

Senning repair for transposition of the great arteries in the first week of life

G. PAUL MATHERNE, M.D., JERRY D. RAZOOK, M.D., WEBB M. THOMPSON, JR., M.D.,
MARY M. LANE, M.P.H., CYNTHIA K. MURRAY, M.P.H., AND RONALD C. ELKINS, M.D.

ABSTRACT Infants with D-loop transposition of the great arteries (D-TGA) may have unacceptable results after balloon septostomy while awaiting surgery. It has been our policy to repair defects in infants with D-TGA and intact ventricular septum or small ventricular septal defect at the time of diagnosis. We report our experience with the Senning operation in 18 newborns less than 1 week of age. The mean age at operation was 3 days (range 12 hr to 7 days) and the mean weight was 3.5 kg (range 2.8 to 4.8). There were two early postoperative deaths (11%) and one late death (5%). Early mortality was associated with preoperative acidosis and congestive heart failure. Late mortality was associated with severe left ventricular outflow tract obstruction (LVOTO). The 15 long-term survivors have been followed for an average of 27 months and 11 of the 16 perioperative survivors have undergone postoperative catheterizations. There was no evidence of systemic or pulmonary venous obstruction. One patient developed LVOTO that led to his death. Two patients had residual atrial shunts. Electrocardiograms revealed no major arrhythmias. All patients are clinically asymptomatic. Good hemodynamic, electrocardiographic, and clinical results can be obtained with correction of D-TGA in the first week of life.

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MANAGEMENT OF D-loop transposition of the great arteries (D-TGA) has undergone dramatic change in the past 35 years. The development of the Blalock-Hanlon,^{1,2} Mustard,³ Senning,^{4,5} and Jatene⁶ procedures, along with Rashkind balloon septostomy,⁷ has led to significant decreases in mortality and morbidity.

Recently, interest has been focused on the correct age for repair. The trend has been toward earlier correction to avoid morbidity and mortality.⁸⁻¹⁷ The long-term results of early repair are comparable to those of later repair without the risks associated with uncorrected D-TGA.^{11, 16, 17}

While palliation is achieved in many infants with D-TGA with balloon septostomy, significant complications can occur while these infants are awaiting surgery. Gutgesell et al.¹⁸ have reported a 22% incidence of death, cerebrovascular accident, or obstructive pulmonary vascular disease in infants with palliated D-TGA awaiting surgery.¹⁸ Because of this unacceptable morbidity and mortality, it has been the policy at our institution to repair defects in all infants with D-TGA at

the time of diagnosis. We report the results of 18 infants with D-TGA corrected with the Senning procedure during the first week of life.

Methods

Patients. From April 1979 through January 1984, 18 infants 1 week or less old underwent Senning repair for D-TGA. The patient population was derived from records of the Departments of Pediatric Cardiology and Thoracic Surgery. Infants with a patent ductus arteriosus (PDA) or small ventricular septal defect (VSD) without adequate mixing were included. Initial evaluation included cardiac catheterization at our institution in 13 and at a referring hospital in five.

Surgical procedure. A modified Senning operation was performed in all 18 infants. The atrial patch was augmented with knitted Dacron in 11 patients and enlargement of the new pulmonary venous atrium with a pericardial patch was necessary in one patient. All PDAs were ligated and three patients had suture closure of a VSD. Hypothermic circulatory arrest was used in all patients (18° C in 17 and 20° C in 1). The mean period of circulatory arrest was 57 min (range 47 to 77).

Follow-up. Clinical history, physical examination, and growth parameters were reviewed along with chest roentgenograms and electrocardiograms. Postoperative cardiac catheterization was performed in 11 patients. Measurement for left ventricular outflow tract obstruction (LVOTO) was performed if clinically indicated by elevated left ventricular pressures or by the presence of a murmur suggestive of LVOTO. Pulmonary venous pressures were measured if indicated by clinical evidence of obstruction. Systemic venous obstruction was determined by measuring the gradient between the mean superior vena caval or inferior vena caval pressure and the mean system-

From the Departments of Pediatrics, Pediatric Cardiology, and Surgery, University of Oklahoma Health Sciences Center, Oklahoma City.

Address for correspondence: Ronald C. Elkins, M.D., Section of Thoracic Surgery, PO Box 26307, Oklahoma City, OK 73126.

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ic venous atrial pressure. Intracardiac shunts were determined by oximetry data.

