Our surgical experience and mid-term results with the Senning procedure

Senning işlemiyle elde ettiğimiz cerrahi deneyimimiz ve orta dönem sonuçlarımız

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Background: This study aims to evaluate the mid-term surgical results of Senning procedure in infant patients with transposition of great arteries (TGA).

Methods: Seven patients (mean age 23.6±32.5 months; range 6 to 96 months and mean weight 9.6±4.6 kg; range 7 to 20 kg) who underwent operation with the diagnosis of d-transposition of great arteries (d-TGA) were included in the study. Simple TGA with atrial septal defect was observed in three of the seven patients and in the remain four patients complex TGA (ventricular septal defect and pulmonary stenosis) was present. Before Senning operation, four (57%) patients had undergone balloon atrial septostomy. Mean preoperative pulmonary arterial pressure was 34.6±27.5 mmHg. Mean preoperative systemic arterial oxygen saturation was 76.3±9.2 percent. Preoperatively, New York Heart Association (NYHA) functional class II was observed in six (86%) patients and class III in one (14%) patient. The retrospectively analyzed parameters included cardiopulmonary bypass time, aortic cross-clamp time, mechanical ventilation duration, and intensive care unit stay.

Results: One (14%) patient died in the hospital after the operation. Mean cardiopulmonary bypass time was 155.9±23.6 minutes and aortic cross-clamp time was 99.9±23.5 minutes. Postoperatively all patients remained in normal sinus rhythm, except for one patient who developed complete atrioventricular block and this patient required a permanent pacemaker. Mild superior vena cava baffle obstruction developed in one patient with a mean gradient of 2 mmHg. The mean follow-up was 20.4±18.3 months. Five (84%) patients were classified as class I according to the NYHA functional classification.

Conclusion: Senning procedure performed in patients with d-TGA during infancy period is a safe operation with low mortality and morbidity rates in the mid-term follow-up.

Key words: Morbidity; mortality; Senning procedure; transposition of great arteries.

Amaç: Büyük arter transpozisyonu (TGA) tanısı ile ameliyat edilen bebek hastalarda Senning işleminin orta dönem cerrahi sonuçları değerlendirildi.

Çalışma planı: Büyük arter d-transpozisyonu (d-TGA) tanısı ile ameliyat edilen yedi hasta (ort. yaş 23.6±32.5 ay; dağılım 6-96 ay ve ort. ağırlık 9.6±4.6 kg; dağılım 7-20 kg) çalışmaya dahil edildi. Yedi hastanın üçünde basit TGA ve atriyal septal defekt gözlendi, kalan dört hastada ise kompleks TGA (ventriküler septal defekt ve pulmoner stenozlu) vardı. Senning ameliyatı öncesi dört hastada (%57) balon atriyal septostomi yapılmış idi. Ortalama ameliyat öncesi pulmoner arter basıncı 34.6±27.5 mmHg idi. Ameliyat öncesi ortalama sistemik arteriyel oksijen satürasyonu yüzde 76.3±9.2 idi. Ameliyat öncesi New York Heart Association (NYHA) sınıflandırması altı hastada (%86) fonksiyonel sınıf II ve bir hastada (%14) sınıf III idi. Retrospektif olarak analiz edilen parametreler kardiyopulmoner bypass zamanını, aortik kros klemp zamanını, mekanik ventilasyonu süresini ve yoğun bakımda kalma süresini içermekteydi.

Bulgular: Bir hasta (%14) ameliyat sonrasında hastanede kaybedildi. Ortalama kardiyopulmoner bypass zamanı 155.9±23.6 dakika ve aortik kros klemp zamanı 99.9±23.5 dakika idi. Ameliyat sonrasında komplet atrioventriküler blok gelişen ve kalıcı pacemaker yerleştirilen bir hasta dışında tüm hastalar normal sinus ritminde kaldı. Bir hastada hafif süperiyor vena kava baffle obstrüksiyonu gelişti ve ortalama gradyan 2 mmHg olarak ölçüldü. Ortalama takip süresi 20.4±18.3 ay idi. Beş hasta (%84) NYHA fonksiyonel sınıflandırmasına göre sınıf I olarak değerlendirildi.

Sonuç: İnfant döneminde d-TGA'lı hastalarda gerçekleştirilen Senning işlemi düşük mortalite ve morbidite oranları ile orta dönemde izlem sürecinde güvenli bir ameliyattır.

