Modified Lecompte Procedure for the Anomalies of Ventriculoarterial Connection

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Background. The Lecompte procedure for correcting transposition of the great arteries has an advantage because it obviates the need for an extracardiac conduit for the reconstruction of the pulmonary outflow tract. In this study, we evaluated the effectiveness and the application of the Lecompte procedure based on our experiences.

Methods. A retrospective review was conducted of the records of 45 patients who underwent the Lecompte procedure during the past 11 years to achieve direct right ventricle to pulmonary artery continuity. Mean age at operation was 2.4 ± 1.7 years (range 3.5 months to 6.9 years). The diagnoses involved anomalies of the ventriculoarterial connection with ventricular septal defect and pulmonary outflow tract obstruction, such as transposition of the great arteries, double-outlet right ventricle, and double-outlet left ventricle.

Results. Early mortality was 4.4% (2 of 45 patients) and late mortality was 4.7% (2 of 43). The mean follow-up was 4.9 ± 3.1 years. Fourteen patients (34.1% of survivors, n = 41) had pulmonary stenosis (pressure gradient above 30 mm Hg), the main reason for which was a calcified monocusp valve (n = 10, 71.4%). Eight of 45 patients (17.8%) underwent reoperation: 2 for residual ventricular septal defect, 1 for recurrent septic vegetation, and 5 for pulmonary stenosis. The cumulative survival rates were 91.1% ± 4.2% at 10 years. The actuarial probabilities of freedom from reoperation for pulmonary stenosis were 93.8% ± 4.3% and 71.4% ± 11.8% at 5 and 10 years, respectively.

Conclusions. Our review suggests that the Lecompte procedure is an effective treatment modality for anomalies of the ventriculoarterial connection with ventricular septal defect and pulmonary outflow tract obstruction. Repair in early age is possible with acceptable morbidity and mortality, but recurrent right ventricular outflow tract obstruction caused by degeneration of the monocusp valve is a problem that needs resolution.

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In 1969, Rastelli [1] introduced a new surgical technique to anatomically correct transposition of the great arteries (TGA). Thereafter, the Rastelli operation was considered the standard for the repair of TGA with ventricular septal defect (VSD) and pulmonary stenosis (PS). However, the Rastelli operation is not ideal for at least four reasons: (1) it is not feasible in some patients because of unfavorable intracardiac anatomy; (2) the use of an extracardiac prosthetic conduit for reconstruction of the pulmonary outflow tract needs a subsequent reoperation to change this conduit; (3) it delays complete correction until a larger conduit can be placed; and (4) homografts are not always available because of limited supply, especially in developing countries.

In an effort to overcome these limitations, Lecompte and colleagues [2] introduced a new surgical technique that includes extensive resection of the conal septum and direct reimplantation of the pulmonary trunk on the superior margin of the right ventricular infundibulotomy without a prosthetic conduit. Using this procedure the size of the VSD and abnormal attachment of the tricuspid chordae on the conal septum are not limiting factors.

Now the technique is widely used in the treatment of TGA, double-outlet right ventricle (DORV), truncus arteriosus, and various cardiac anomalies associated with pulmonary outflow tract obstruction and VSD [3]. However, some anatomic contraindications remain, for example, remote VSD or Swiss-cheese-type multiple VSDs, which make the construction of a left ventricular-aortic tunnel impossible; hypoplasia of one of the ventricles; and diffuse hypoplasia of the pulmonary arteries [4].

One of the most important considerations, when evaluating the effectiveness of this procedure, is the fate of the right ventricular outflow tract (RVOT). Vouhé and associates [4] reported that RVOT obstruction (RVOTO) occurs in 26% of patients, with a mean follow-up of 55 months. Therefore, there has been much concern about the potential for growth of the native pulmonary trunk and changes of the monocusp valve with time.

Here, we review our experiences with the Lecompte procedure in 45 consecutive patients with anomalies of ventriculoarterial connection and evaluate its effectiveness with a mean follow-up of 59 months.

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Material and Methods

Patients

During an 11-year period (July 1988 to March 1999), 45 patients underwent the Lecompte procedure. The male to female ratio was 25:20 and age at operation ranged from 3.5 months to 6.9 years (mean 2.4 ± 1.7 years). Forty-one patients (91%) were less than 5 years of age. Eight patients were less than 1 year of age, 13 from 1 to 2 years, 11 from 2 to 3 years, 8 from 3 to 4 years, and 1 from 4 to 5 years. Weight at operation ranged from 5.7 to 20 kg (mean 10.2 ± 1.9 kg). Twenty-three patients (51.1%) weighed less than 10 kg.