Survival analysis. Survival was analyzed by the Kaplan-Meier method for actuarial survival.¹⁹

Results

Patient profile. Eighteen neonates with D-TGA underwent Senning repair between April 1979 and January 1984 (table 1). This group comprised all but five newborns with D-TGA seen at our institution during that period; one infant was excluded because repair was delayed until 2 months of age and four infants were excluded because they had VSDs. Six of the patients had no associated cardiac defects, five had associated PDA, four had an associated VSD, and three patients had both PDA and a VSD. LVOTO was not seen preoperatively. All of the patients with VSDs had small defects without adequate mixing. The age range at operation was 12 hr to 7 days (mean 3 days), and the weight range was 2.8 to 4.8 kg (mean 3.5). Sixteen patients had undergone Rashkind balloon septostomy before operation.

Preoperative and postoperative profile. Preoperative complications consisted mainly of hypoxemia and congestive heart failure. Seven patients underwent a trial of prostaglandin E₁ for persistent hypoxemia, and three of the patients received digoxin for congestive heart failure. Three patients underwent repeat Rashkind septostomy because of persistent hypoxia. Other preoperative complications were transient supraventricular tachycardia during catheterization in one patient and a blood culture positive for *Staphylococcus aureus* in one patient.

After surgical repair, all of the patients were weaned from cardiopulmonary bypass. Seven patients had transient postoperative complications that resolved without sequelae, while two patients had complications that led to their deaths. Transient complications

included junctional rhythm in four, supraventricular tachycardia in one, ventricular fibrillation in one, cardiac arrest in one, and seizures in one patient. Two patients with transient junctional rhythms developed passive arrhythmias on follow-up; one of these patients had first-degree atrioventricular block and the other had ectopic atrial pacemaker and occasional junctional beats. Fatal complications included ventricular failure in one patient and severe ischemic central nervous system damage in one patient. No patient demonstrated evidence of systemic or pulmonary venous obstruction postoperatively. However, one patient who died had evidence of systemic venous obstruction and required augmentation of the systemic atrium during weaning from bypass. No patient underwent reoperation for systemic or pulmonary venous obstruction.

Among the 16 perioperative survivors the duration of ventilator support ranged from ½ to 7 days (mean 1.5). The duration of hospitalization was from 7 to 21 days (mean 11).

Mortality. The overall mortality was 17% (3/18; table 2). Two patients died during the perioperative period (perioperative mortality 11%) and one patient died at 33 months of age.

The two patients that died during the perioperative period had very complicated preoperative courses. Both patients developed severe acidosis and hypoxia that required urgent surgical correction. One patient whose pH was less than 7.03 for 5 hr before surgery developed severe neurologic dysfunction shortly after surgery. He died on the tenth postoperative day without neurologic recovery. The second patient was responsive only to deep pain with nonreactive pupils upon arrival at our institution. The emergency surgical procedure was complicated by obstruction of the superior and inferior venae cavae when the patient was first weaned from cardiopulmonary bypass, which required augmentation of the systemic atrium. The patient was weaned from bypass the second time, but died a short time later from continued hypotension and poor ventricular function. Autopsy in both infants revealed good surgical repair without evidence of systemic or pulmonary venous obstruction.

The patient who died late after surgery was found to have LVOTO and a residual VSD on postoperative catheterization at 12 months of age. At the initial catheterization he was thought to have a small 3 to 4 mm supracristal VSD, but LVOTO was not found. At 27 months of age, he underwent patch closure of the VSD, pulmonary commissurotomy, and infundibular resection. Postoperative catheterization revealed residual severe LVOTO. At 33 months of age, he under-

TABLE 1
Patient characteristics

No. of patients	18
Ratio of male/female patients	15/3
Age at operation (days)	
Mean (SEM)	3.0 (0.5)
Range	0.5–7.3
Weight at operation (kg)	
Mean (SEM)	3.5 (0.1)
Range	2.8–4.2
Associated defects	
PDA	5
VSD	4
PDA VSD	3
Rashkinds	16

TABLE 2
Findings at follow-up

Perioperative survivors	16/18 (89%)
Long-term survivors	15/18 (83%)
Length of follow-up (months)	
Mean (SEM)	27.0 (4.2)
Range	9–64
Postoperative catheterization	11/16 (69%)
Age at 1st postop. cath. (months)	
Mean (SEM)	14.6 (1.8)
Range	4–26
Pressures at postop. catheterization (mm Hg)	
Mean SVC (SEM)	6.7 (0.8)
Mean SA (SEM)	5.3 (0.6)
Mean SVC-SA gradient (SEM)	1.0 (0.3)
Mean LV	30.4 (2.8)
Electrocardiography (n)	
Sinus rhythm	11
SR primary AV block	1
Junctional rhythm	1
Ectopic pacemaker	1
Sinus bradycardia	1
Chest roentgenography (n)	
Normal	12
Increased pulmonary vasculature	1
Increased pulmonary vasculature and enlarged heart	2