Anahtar sözcükler: Morbidite; mortalite; Senning işlemi; büyük arter transpozisyonu.

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Transposition of the great arteries (d-TGA) is observed in approximately 1:2100 to 1:4500 of all live births and constitute about 10% of all congenital heart diseases observed in childhood.[1] Transposition of the great arteries is characterised by atrioventricular (AV) concordance and ventriculo-arterial discordance. The circulatory mixing occurs via a patent ductus, ventricular septal defect (VSD) or atrial septal defect (ASD). If ASD or VSD is not present, the physiological closure of the ductus causes abrupt cyanosis. Cyanotic babies may be treated percutaneously with a Rashkind[2] atrial balloon septostomy. Creating an atrial septal defect in patients with d-TGA dramatically improves their oxygenation. Advances in the pediatric echocardiographic exam in the neonatal period provide early diagnosis of d-TGA. A definitive surgical procedure in these babies is the arterial switch operation. The aim of the arterial switch operation is to achieve complete physiological and anatomical repair. Recently, in many centers, this procedure is usually performed with success and the mortality rates have improved considerably.[3] The necessity of performing Senning operations has diminished and it is less frequently done compared to arterial switch operations.

The first atrial switch procedure was performed by Senning in 1958 and involves the creation of an atrial baffle from autologous tissue to direct the venous return to the contralateral AV valve and ventricle. As a result, oxygenated blood from the pulmonary venous return is directed into the morphological right ventricle (RV) and deoxygenated blood from the vena cava is directed to the mitral valve. Operative mortality of the Senning procedure ranges from 0% to 15.7%.[4]

Our goal in this study was to evaluate the factors that are involved in the development of systemic ventricular dysfunction and to investigate the most commonly observed postoperative parameters that are important in the follow-up after the Senning procedure. The investigated postoperative parameters include; tricuspid regurgitation, rhythm disturbances and atrial baffle obstruction or leaks.

PATIENTS AND METHODS

Patients

Between January 2005 and October 2009, seven patients (6 boys, 1 girl; mean age 23.6±32.5 months; range 6 to 96 months) underwent the Senning procedure and a retrospective analysis of their data was performed through the evaluation of their charts. The study design includes retrospective chart investigation, prospective phone calls and clinical follow-ups. Patient consent was obtained during admission to the hospital for all procedures and research purposes and the study was conducted after approval of the Institutional Ethical Committee.

The preoperative diagnosis was simple TGA with ASD in three patients and complex TGA (VSD, PS) in four patients. Before the Senning operation, four (57%) patients required balloon atrial septostomy (Table 1). A total of six survivors (86%) out of seven patients had follow-up visits every six months at our institution. During this visit, all patients had history, physical examination, electrocardiogram (ECG), radiography and echocardiography and valve-related complications, arrhythmias and NYHA (New York Heart Association) classification were also evaluated.

Transthoracic echocardiography was performed in follow-up visits using a Vivid three System (GE, Vingmed Ultrasound, Horten, Norway). The severity of baffle obstructions, valve competences, ventricular end-diastolic and end-systolic dimensions, atrial diameters and systolic pulmonary artery pressures were evaluated.

Surgical Procedure

All repairs were performed through a median sternotomy and under cardiopulmonary bypass (CPB) with

Table 1. Demographic characteristics

Case no	Age (months/gender)	Weight (kg)	BSA	Echocardiographic findings	Surgery	Follow-up (month)	NYHA class	Outcome
1	96/M	20	0.98	TGA, ASD (BAS)	SP	69	II	Well
2	24/M	8.3	0.41	TGA, ASD (BAS)	SP	22	II	Well
3	11/M	8	0.42	TGA, ASD (BAS), VSD	SP	–	–	Died
4	9/M	7.3	0.43	TGA, ASD, VSD, PS	SP	14	I	Well
				VSD closure				
5	6/F	7	0.37	TGA, ASD, VSD, PS	SP	16	II	Well
				VSD closure				
6	10/M	7.5	0.44	TGA, ASD (BAS)	SP	18	I	Well
7	9/M	9.3	TGA, ASD, VSD	TGA, ASD, VSD	SP	4	II	Well
					VSD closure			

BSA: Basal surface area; NYHA: New York Heart Association classification; TGA: Transpositon of great arteries; ASD: Atrial septal defect; BAS: Balloon atrial septostomy; PS: Pulmoner stenosis; SP: Senning procedure; VSD: Ventricular septal defect.