Preoperative diagnosis was TGA with VSD and PS (or pulmonary atresia) in 29 (64.4%), DORV with VSD and PS (or pulmonary atresia) in 14 (31.1%), TGA with endocardial cushion defect (ECD) and PS in 1 (2.2%), and double-outlet left ventricle with VSD and PS in 1 (2.2%). Associated anomalies were patent ductus arteriosus (n = 27), atrial septal defect (n = 26), juxtaposed atrial appendage (n = 11), bilateral superior vena cava (n = 10), dextrocardia (n = 3), systemic venous anomaly (n = 3), coronary artery anomaly (n = 3), multiple VSD (n = 2), complete ECD (n = 1), and criss-cross heart (n = 1). In 11 patients, the great arteries were side by side, whereas the others had the usual anteroposterior relationship. Four patients had abnormal insertion of the tricuspid tension apparatus (papillary muscle in 3, septal chordae in 1) on the outlet septum. Twenty-four patients had one previous Blalock–Taussig shunt, and 1 had two previous shunts. One had balloon atrial septostomy during cardiac catheterization. Time interval from palliation to complete repair was 2.3 ± 1.2 years.

Surgical Technique

All patients were operated on by median sternotomy. Cardiopulmonary bypass (CPB) was conducted at moderate systemic hypothermia (28°C). In 6 patients, total circulatory arrest and deep hypothermia was used. Before CPB, the branches of pulmonary artery were mobilized sufficiently beyond the pericardial reflection and previous shunts were controlled. The Lecompte procedure was performed in the same manner as described previously [5]. Resection of the conal septum or VSD extension was undertaken in all patients. This resection enlarges even a small restrictive VSD and constructs a straighter left ventricular outflow tract, which helps prevent obstruction. After intraventricular baffling, the pulmonary artery was pulled down to the superior margin of the right ventriculotomy, without translocating the pulmonary artery anterior to the aorta. This adaptation is known as the Lecompte maneuver [6]. Right translocation of the main pulmonary trunk was performed in 9 patients, which depended on the initial position of the great arteries. Therefore, the pulmonary bifurcation was always located posterior to the ascending aorta in all of our cases. In cases involving the abnormal insertion of the tricuspid tension apparatus (papillary muscle in 3, septal leaflet chordae in 1), we transferred them onto the right side of the patch after division, instead of using the flap technique [3]. Finally, the RVOT was reconstructed with an anterior patch, after a monocusp valve was inserted along the margin of the ventriculotomy. It covered the upper round margin of the RVOT sufficiently and was constructed by securing a portion of pericardium about 20% larger than the width of the outflow tract patch. Materials for the monocusp valve were autologous pericardium (0.625% glutaraldehyde treated) in 33 (73.3%), bovine pericardium in 7 (15.6%), Gore-Tex (W. L. Gore and Associates, Flagstaff, AZ) membrane in 3 (6.7%), and homograft monocusp valve in 2 (4.4%). Additional operative procedures were performed in 8 patients: branch pulmonary artery angioplasty in 5, tricuspid annuloplasty in 1, mitral valvuloplasty in 1, and atrioventricular valve replacement in 1, who was diagnosed as having TGA, ECD, and PS.

Results

Two patients (4.4%) died after the operation. In 1 patient, the cause of death was myocardial failure associated with hypoxia. Postoperative ratio of right ventricle to left ventricle pressure was 0.37 and cardiac arrest occurred in the intensive care unit. Reoperation for closure of uncorrected atrial septal defect was performed the same day but he was not weaned from cardiopulmonary bypass. The other patient, who was diagnosed as having TGA, ECD, and PS and received mitral valve replacement simultaneously, died of myocardial failure. These two cases were our early experiences in 1988.

There were two late deaths. One patient needed reoperation for the closure of another muscular VSD by left ventriculotomy, which was not found at initial diagnosis, and then she died of *Candida* sepsis on postoperative day 56. The other patient died 3 months postoperatively because of permanent pacemaker failure associated with myocarditis. A pacemaker had been implanted because she had developed a complete atrioventricular block postoperatively. All deaths occurred in patients who were older than 1 year at operation. Mortality was not influenced by age.

