiology in 1.

The arrhythmia-free survival and reoperation-free survival rates were 72.4% ± 5.0% at 30 years ($P > .05$) and 18.7% ± 4.6% at 30 years ($P < .05$) (Figure 1). The freedom from the first reoperation after REV versus Rastelli repair was 35.9% ± 8.3% at 29.8 years versus 6.7% ± 4.3% at 31.8 years ($P < .05$) (Figure 2). The freedom from the second reoperation after the REV procedure versus Rastelli repair was 83.2% ± 6.3% at 29.8 years versus 21.2% ± 15.6% at 35.8 years ($P <$ .05) (Figure 3). The freedom from the third reoperation after REV versus Rastelli repair was 94.1% ± 4.1% at 29.8 years versus 56.1% ± 10.9% at 37.3 years ($P < .05$) (Figure 4). The freedom from the fourth reoperation after REV versus Rastelli repair was 97.0% ± 3.0% at 29.8 years versus 74.3% ± 10.2% at 37.3 years ($P < .05$) (Figure 5). In multivariate analysis, aortic cross-clamp time was a statistically significant risk factor for mortality, and the Rastelli procedure was a statistically significant risk factor for reoperation.

The reasons and frequency of reoperations are listed in Table 4. Fifty-two of 100 patients (52%) required 81 reoperations for PS. Reoperation for PS was required in 35 patients after the Rastelli repair and in 17 patients after the REV. Reoperation for PS was required in 2.06 times more patients after the Rastelli repair than after the REV (odds ratio, 4.53; $P = .001$). Reoperations for PS were required 3.05 times more after Rastelli repair ($n = 61$) than after the REV ($n = 20$).

Sixteen of 100 patients (16%) required 17 reoperations for LVOT obstruction. Reoperation for LVOT obstruction was

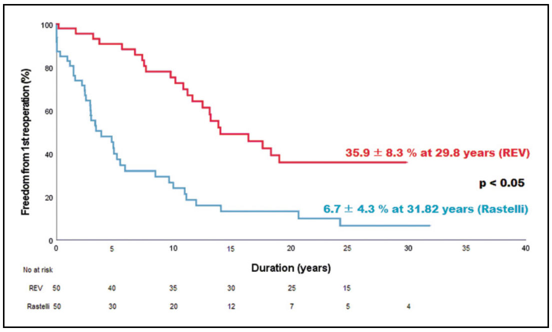

Figure 2. Freedom from the first reoperation after the modified REV versus Rastelli repair was 35.9% ± 8.3% at 29.8 years versus 6.7% ± 4.3% at 31.8 years ($P < .05$).
REV, réparation à l'étage ventriculaire.

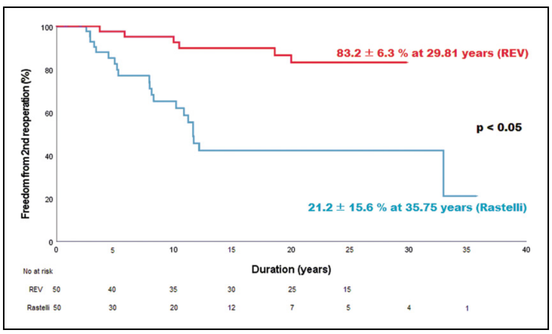

Figure 3. Freedom from the second reoperation after the modified REV versus Rastelli repair was 83.2% ± 6.3% at 29.8 years versus 21.2% ± 15.6% at 35.8 years ($P < .05$).
REV, réparation à l'étage ventriculaire.

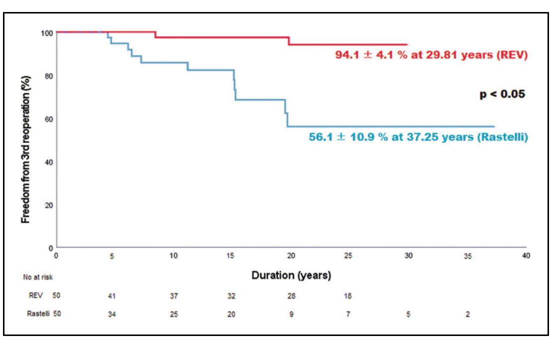

Figure 4. Freedom from the third reoperation after the modified REV versus Rastelli repair was 94.1% ± 4.1% at 29.8 years versus 56.1% ± 10.9% at 37.3 years ($P < .05$).
REV, réparation à l'étage ventriculaire.