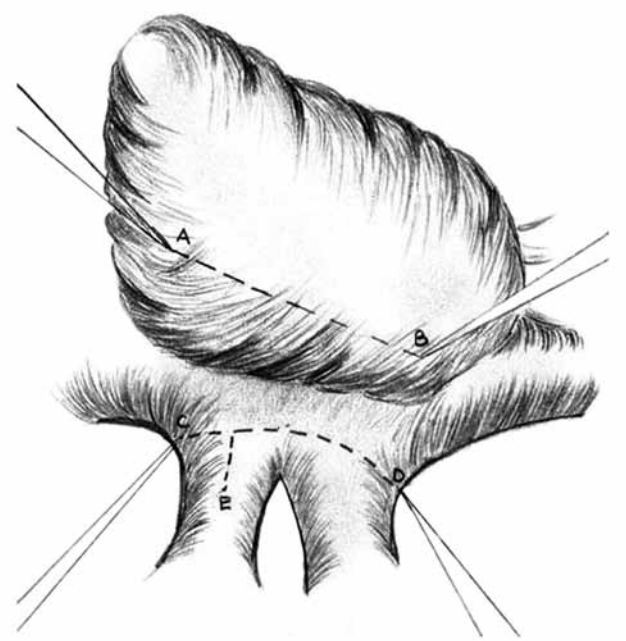

Fig. 1. (a, b) Right and **(c, d)** left atrial incisions. **(e)** A nick over the right pulmonary vein.

moderate hemodilution and hypothermia (28 °C). After pericardiotomy, the right atrium was marked with two stitches (A and B) indicating the site of the planned right atriotomy. Another line (B and D) was planned for left atriotomy at the level of the crista terminalis. A small nick incision was performed on the right pulmonary vein (E) (Fig. 1). The preferred cannulation technique requires that it is performed at a distance as far as possible outside of the right atrium. Standard techniques were performed during CPB. After cross-clamping, cardioplegia was administered. A right atriotomy was performed through A and B lines and an incision was made into the interatrial septum around the limits of the fossa ovalis. Coronary sinus cutback was done to augment the venous baffle pathways. A posteriorly based flap was created with a small pericardial patch and lowered into the left atrium. A suture was placed above the orifices of the left pulmonary veins (Fig. 2). The systemic venous tunnel was completed by suturing the free edge of the right atriotomy around both caval orifices. The systemic venous pathway was directed into the mitral valve. Pulmonary venous rerouting was accomplished after a horizontal incision was made into the left atrium, parallel to the interatrial groove. Also a nick was done to expand the orifice area of pulmonary venous return through the tricuspid valve into the right ventricle. If there was a suspicion of pulmonary venous pathway obstruction, than a small pericardial patch could be placed over the right superior pulmonary vein (Fig. 3). In patients with VSD, a continous 5/0 prolene suture was used for closure. In all these three patients pulmonary stenosis was mild therefore no additional procedure was done (Table 1). The free edge of the right atrium was brought down to the left atriotomy incision. A shallow bite should be taken over the entrance of the superior vena cava to the right atrium or the suture line could be placed over the superior vena cava (Fig. 4).

RESULTS

The mean weight of the patients was 9.6±4.6 kg (range 7 to 20). The mean basal surface area (BSA) was 0.49±0.22. Preoperative New York Heart Association (NYHA) functional class II was observed in six (86%) of the patients and class III was seen in one (14%)

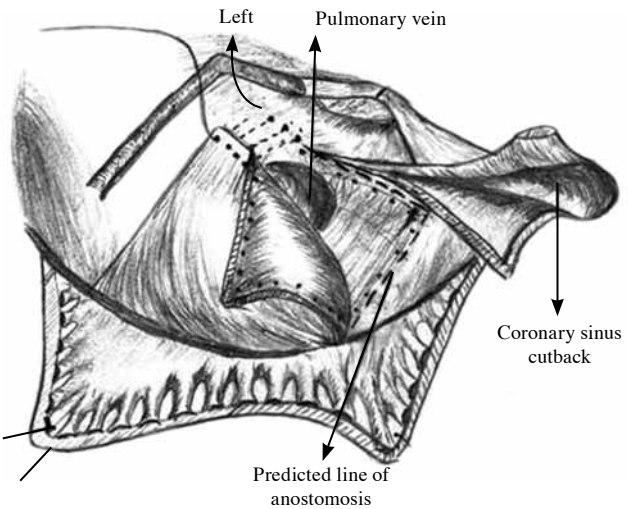

Fig. 2. Coronary sinus cutback, a posteriorly based flap were shown. A suture was placed above the orifices of the left pulmonary veins.