Postoperative major and minor complications developed in 21 patients (46.7%). Six patients had surgical bleeding. Four patients had infections: empyema in 1, bronchopneumonia in 1, recurrent septic vegetation in 1, and *Candida* sepsis in 1, which resulted in the late death. Three patients had minor wound problems. Arrhythmia developed in 3 patients: complete atrioventricular block in 1, transient Mobitz type II atrioventricular block in 1 that returned to sinus rhythm 2 weeks later, and wandering pacemaker in 1. The other complications were chylothorax in 3, postpericardiotomy syndrome in 1, and transient cortical blindness related to an air embolism in 1.

Mean follow-up was 4.9 ± 3.1 years (range 15.9 months to 10.1 years). Eight patients (17.8%) underwent reoperation between 1.3 months and 7.6 years after the initial repair, for the causes listed in Table 1. The cause of reoperation for residual PS was mainly due to calcification of the monocusp valve (n = 4, 80%). In 3 patients,

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Table 1. Cause of Reoperation

Cause	No. of Patients
Residual shunt	2
Baffle leak (Qp/Qs = 1.8)	1
Another muscular VSD[a]	1
Recurrent septic vegetation	1
RVOTO	5
Focal narrowing of LPA origin	1
PS due to calcification of monocusp valve	4
Total	8 (17.8%)

[a] It was found postoperatively.

LPA = left pulmonary artery; PS = pulmonary stenosis; RVOTO = right ventricular outflow tract obstruction; VSD = ventricular septal defect

reoperations consisted of the excision of the calcified valve and reconstruction of the right ventricle outflow tract with a valved conduit (n = 1), pulmonic homograft (n = 1), and Gore-Tex patch (n = 1). One patient required only the excision of a severely calcified valve. In these 4 patients, the time interval to reoperation was 3.7, 6.7, 7.3, and 7.6 years, respectively.

All survivals were evaluated by Doppler echocardiography within 1 month after operation and followed up regularly. Left ventricular function (assessed by the measurement of ventricular cavity dimensions and the shortening fraction of the left ventricular axis) was normal in all patients. There was no residual left ventricular-aortic pressure gradient in any patients. Follow-up angiocardiogram within 24 months (n = 15) showed that right ventricle to left ventricle pressure ratio was 0.46 ± 0.09 and pressure gradient in RVOT was insignificant. However, the last follow-up echocardiography revealed that 9 patients had an estimated pressure gradient of more than 30 mm Hg (36 to 41 mm Hg), although they were in good clinical condition. Six patients had thickened, calcified, or immobile monocusp valves and 3 patients had mild stenosis of the branch pulmonary arteries. In these 9 patients, the time from operation to last echocardiography was 6.7 ± 2.0 years. Therefore in the surviving patients, 14 (34.1%) had RVOT obstructions (Table 2), but the major reason was calcification of the monocusp valve (71.4%). Mild to moderate pulmonary regurgitation was present in most patients, but severe pulmonary regurgitation or right ventricular dysfunction was not detected. Residual shunt from intraventricular baffling was found in six patients, but the amount of the shunt was negligible, and disappeared spontaneously in 2 patients during the follow-up period. With the exception of one late death, 3 patients who had transfer of tension apparatus of the tricuspid valve showed only mild valvular regurgitation.

Table 2. Cause of RVOT Obstruction

Cause	No. of Patients
Calcified monocusp valve	10 (71.4%)
Reoperation	4
Observation[a]	6
Stenosis of branch pulmonary artery	4 (28.6%)
Reoperation	1
Observation[a]	3

n = 14.

[a] Pressure gradient >30 mm Hg.

RVOT = right ventricular outflow tract.

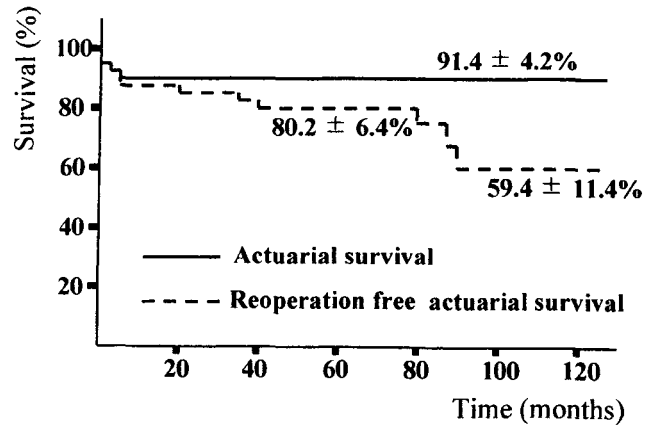

Fig 1. Actuarial survival curve by Kaplan–Meier method.