SVC = superior vena caval; SA = sinoatrial; LV = left ventricular.

went repeat infundibular resection, but some LVOTO persisted and he died after surgery from ventricular failure. Autopsy revealed evidence of the previous surgical procedures along with a stenotic pulmonic valve and biventricular hypertrophy. There was no evidence of systemic or pulmonary venous obstruction.

General clinical follow-up. The 15 long-term survivors have been followed from 9 to 64 months (mean 27; table 2). All patients were asymptomatic and doing well without limitations of activity and with grossly normal development. Two patients have weights lower than the 5th percentile for their ages, but the remaining patients are growing normally.

Chest roentgenography. Chest roentgenograms showed no evidence of pulmonary venous congestion in any patient. Twelve patients had normal cardiac silhouettes and normal pulmonary vascular markings. Two patients with a residual atrial shunt had evidence of increased pulmonary vascularity; one of these had mild cardiomegaly. One other patient had mild cardiomegaly with prominent pulmonary vascular markings.

Electrocardiography. No major arrhythmias were detected in any patient. Sinus rhythm was present in 11 patients, as determined from the follow-up electrocardiogram. Five patients had passive arrhythmias, including first-degree atrioventricular block, junctional

rhythm, ectopic atrial pacemaker with occasional junctional beats, and sinus bradycardia with occasional junctional beats.

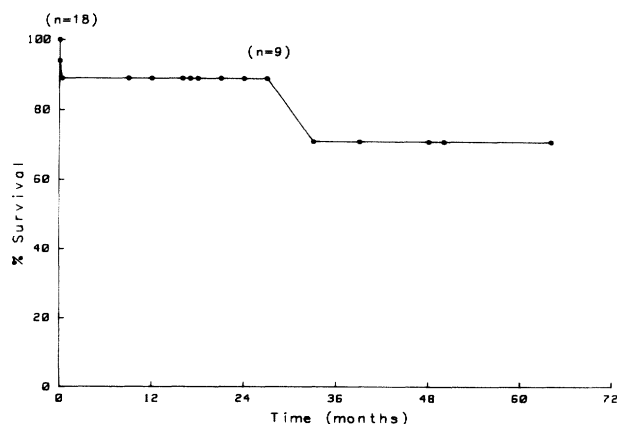
The patient with the sinus bradycardia had a possible episode of supraventricular tachycardia at another hospital, but the episode was not documented and has not recurred.

Cardiac catheterization. Postoperative cardiac catheterization was performed in 69% (11/16) of the patients who survived the perioperative period. The mean age at catheterization was 14.5 months (range 4 to 26). No patient demonstrated evidence of pulmonary or systemic venous obstruction. The superior vena caval-to-systemic venous atrial gradient ranged from 0 to 2.5 mm Hg. We were unable to enter the inferior vena cava from the femoral vein in two patients, but neither showed angiographic or hemodynamic evidence of systemic venous obstruction. All patients had evidence of good systemic and pulmonary ventricular function. Two patients had evidence of residual atrial shunts. One of the patients with a residual atrial shunt had evidence of mild LVOTO (23 mm Hg gradient) that was thought to be secondary to flow. One patient had severe LVOTO, with an 85 mm Hg gradient. One patient showed evidence of mitral incompetence that was thought to be catheter induced.

Survival analysis. Survival was analyzed with the Kaplan-Meier method for actuarial survival for small samples.¹⁹ The resulting estimated cumulative patient survival curve for the 18 patients is shown in figure 1. The estimated 2 year survival rate is 89%, with nine patients so far having survived 2 years.

Discussion

The infant with D-TGA after septostomy is at risk for many complications, including recurrent hypoxia,²⁰ cerebrovascular accidents,^{18, 21, 22} pulmonary

**FIGURE 1.** Cumulative patient survival computed by the Kaplan-Meier method.

hypertension,^{23, 24} growth retardation,²⁵ and death. Mortality for infants after septostomy and before correction varies from 12% to 28%.^{18, 20, 26–30} The high mortality for infants awaiting repair has led to earlier repair,^{8–17} but the optimal age has remained controversial.