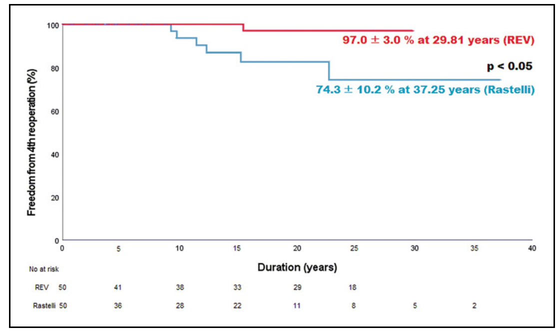

Figure 5. Freedom from the fourth reoperation after the modified REV versus Rastelli repair was 97.0% ± 3.0% at 29.8 years versus 74.3% ± 10.2% at 37.3 years ($P < .05$).
REV, réparation à l'étage ventriculaire.

required in 12 patients after the Rastelli repair and in 4 patients after the REV. Reoperation for LVOT obstruction was required in 3 times more patients after the Rastelli repair than after the REV (odds ratio, 3.63; $P = .029$). Reoperations for LVOT obstruction were required 3.25 times more after the Rastelli repair ($n = 13$) than after the REV ($n = 4$).

Eight of 100 patients (8%) required 18 reoperations for arrhythmias. Reoperation for arrhythmia was required in 6 patients for atrioventricular block ($n = 4$) and sinus node dysfunction ($n = 2$) after Rastelli repair, and in 2 patients for atrioventricular block after the REV. Reoperation for arrhythmia was required in 3 times more patients after the Rastelli repair than after the REV (odds ratio, 3.27; $P = .269$). Reoperations for arrhythmia were required 2.6 times more after the Rastelli repair ($n = 13$) than after the REV ($n = 5$).

Eleven of 100 patients (11%) required 12 reoperations for residual VSD. Reoperation for VSD was required in 6 patients after the Rastelli repair and in 5 patients after the REV (odds ratio, 1.23; $P = .749$). Reoperation for pulmonary regurgitation was required more frequently after REV ($n = 7$) than after the Rastelli repair ($n = 0$) ($P = .012$).

Five of 100 patients (5%) required 7 reoperations for aortic regurgitation (AR) ($P = .362$). Four of 100 patients (4%) required 6 reoperations for tricuspid regurgitation ($P = 1.000$). Four patients (4%) required 5 reoperations for endocarditis ($P = .617$). Three patients (3%) required 5 reoperations for mitral regurgitation ($p = 1.000$). Two patients (2%) required 2 reoperations for residual atrial septal defect ($P = .495$). One patient (1%) required 1 reoperation for tricuspid stenosis ($P = 1.000$). One patient (1%) required 1 reoperation for mitral stenosis ($P = 1.000$). Four patients required 4 reoperations for other causes, including foreign body removal ($n = 1$), diaphragmatic plication ($n = 2$), and ligation of major aortopulmonary collateral artery ($n = 1$) ($P = .117$).

At last follow-up, 42 survivors are in New York Heart Association (NYHA) Class I and 2 in NYHA Class II for the REV procedure, and 38 in NYHA Class I and 3 in NYHA Class II ifor the Rastelli procedure ($P > .05$). On Doppler echocardiography, LV ejection fraction was 59.89% ± 7.96% in REV, and 58.16% ± 10.46% in the Rastelli procedure ($P > .05$). On cardiac catheterization, LV end-diastolic pressure was 10.16 ± 3.14mm Hg for REV, and 11.92 ± 4.42mm Hg for the Rastelli procedure ($P > .05$), and RV end-diastolic pressure was 9.57 ± 3.33mm Hg for REV, and 11.15 ± 3.17mm Hg for the Rastelli procedure ($P > .05$). On cardiopulmonary exercise test, maximal oxygen consumption (normal >30 mL/kg/min) was 27.91 ± 6.42 mL/kg/min for REV, and 27.05 ± 7.80 mL/kg/min for the Rastelli procedure ($P > .05$).

Table 4. The Cause of Reoperations.

Cause of reoperation	REV (*n* = 50)	Rastelli (*n* = 50)	Total (*n* = 100)	*P*-value
Pulmonary stenosis	17 (20)	35 (61)	52 (81)	.001
Left ventricular outflow tract obstruction	4	12 (13)	16(17)	.029
Arrhythmia	2 (5)	6 (13)	8(18)	.269
Ventricular septal defect	5 (6)	6	11 (12)	.749
Pulmonary regurgitation	7	0	7	.012
Aortic regurgitation	1	4 (6)	5 (7)	.362
Tricuspid regurgitation	2	2 (4)	4 (6)	1.000
Endocarditis	1 (2)	3	4 (5)	.617
Mitral regurgitation	2 (3)	1 (2)	3(5)	1.000
Atrial septal defect	0	2	2	.495
Ascending aorta dilatation	0	2	2	.495
Tricuspid stenosis	0	1	1	1.000
Mitral stenosis	1	0	1	1.000
Others	0	4	4	.117
No of reoperations [No of causes]	32 [51]	78 [117]	110 [168]	