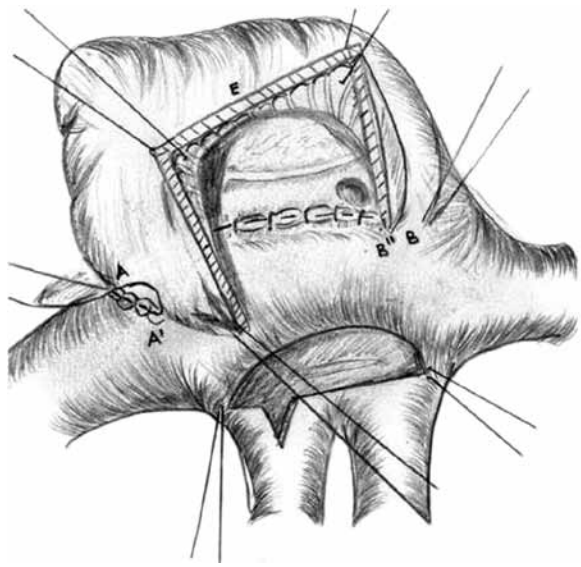

Fig. 3. Creation of pulmonary venous pathway.

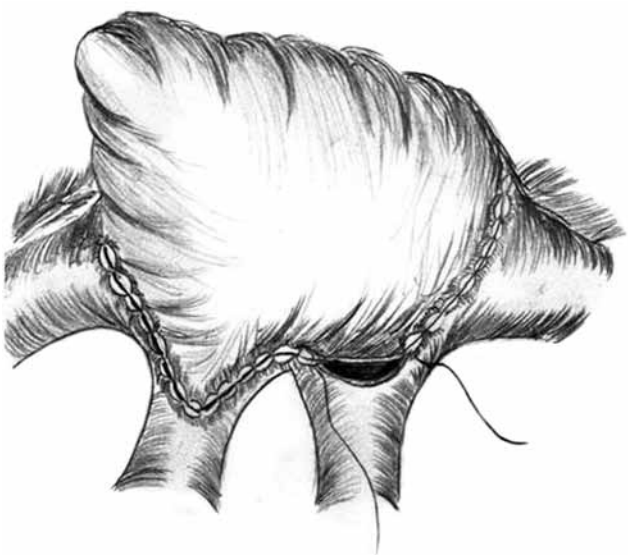

Fig. 4. Completion of pulmonary venous pathway by a shallow bite over the entrance of the superior vena cava to the right atrium or the suture line can be placed over the superior vena cava.

patient. Mean preoperative pulmonary arterial pressure was 34.6±27.5 mmHg. Mean preoperative systemic arterial oxygen saturation was 76.3±9.2%.

Surgery was done with moderate hypothermia (25.4±1.6). Mean CPB was 155.9±23.6 minutes and aortic cross-clamp time was 99.9±23.5 minutes. The average duration of follow-up was 20.4±18.3 months (range 5 to 96).

Postoperatively, six patients remained in normal sinus rhythm and only one patient (17%) developed complete atrioventricular block. This patient required a permanent pacemaker. Mild superior vena cava baffle obstruction developed in another patient and a mean gradient of 2 mmHg was observed. One patient (14%) died due to sepsis in the early postoperative period. Postoperatively, the NYHA functional class of six late survivors was class I to II in five (84%) and class III in only one.

DISCUSSION

In d-TGA, the normal position of the arteries is reversed with ventriculoarterial discordance. In this pathology, early surgery is essential for the survival of the patient. The arterial switch operation restores the morphologic left ventricle and mitral valve to the systemic circulation. Recently, many authorities on this topic agree that the arterial switch operation is the optimal treatment for transposition of the great arteries in the neonatal period showing good results in the follow-up period.[5]

After the neonatal period of life, in approximately half of the infants with d-TGA and an intact ventricular septum the left ventricle functions deteriorates.[6] In this situation, the Senning procedure could be an alternative surgical procedure to arterial switch operation in the early infancy period. The Senning operation was first performed by Ake Senning in 1959. This operation was considered as a complex surgical procedure that requires technical experience. One of the most significant complications after the Senning procedure for physiologic repair of transposition is dysfunction of the systemic (morphologically right) ventricle and/or atrioventricular valve.[7]