Our data show that the Senning procedure can be performed in the first week of life with excellent results. The perioperative mortality of 11% (2/18) is comparable to that in other series in infants^{14, 16, 17} and in older patients.^{5, 11, 31–34} The two patients who died in the perioperative period were both moribund at the time of surgery because of complicated preoperative courses. The patient who died late after surgery developed intractable LVOTO and expired after the second surgical procedure to relieve the obstruction. It is encouraging that no deaths were associated with complications related to the Senning procedure; all were associated with preoperative condition or additional cardiac anomalies.

Few studies have taken into account preoperative morbidity and mortality along with perioperative mortality in the analysis of final outcome of treatment of D-TGA. Among infants with uncomplicated D-TGA who were treated with septostomy, Gutgesell et al.¹⁸ reported 8% mortality during the first month of life. Among the 1 month survivors they reported an additional 14% incidence of death or major complication in infants awaiting surgical correction. Their estimated 2 year survival for patients with uncomplicated and complicated (significant VSD and LVOTO) D-TGA was 70%. Our survival rate of 90% at 2 years compares favorably. Although the study by Gutgesell et al.¹⁸ included patients with complicated D-TGA and included patients who had undergone the Mustard procedure,² it highlights the significant morbidity and mortality that occur in infants with D-TGA after septostomy and before surgical correction.

Postoperative complications in survivors were transient without sequelae. No patient with postoperative rhythm disturbances showed evidence of significant arrhythmias on long-term follow-up. There were no long-term neurologic sequelae in the patients who experienced cardiopulmonary arrest or seizures. While the incidence of postoperative complications was disquieting, the long-term morbidity and mortality was not affected.

The long-term complications of the Senning procedure include pulmonary^{11, 17, 32, 34} and systemic venous obstruction,^{11, 17, 32} arrhythmias,^{5, 14, 17, 31, 33} and residual atrial shunts.^{5, 11, 17} The incidence of these complications with the Senning procedure is lower than with the

Mustard operation, but they remain a significant problem. Some authors^{8, 35} have suggested that complications occur more frequently with the Mustard operation in young patients, but this has not been found with the Senning procedure.¹¹

Systemic venous obstruction was not found in the patients in our series. This compares favorably with the reported incidence of up to 5% in infants¹⁷ and up to 10% in older patients.¹¹ Although the length of follow-up is limited (mean 27 months), our results are encouraging. Pulmonary venous obstruction was also not found in our patients. Others have reported incidences of up to 16% in infants¹⁷ and 10% in older patients.¹¹

The incidence of residual atrial shunts was 11% (2/18) in this series. Neither of the patients with a shunt is symptomatic, although one weighs less than the 5th percentile weight for his age. It is planned that both patients will have elective repair in the future. Development of atrial shunts has been reported after the Senning procedure, with an incidence up to 15% in older patients⁵ and an incidence of up to 12.5% in infants.¹¹ Whether this complication is related to age and size or some other factor is not known, but it has not been a significant cause of morbidity and mortality.

The incidence of LVOTO was 11% (2/18). In one patient it was severe and led to death and in the other patient it was mild and believed to be secondary to flow from an atrial shunt. In other series, LVOTO has been reported to occur in up to 59% of the patients, with severe LVOTO in 8%.^{11, 17}

The incidence of passive arrhythmias was 25% in our series and no active arrhythmias were noted. No morbidity or mortality was related to arrhythmia. Other series have reported transient junctional rhythm postoperatively^{5, 14, 17, 31, 32} and on follow-up.^{5, 17} The presence of active arrhythmias that require pacemaker implantation have also been reported after the Senning procedure.^{11, 14} Whether or not passive arrhythmia will change to active ones is not known, but these patients will require close follow-up.

No patient in this series showed evidence of cardio-respiratory compromise. They were all reported to be in general good health with grossly normal development. Two patients did have weights lower than the 5th percentile for their ages. One patient had an atrial septal defect on postoperative catheterization that may have been the cause of growth failure. The other patient had a normal postoperative study and there was no identifiable cause for his low weight.

This report and others³⁶ have demonstrated the ability to surgically correct the heart defects of children

with uncomplicated D-TGA during the first week of life and the operative mortality in this and the other studies was similar. The decision of whether to use the Jatene arterial switch procedure or to perform a Senning procedure should be based on the child's anatomy and the surgeons experience. The Senning procedure is not as technically demanding as the Jatene and may not result in as many late operative complications. The incidence of late anastomotic stricture at the coronary artery anastomosis or the arterial, pulmonary, or aortic anastomosis is not known, particularly in children who undergo the Jatene procedure as neonates. The incidence of late operative complications in this series of patients is gratifyingly low, but the incidence of late sequelae due to the right ventricle and the tricuspid valve being subjected to systemic pressures indicate the necessity for continued long-term follow-up.