The number in parentheses means the total number of reoperations for the same cause.
Abbreviations: REV, réparation à l'étage ventriculaire

Discussion

Surgical techniques for the correction of VA discordance, VSD, and PS were introduced into clinical practice more than 5 decades ago. However, the optimal surgical strategy remains controversial.[11–13] Specific anatomical and pathological findings need to guide decision-making surrounding procedural selection,[13–15] and the surgical option needs to be selected based on the features of the respective procedures, as well as the surgeon's and institutional experience and preference.[13,16,17] The main reason for the difficulties in providing a universal concept is the distinct heterogeneity of the underlying pathology regarding the size and location of the VSD, the coronary anatomy, and the degree and anatomic substrate of LVOT obstruction.[12,18]

Although the Rastelli operation has been the most widely performed surgical procedure in recent decades, several studies have shown its suboptimal long-term prognosis.[3,11] The Rastelli operation renders the need for reoperation across the patient's lifetime for conduit obstruction, LVOT obstruction at the level of the VSD or interventricular tunnel, and arrhythmia, including sinus dysfunction and atrioventricular block.[12,13] With the REV procedure, a conduit is avoided; however, the resulting free PR does not eliminate the need for reoperation.[13] The long-term surgical results at our institution revealed the unique advantages and disadvantages of the respective procedures.

Recently, the Rastelli operation has been reported to offer excellent mid- to long-term survival[17,19,20] and be performed in the current era with an early mortality rate of approximately 0% and a 20-year survival that exceeds 70%.[21] The REV procedure showed excellent long-term survival in terms of VA discordance, VSD, and PS, and the long-term performance of the reconstructed LVOT and RVOT was satisfactory.[11,15,17,20] Comparisons between these operations are complicated because of the different surgical eras, differences in follow-up, and the number of included patients. Furthermore, a selection bias of a specific technique and in surgical reporting may exist.[22] Our actuarial survival and arrhythmia-free survival for both operations ($n = 50$ vs $n = 50$) were 83.4% ± 4.0% ($P > .05$), and 72.4% ± 5.0% at 37.25 years ($P > .05$), which is similar to or relatively higher than previous reports.[3,23]

In this study, freedom from the first, second, third, and fourth reoperations were significantly higher after the REV procedure than after the Rastelli repair. The most common causes of reoperation after the Rastelli repair were PS, LVOT obstruction, and arrhythmia; however, the most common cause of reoperation after the REV was PR. The REV group had a significantly lower proportion of LVOT- and RVOT-related reoperations than the Rastelli group,[17] and the long-term performance of the reconstructed LVOT and RVOT was satisfactory.[15,20] Although long-term survival is good without detectable differences between operations, the reoperation rate was lower for the REV procedure (16% of the mean 12 years), and surgery-specific and -unspecific reoperations are more common after the Rastelli technique.[24]

The REV is superior to the Rastelli operation for RVOT reoperation. However, reoperations need not necessarily be considered adverse outcomes but a part of an integrated treatment concept to maintain ventricular function at the expense of one or more additional operations to restore unobstructed RVOT and valvular competence. Given that RV function plays an important role in long-term survival and quality of life, the follow-up time needs to be sufficient in order to estimate the impact of long-standing PR on late mortality, as in this study.[12] Although patients who underwent the Rastelli operation had recurrent RVOT operations due to RVOT dysfunction, no late mortality was recorded in this study.[14]

The Rastelli operation has limited durability of the valved conduits used in RVOTs. Meanwhile, the modified REV procedure allows the RVOT to be positioned stereotactically posteriorly, preventing sternal compression and eliminating the use of valved conduits. Therefore, it significantly improves the durability of the RVOT. This study showed that 61 reoperations for PS were required in 70% of the patients (35/50) after the Rastelli operation, although only 20 reoperations for PS were required in 34% of the patients (17/50) after the REV procedure ($P = .001$) because of somatic growth of the translocated pulmonary artery and RVOT. By contrast, no reoperations for PR were required after the Rastelli, where 7 reoperations for PR were required after REV ($P = .012$).

The fate of the RVOT is of paramount consideration. Compared with the Rastelli operation, the REV has a significantly lower RVOT reoperation rate,[9,20,23] which shows the superiority of the REV over the Rastelli operation in terms of RVOT performance[20] due to the potential for somatic growth of the native pulmonary root and possible preservation of the valve.[20,25] The Rastelli operation is time-tested and avoids many risks associated with translocation procedures.[26] However, the need for conduit replacement remains the most common indication for reoperation following the Rastelli operation.