The cumulative survival rate was 91.1% ± 4.2% at 1, 5, and 10 years (Fig 1). The reoperation free survival rate was 88.9% ± 4.7%, 80.2% ± 6.4%, and 59.4% ± 11.4% at 1, 5, and 10 years, respectively. The actuarial probabilities of freedom from reoperations for residual RVOTO were 93.8% ± 4.3% and 71.4% ± 11.8% at 5 and 10 years (Fig 2). All survivals including those who underwent reoperation were in good clinical condition at the time of review. Thirty-nine patients were in New York Heart Association class I and 2 were in class II.

Comment

Initially, the Lecompte procedure was designed to overcome the limitations of the Rastelli operation. The principles of the technique are (1) resection of the infundib-

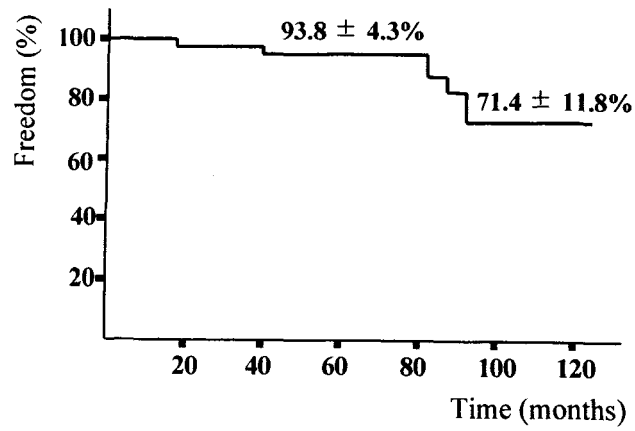

Fig 2. Actuarial freedom from reoperation for residual right ventricular outflow tract obstruction.

ular septum creating a large and direct subarterial communication between the left ventricle and aorta; (2) construction of a straight tunnel from left ventricle to aorta by intraventricular partition; and (3) direct anastomosis of the pulmonary trunk to the right ventricle without a prosthetic conduit. In this procedure, the pulmonary bifurcation was usually placed anterior to the ascending aorta, the so-called Lecompte maneuver [6], if the relationship of great arteries was more or less anteroposterior, not side by side. The anteriorly located pulmonary bifurcation was the possible cause of pulmonary outflow tract obstruction [4]. To solve this problem, Lecompte resected a generous part of the ascending aorta to create enough space in the anterior mediastinum for the pulmonary outflow tract. So the procedure became more complicated, involving transection of the aorta and reanastomosis.

Recently, Metras and associates [7] pointed out the possibility of anterior compression of the main pulmonary trunk caused by the Lecompte maneuver even after resection of aorta. They modified the procedure using an aortic autograft, leaving the pulmonary arteries orthotopically posterior, and emphasized that a tension-free anastomosis could be achieved only by the extension with the autograft. In our series, we did not use the Lecompte maneuver in any patient even when the great arteries had an anteroposterior relationship and could bring directly the main pulmonary artery to the right ventricle. We decided not to use the Lecompte maneuver in the Lecompte procedure because orthotopically posterior-positioned pulmonary arteries reduce the possibility of the pulmonary outflow tract obstruction as seen in arterial switch operations [8–10], and we wanted to simplify the procedure and reduce the risk of bleeding by avoiding the transection of aorta and reanastomosis. Tension-free anastomosis was accomplished by sufficient dissection of the pulmonary arterial branches beyond the pericardial reflection. The pulmonary arterial trunk was incised longitudinally on its anterior aspect, and then direct anastomosis was performed. If this direct anastomosis caused tension, the pulmonary artery incision was extended more distally. The resection of the conal septum is important in this procedure as Lecompte and his associates insisted [2, 3]. However, considering that the Lecompte procedure was designed to overcome the limitations of the Rastelli operation and infundibular septum resection is needed to construct a more straight and wide left ventricle to aorta tunnel, even in the Rastelli procedure, there is little difference between the two procedures in this point. In addition, we did not apply the Lecompte maneuver in all cases. Consequently, it is important to decide whether the main pulmonary artery will be translocated on the right or the left of the aorta. Therefore, we believe the essential point of this procedure is the translocation of the pulmonary artery. In our series, 9 cases involved translocation of the main pulmonary artery to the right of the aorta, based on the initial position of the great arteries.