Correcting heart defects in infants with D-TGA during the first week of life offers several advantages over later repair. With early repair the significant morbidity and mortality associated with palliation in infants with D-TGA^{18, 20-30} can be avoided, thereby improving the overall mortality and morbidity of infants with D-TGA. Early repair also has the advantage of decreasing the duration of cyanosis, which has been associated with poor somatic growth^{37, 38} and decreased cognitive and gross motor development^{39, 40} and has been postulated to be associated with late right ventricular dysfunction.^{33, 41} While the period of follow-up in this study was short (mean 27 months) and the number of patients was small ($n = 18$), the results presented are convincing evidence in favor of early elective repair of infants with D-TGA.

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References

- Blalock A, Hanlon CR: Interatrial septal defect — its experimental production under direct vision without interruption of the circulation. *Surg Gynecol Obstet* **87**: 183, 1948
- Blalock A, Hanlon CR: The surgical treatment of complete transposition of the aorta and the pulmonary artery. *Surg Gynecol Obstet* **90**: 1, 1950
- Mustard WT: Successful two stage correction of transposition of the great vessels. *Surgery* **55**: 469, 1964
- Senning A: Surgical correction of transposition of the great vessels. *Surgery* **45**: 966, 1959
- Quaeghebeur JM, Rohmer J, Brom AG: Revival of the Senning operation in the treatment of transposition of the great arteries. *Thorax* **32**: 517, 1977
- Jatene AD, Fontes VF, Paulista PP, Souza LCB, Neger F, Galantier M, Sousa JEMR: Anatomic correction of transposition of the great vessels. *J Thorac Cardiovasc Surg* **72**: 364, 1976
- Rashkind WJ, Miller WW: Creation of an atrial septal defect without thoracotomy — a palliative approach to transposition of the great arteries. *JAMA* **196**: 991, 1966
- Stark J, deLeval MR, Waterston DJ, Graham GR, Bonham-Carter RE: Corrective surgery of transposition of the great arteries in the first year of life. *J Thorac Cardiovasc Surg* **67**: 673, 1974
- Egloff LP, Freed MD, Dick M, Norwood WI, Castaneda AR: Early and late results with Mustard operation in infancy. *Ann Thorac Surg* **26**: 474, 1978
- Turley K, Ebert PA: Total correction of transposition of the great arteries. *J Thorac Cardiovasc Surg* **76**: 312, 1978
- Marx GR, Hougren TJ, Norwood WI, Fyler DC, Castaneda AR, Nadas AS: Transposition of the great arteries with intact ventricular septum: results of Mustard and Senning operations in 123 consecutive patients. *J Am Coll Cardiol* **1**: 476, 1983
- Kawabori I, Guntheroth WG, Morgan BC, Mohri H, Dillard DH: Surgical correction in infancy to reduce mortality in transposition of the great arteries. *Pediatrics* **60**: 83, 1977
- Bailey LL, Jacobson JG, Merritt WH, Doroshaw RW, Petry EL: Mustard operation in the first month of life. *Am J Cardiol* **49**: 766, 1982
- Fortune RL, Paquet M, Collins-Nakai RL, Duncan NF: Intracardiac repair of dextro-transposition of the great arteries in the newborn period. Early and late results. *J Thorac Cardiovasc Surg* **85**: 371, 1983
- Idriss FS, Paul MH, DeLeon SY, Muster AJ, Nikaidoh H, Tin N: Mustard operation for transposition of the great arteries in the first three months of life. *Am J Cardiol* **43**: 346, 1979 (abst)
- Mahony L, Turley K, Ebert P, Heymann MA: Long-term results after atrial repair of transposition of the great arteries in early infancy. *Circulation* **66**: 253, 1982
- DeLeon VH, Hougren TJ, Norwood WI, Lang P, Marx GR, Castaneda A: Results of the Senning operation for transposition of the great arteries with intact ventricular septum in neonates. *Circulation* **70**(suppl 1): I-21, 1984
- Gutgesell HP, Garson A, McNamara DG: Prognosis for the newborn with transposition of the great arteries. *Am J Cardiol* **44**: 96, 1979
- Lee ET: Statistical methods for survival data analysis. Belmont, CA, 1980, Lifetime Learning Publications, p 76
- Henny CG, Goldring D, Hartman AF, Weldon CS, Straus AW: Treatment of D-Transposition of the great arteries: management of hypoxemia after balloon atrial septostomy. *Am J Cardiol* **47**: 299, 1981
- Tynan M: Survival of infants with transposition of great arteries after balloon atrial septostomy. *Lancet* **1**: 621, 1971
- Parsons CG, Astley R, Burrows FGO, Singh SP: Transposition of the great arteries. A study of 65 infants followed 1 to 4 years after balloon septostomy. *Br Heart J* **33**: 725, 1971
- Newfield EA, Paul MH, Muster AJ, Idriss FS: Pulmonary vascular disease in transposition of the great vessels and intact ventricular septum. *Circulation* **59**: 525, 1979
- Clarkson PM, Neutze JM, Wardill JC, Barratt-Boyes BG: The pulmonary vascular bed in patients with complete transposition of the great arteries. *Circulation* **53**: 539, 1976
- Levy RJ, Rosenthal A, Castaneda AR, Nadas AS: Growth after surgical repair for simple D-Transposition of the great arteries. *Ann Thorac Surg* **25**: 225, 1978
- Rashkind WJ, Miller WW: Transposition of the great arteries. Results of palliation by balloon atrioseptostomy in thirty-one infants. *Circulation* **38**: 453, 1968
- Clarkson PM, Barratt-Boyes BG, Neutze JM, Lowes JB: Results over a ten year period of palliation followed by corrective surgery for complete transposition of the great arteries. *Circulation* **45**: 1251, 1972
- Kidd BSL: The fate of children with transposition of the great arteries following balloon atrial septostomy. In Kidd BSL, Rowe RD, editors: The children with congenital heart disease after surgery. New York, 1976, Futura, p 153
- Gutgesell HP, McNamara DG: Transposition of the great arteries: results of treatment with early palliation and late intracardiac repair. *Circulation* **51**: 32, 1975
- Neches WH, Mullins CE, McNamara DG: The infant with transposition of the great arteries. II. Results of balloon atrial septostomy. *Am Heart J* **84**: 603, 1972
- Parenzan L, Locatelli G, Alfieri O, Villani M, Invernizzi G, Pacifico AD: The Senning operation for transposition of the great arteries. *J Thorac Cardiovasc Surg* **76**: 305, 1978
- Otero Coto E, Norwood WI, Lang P, Castaneda AR: Modified