LVOT obstruction remains a late complication of the Rastelli procedure,[26] and a relatively high LVOT reoperation rate following the Rastelli operation has been documented.[20,22] The late risk of important LVOT obstruction was also reported to range from approximately 13% to 22% at 20 years after the Rastelli operation, with no increase in risk among patients operated on before the age of 5 years.[21] Regarding the REV, total resection of the conal septum creates a wide and straight LV-aorta tunnel, which helps prevent late LVOT obstruction.[20] In this study, 13 reoperations for LVOT obstruction were required in 24% of patients (12/50) after the Rastelli operation, whereas only four reoperations for LVOT obstruction were required in 8% of patients (4/50) after the REV procedure ($P = .029$).

Several other studies have also confirmed the efficacy of VSD enlargement and conal septum resection in Rastelli operations.[27] In patients with dextro-TGA or double-outlet RV with a small VSD and LVOT obstruction, VSD enlargement using the Rastelli procedure can be safely performed without operative mortality and with low long-term mortality and morbidity in terms of arrhythmia, LV function, and long-term LVOT obstruction.[28] The arterial switch operation group had a high proportion of substantial neo-AR (29%) but no recurrence of LVOT obstruction.[17] In this study, 6 reoperations for AR were required in 4 patients after the Rastelli procedure (8%), whereas only one reoperation for AR was required after the REV (2%).

As an alternative surgical option, a more time-consuming aortic root translocation has been reported with similar early outcomes, and indicated for RV hypoplasia, aorta distant from the LV, remote or noncommitted small VSD, and atrioventricular valve straddling.[13,22] Patients benefit the most from an individualized surgical approach.[22] Since this study is still limited by selection bias, future multicenter studies with larger sample sizes and long-term follow-up are necessary to draw a definite conclusion regarding the optimal surgical treatment for these patients.[13,16,18]

Conclusion

The modified REV and Rastelli repairs provided satisfactory results at long-term follow-up. However, the Rastelli repair requires repeated reoperations, particularly for biventricular tract obstruction and arrhythmia.

Data Availability

The data underlying this article will be shared on reasonable request by the corresponding author.

Declaration of Conflicting Interests

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References

1. Rastelli GC, McGoon DC, Wallace RB. Anatomic correction of transposition of the great arteries with ventricular septal defect and subpulmonary stenosis. *J Thorac Cardiovasc Surg*. 1969;58(4):545-552.
2. Lecompte Y, Neveux JY, Leca F, et al. Reconstruction of the pulmonary outflow tract without prosthetic conduit. *J Thorac Cardiovasc Surg*. 1982;84(5):727-733.
3. Kreutzer C, De Vive J, Oppido G, et al. Twenty-five-year experience with Rastelli repair for transposition of the great arteries. *J Thorac Cardiovasc Surg*. 2000;120(2):211-223.
4. Dearani JA, Danielson GK, Puga FJ, Mair DD, Schleck CD. Late results of the Rastelli operation for transposition of the great arteries. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu*. 2001;4:3-15.
5. Hörer J, Schreiber C, Dworak E, et al. Long-term results after the Rastelli repair for transposition of the great arteries. *Ann Thorac Surg*. 2007;83(6):2169-2175.
6. Kim YJ, Song H, Lee JR, Rho JR, Suh KP. Lecompte procedure for complete transposition of the great arteries with ventricular septal defect and pulmonary stenosis. *Ann Thorac Surg*. 1994;57(4):876-879.
7. Kim YJ, Park JJ, Lee JR, et al. Modified Lecompte procedure for the anomalies of ventriculoarterial connection. *Ann Thorac Surg*. 2001;72(1):176-181.
8. Lee JR, Lim HG, Kim YJ, et al. Repair of transposition of the great arteries, ventricular septal defect and left ventricular outflow tract obstruction. *Eur J Cardiothorac Surg*. 2004;25(5):735-741.
9. Lim HG, Kim WH, Lee JR, Kim YJ. Twenty-five years' experience of modified Lecompte procedure for the anomalies of ventriculoarterial connection with ventricular septal defect and pulmonary stenosis. *J Thorac Cardiovasc Surg*. 2014;148(3):825-831.
10. Lecompte Y, Zannini L, Hazan E, et al. Anatomic correction of transposition of the great arteries. *J Thorac Cardiovasc Surg*. 1981;82(4):629-631.
11. Hazekamp MG, Gomez AA, Koolbergen DR, et al. Surgery for transposition of the great arteries, ventricular septal defect and left ventricular outflow tract obstruction: European congenital heart surgeons association multicentre study. *Eur J Cardiothorac Surg*. 2010;38(6):699-706.
12. Hörer J. Surgery for TGA/VSD/LVOTO-many treatment options for a heterogeneous and rare malformation. *World J Pediatr Congenit Heart Surg*. 2018;9(6):613-615.
13. Seese L, Turbendian HK, Thibault D, et al. Utilization and outcomes of the Nikaidoh, Rastelli, and REV procedures: an analysis of the society of thoracic surgeons congenital heart surgery database. *Ann Thorac Surg*. 2022;114(3):800-808.
14. Bierbach B, Arenz C, Suchowerskyj P, et al. Current mid-term outcome with an integrated surgical strategy for correction of d-transposition of the great arteries with ventricular septal defect and left ventricular outflow tract obstruction. *Eur J Cardiothorac Surg*. 2016;50(4):617-625.