In 1964, Mustard[8] started to use a new technique involving the use of a large pericardial patch to redirect the venous return. This technique is considered less complicated and easier to perform but it is associated with serious complications such as obstruction in the caval and pulmonary venous pathways, increased incidence of arrhythmias and development of right ventricular dysfunctions.[9,10]

The Senning operation is an alternative to the two-stage arterial switch operation after the neonatal period.[11] The atrial switch operation has been evaluated extensively in the literature and the findings of the studies determine that it is associated with low risk of postoperative complications and favorable long-term results in infants with d-TGA.[11-13] Another indication for the Senning procedure is palliation of patients with pulmonary vascular disease from an associated ventricular septal defect. The Senning procedure improves the arterial oxygen saturation in patients who would not tolerate a combined procedure of ventricular septal defect closure and arterial switch. The atrial switch operation is also required in patients with congenitally corrected transposition and this operation includes both a venous and an arterial switch (double switch) procedure.[11] Furthermore, the Senning procedure could be a surgical option in isolated ventricular inversion and in this pathology there is AV discordance with ventriculoarterial concordance as well.[12]

In our study, nine months after the operation, one patient (8 years-old) developed complete AV block and this rhythm disturbance was treated by implantation of permanent pacemaker. Sinus node dysfunction is common in older ages, and the reason is related to the damage of the sinus node and atrial conduction tissue. Development of both atrial bradyarrhythmias and tachyarrhythmias are late complications of atrial baffle surgery and these are likely to occur in the late-term period.[13] In the series of Gelatt et al.,[14] sinus rhythm was present in 77% of the patients at five years and in only 40% of the patients at 20 years. Atrial arrhythmias can precipitate a significant deterioration in systemic ventricular function, and in general, sinus rhythm should

be restored when possible. Antiarrhythmic drugs should be used in caution and precipitation of heart blocks should be prevented.

In our study, the echocardiographic examinations in the follow-up periods showed that none of the late survivors developed right ventricular dysfunction or tricuspid regurgitation. After the Senning procedure, the RV is the systemic ventricle. Right ventricle dysfunction and tricuspid regurgitation may be seen in the late-term follow-up period. Mild to moderate tricuspid regurgitation is frequent in adult survivors and tends to worsen progressively. Both RV dysfunction and tricuspid regurgitation increase the propensity for atrial arrhythmias.[15]

One of our patients had mild superior vena cava obstruction. Narrowing of the intra-atrial buffle is a rare late complication but should always be assessed by transthoracic Doppler echocardiography.[16] The superior vena cava is more commonly involved than the inferior vena cava and this may produce superior vena cava syndrome (SVC syndrome). Inferior vena cava obstruction may cause hepatic congestion or cirrhosis. In a meta-analysis by Graham et al.,[17] it is reported that both caval obstruction and pulmonary venous stenosis are more frequent after a Mustard operation than after a Senning operation.

In our study, mean pulmonary artery pressures in most of the patients were above 35 mmHg, however, pulmonary stenosis was observed in only two patients. Pulmonary hypertension is a serious complication of the Senning procedure that survives to adulthood. The exact cause is not completely clear, but patients appear more likely to develop pulmonary vascular disease if an operation is performed after the infancy period.[18]

Diminution of early left ventricular filling has been reported after both Mustard and Senning operations in several publications and was also assessed by Doppler ultrasound.[19] In the study by Reich et al.,[20] it was reported that in patients who underwent atrial correction of transposition of the great arteries, there was reduced exercise tolerance and inability to increase cardiac output on exercise. These findings suggest that there is inability to increase the flow over the intra-atrial baffle. Impaired left ventricular filling may be a major factor influencing performance of patients after intra-atrial correction of transposition.

After atrial switch operations arrythmias, baffle leak, systemic or pulmonary return obstructions, RV and tricuspid valve insufficiencies can be observed as late period complications. The short- and mid-term results of follow-ups of arterial switch operations provide data that it has better clinical outcomes in the short and mid-term periods in comparison with the atrial switch operations. For this reason, in recent studies it is reported that the arterial switch operation (also called the Jatene procedure) is a more commonly preferred method.[21-25] The most important advantage of performing an arterial switch operation is that the left ventricle (LV) becomes the systemic ventricle after the operation. The structural characteristics of RV prohibits its use as a systemic ventricle and its work is restricted against a highly pressurized systemic flow. The right angle between the RV entrance and exit pathways provides a comma like figure to the RV cavity. For this reason, when the ventricle contracts, a peristaltic flow occurs from inflow to outflow tract. The ellipsoid configuration of the LV causes a spiral shaped flow. This causes a strong and rapid blood flow. In the RV cavity, the connection parts of the papillary muscles to the tricuspid valve are shaped in triangular form. The muscle spindle that connects to the septal part of the valve are in opposite direction to the muscle spindles that connect to the free wall. In this way, the dilatation in the RV cavity increases the distance between these connection parts. Finally, closure of the tricuspid valve leaflets are prevented that eventually causes development of tricuspid valve insufficiency.[26]