- Senning operation for treatment of transposition of the great arteries. *J Thorac Cardiovasc Surg* **78**: 721, 1979
33. Bender HW Jr, Graham TP Jr, Boucek RJ, Walker WE, Boerth RG: Comparative operative results of the Senning and Mustard procedures for transposition of the great arteries. *Circulation* **62**(suppl 1): I-197, 1980
34. Alvarez Diaz F, Cabo Salvador J, Rivas J, Alvarado F, Cordovilla Zurdo G: Technical advances in the Senning operation. *Thorac Cardiovasc Surg* **31**: 105, 1983
35. Clarkson PM, Neutze JM, Barratt-Boyes BG, Brandt PWT: Late postoperative hemodynamic results and cineangiographic findings after mustard atrial baffle repair of transposition of the great arteries. *Circulation* **53**: 525, 1976
36. Castaneda AR, Norwood WI, Jonas RA, Colon SD, Sanders SP, Lang P: Transposition of the great arteries and intact ventricular septum: anatomical repair in neonate. *Ann Thorac Surg* **38**: 438, 1984
37. Feldt RH, Strickler GS, Weidman WH: Growth of children with congenital heart disease. *Am J Dis Child* **117**: 573, 1969
38. Linde LM, Dunn OJ, Schireson R, Rasof B: Growth in children with congenital heart disease. *J Pediatr* **70**: 413, 1967
39. Newburger JW, Silbert AR, Buckley LP, Fyler DC: Cognitive function and age at repair of transposition of the great arteries in children. *N Engl J Med* **310**: 1495, 1984
40. Newburger JW, Tucker AD, Silbert AR, Fyler DC: Motor function and timing of surgery in transposition of the great arteries, intact ventricular septum. *Pediatr Cardiol* **4**: 317, 1983 (abst)
41. Graham TP Jr, Atwood GF, Boucek RJ Jr, Boerth RC, Bender HW: Abnormalities of right ventricular function following Mustard's operation for transposition of the great arteries. *Circulation* **52**: 678, 1975

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