We experienced stenosis of the branch pulmonary arteries during follow-up in 4 patients. Among these, reoperation for the relief of stenosis of the left pulmonary artery origin was performed in 1 patient who had had a severe proximal stenosis of the left pulmonary artery at the time of initial diagnosis. Three patients had pressure gradients of more than 30 mm Hg at the level of the branch pulmonary artery. However, 2 of them had had concomitant angioplasty for the relief of native branch stenosis during the initial operation. Therefore, direct anastomosis of the pulmonary artery could contribute toward the development of residual PS in patients with stenosis of branch pulmonary arteries at initial repair, but not in all cases.

We encountered 4 patients with abnormal insertions of tricuspid tension apparatus, which prevents a proper intraventricular tunneling. We did not use the flap technique [3], but directly transferred these tension apparatuses to the patch after division. Except one late death, echocardiography revealed mild regurgitation in 3 patients at 9.1, 9.5, and 6.8 years postoperatively. Therefore, we think this is a reliable alternative for transfer of the abnormal tension apparatus.

Lecompte and coworkers [2] emphasized in their first report of this procedure that pulmonary regurgitation should be prevented by a reliable method of inserting a valve in the pulmonary outflow tract. In all cases, we placed a monocusp valve expecting this valve to improve the immediate postoperative result by preventing a sudden hemodynamic change from a pressure-loaded right ventricle to a volume-loaded ventricle. Pulmonary regurgitation was insignificant in all patients.

However, concerning development of RVOTO, the main reason for residual PS was severe calcification of the monocusp valve (71.4%) in our experiences. Among 5 patients who had reoperations for residual PS, 4 had severe calcification, as did 6 of 9 patients who had a pressure gradient of more than 30 mm Hg at the last follow-up echocardiography. Echocardiographic findings were immobile, thickened, and calcified monocusp valves. In 1 patient, calcification was demonstrated on the chest roentgenogram. Duration from the initial repair to redo in reoperated patients was 3.7, 6.7, 7.3, and 7.6 years and the duration to the last echocardiography for the 6 patients with pressure gradient greater than 30 mm Hg due to calcification was 9.5, 9.6, 8.2, 6.4, 7.1, and 4.9 years. This is somewhat surprising because degeneration of monocusp patch leads to insufficiency rather than to stenosis. We did not discover the cause of the relatively high incidence of obstruction by the calcification of monocusp valve. However, some possible suggestions may exist: (1) by not applying Lecompte maneuver in our series, turbulence and vortex may develop within the RVOT, possibly resulting from a laterally deviated pulmonary artery by the aorta remaining in situ. This may lead to a gradual development of calcification and cause a gradual increase in the RVOT pressure gradient, although there were no pressure gradients in the immediate postoperative period; (2) our technique of implantation of monocusp valve; and (3) the influence of custom-made glutaraldehyde solution.

The risk of calcification was not influenced by the

monocusp material. Despite RVOTO caused by calcification of monocusp valve, we still believe it is more helpful to place it for the purpose mentioned above. In three recent cases, we used Gore-Tex membrane, which is thought to have a water-repellent nature and makes calcification less likely [11–14]. Long-term follow-up is necessary to determine the fate of the Gore-Tex membrane.

Analyzing our results, it appears that the long-term fate of the reconstructed RVOT depends primarily on the monocusp valve, which is prone to progressive calcification, degeneration, and subsequent valvular dysfunction over time, although this type of repair has an advantage in terms of the potential for the growth of the patient's own native pulmonary artery. The fate of the monocusp valve in RVOT is similar to that in the repaired tetralogy of Fallot, in which the insertion of a monocusp valve within the transannular patch to prevent pulmonary insufficiency is controversial [15, 16]. Therefore, an alternative method of RVOT reconstruction is needed. Recent reports include investigations into the need for valves [7], the preservation of the native pulmonary valves [17], and the use of alternative materials for monocusp valves [11–14].

In conclusion, the Lecompte procedure, after 11 years experience, is superior to the Rastelli procedure for treating anomalies of ventriculoarterial connection with VSD and pulmonary outflow tract obstruction. The Lecompte procedure allows early, complete anatomic repair and reduces the need for late reoperation because of its obviation of an extracardiac conduit and the potential growth of the pulmonary artery. However, late obstruction related to the monocusp valve is a problem that remains to be solved.

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