15. An K, Hu S, Li S, Yan J, Wang X, Hua Z. Outcome of modified réparation à l'ètage ventriculaire (REV) based on anatomical characteristics for the anomalous ventriculoarterial connection with ventricular septal defect and left ventricular outflow tract obstruction. *Interact Cardiovasc Thorac Surg*. 2020;31(5):674-679.
16. Al-Jughiman MK, Al-Omair MA, Van Arsdell GS, Morell VO, Jacobs ML. D-Transposition of the great arteries with ventricular septal defect and left ventricular outflow tract obstruction (D-TGA/VSD/LVOTO): a survey of perceptions, preferences, and experience. *Pediatr Cardiol*. 2015;36(5):896-905.
17. Furuta A, Yamagishi M, Matsumura G, Shinkawa T, Niinami H. Long-term surgical results of transposition of the great arteries with left ventricular outflow tract obstruction. *J Cardiothorac Surg*. 2022;17(1):111.
18. Olds A, Nakamura Y, Levasseur S, et al. Outcomes of surgical repair of complex D-transposition of the great arteries. *World J Pediatr Congenit Heart Surg*. 2018;9(6):605-612.
19. Huang ES, Herrmann JL, Rodefeld MD, Turrentine MW, Brown JW. Rastelli operation for D-transposition of the great arteries, ventricular septal defect, and pulmonary stenosis. *World J Pediatr Congenit Heart Surg*. 2019;10(2):157-163.
20. An K, Li S, Yan J, Wang X, Hua Z. Transposition of the great arteries, ventricular septal defect, and pulmonary stenosis: modified REV versus Rastelli. *Pediatr Cardiol*. 2021;42(4):762-767.
21. Cleveland DC, Kirklin JK, Pavnica JW, et al. Late left ventricular outflow tract obstruction following the Rastelli operation: expectations out to 20 years. *World J Pediatr Congenit Heart Surg*. 2016;7(5):605-610.
22. Hazekamp MG, Nevvazhay T, Sojak V. Nikaidoh vs réparation à l'Etage ventriculaire vs Rastelli. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu*. 2018;21:58-63.
23. Di Carlo D, Tomasco B, Cohen L, Vouhé P, Lecompte Y. Long-term results of the REV (*réparation* à l'*étage ventriculaire*) operation. *J Thorac Cardiovasc Surg*. 2011;142(2):336-343.
24. Kari FA, Bohnens H, Bierbach B, Bacha EA, Stiller B, Bauer U. Repair of complex transposition of great arteries: up to 30 years of follow-up. *Ann Thorac Surg*. 2020;109(2):555-565.
25. da Silva JP, da Silva Lda F, Lopes LM, et al. Pulmonary root translocation in malposition of great arteries repair allows right ventricular outflow tract growth. *J Thorac Cardiovasc Surg*. 2012; 143(6):1292-1298.
26. Barron DJ, Mehsood DK, Kutty RS, et al. Fate of the left ventricular outflow tract after Rastelli with selective infundibular muscle resection. *Ann Thorac Surg*. 2019;107(4):1226-1231.
27. Alsoufi B, Awan A, Al-Omrani A, et al. The Rastelli procedure for transposition of the great arteries: resection of the infundibular septum diminishes recurrent left ventricular outflow tract obstruction risk. *Ann Thorac Surg*. 2009;88(1):137-142.
28. Toyoda Y, Hiramatsu T, Nagashima M, Matsumura G, Yamazaki K. Long-term effect of enlargement of a ventricular septal defect in the Rastelli procedure. *Semin Thorac Cardiovasc Surg*. 2017; 29(2):215-220.