Nowadays, the arterial switch operation is the first surgical option in the treatment of TGA in many centers. After the neonatal period other surgical treatment modalities can be done depending on the surgical team experience and patient characteristics. In our clinic, the Senning procedure is the surgical treatment in patients with late referral and inadequate left ventricul functions.

In our series, the mortality rate was 14%. Operative mortality of the Senning procedure ranges from 0 to 15.7%. This depends on the slower learning curve and experience of the team. Most patients showed physical growth and an active childhood period after the surgery.

In conclusion, after the newborn period, in certain situations, the Senning procedure can be performed safely and our mid-term follow-up results demonstrate low morbidity and mortality in patients with d-TGA.

Study limitation

This study has a relatively small sample size. The strength of our study is that our single center experience provides uniformity of surgical techniques and perioperative care.

Declaration of conflicting interests

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REFERENCES

1. Mavroudis C, Backer CL. Transposition of the great arteries. In: Mavroudis C, Backer CL, editors. Pediatric cardiac surgery. 3rd ed. PhiladelphiaP Mosby; 2003. p. 442-5.
2. Levin DL, Paul MH, Muster AJ, Newfeld EA, Waldman JD. d-Transposition of the great vessels in the neonate. A clinical diagnosis. Arch Intern Med Arch Intern Med 1977;137:1421-5.
3. de Leval MR, Carthey J, Wright DJ, Farewell VT, Reason JT. Human factors and cardiac surgery: a multicenter study. J Thorac Cardiovasc Surg 2000;119:661-72.
4. Senning A. Surgical correction of transposition of the great vessels. Surgery 1959;45:966-80.
5. Ross D, Rickards A, Somerville J. Transposition of the great arteries: logical anatomical arterial correction. Br Med J 1976;1:1109-11.
6. Nakazawa M, Oyama K, Imai Y, Nojima K, Aotsuka H, Satomi G, et al. Criteria for two-staged arterial switch operation for simple transposition of great arteries. Circulation 1988;78:124-31.
7. Bender HW Jr, Stewart JR, Merrill WH, Hammon JW Jr, Graham TP Jr. Ten years' experience with the Senning operation for transposition of the great arteries: physiological results and late follow-up. Ann Thorac Surg 1989;47:218-23.
8. Mustard WT. Successful two-stage correction of transposition of the great vessels. Surgery 1964;55:469-72.
9. Wells WJ, Blackstone E, and Congenital Heart Surgeons Society. Intermediate outcome after Mustard and Senning procedures: a study by the Congenital Heart Surgeons Society. In: Williams WG, editor. Pediatric Cardiac Surgery. Annual of the Seminars in Thoracic and Cardiovascular Surgery. Vol. 3. Philadelphia: W.B. Saunders; 2000. p. 186-97.
10. Duster MC, Bink-Boelkens MT, Wampler D, Gillette PC, McNamara DG, Cooley DA. Long-term follow-up of dysrhythmias following the Mustard procedure. Am Heart J 1985;109:1323-6.
11. Ilbawi MN, Ocampo CB, Allen BS, Barth MJ, Roberson DA, Chiemmongkoltip P, et al. Intermediate results of the anatomic repair for congenitally corrected transposition. Ann Thorac Surg 2002;73:594-9.
12. Konstantinov IE, Alexi-Meskishvili VV, Williams WG, Freedom RM, Van Praagh R. Atrial switch operation: past, present, and future. Ann Thorac Surg 2004;77:2250-8.
13. Warnes CA, Somerville J. Transposition of the great arteries: late results in adolescents and adults after the Mustard procedure. Br Heart J 1987;58:148-55.
14. Gelatt M, Hamilton RM, McCrindle BW, Connelly M, Davis A, Harris L, et al. Arrhythmia and mortality after the Mustard procedure: a 30-year single-center experience. J Am Coll Cardiol 1997;29:194-201.
15. Buch J, Wennevold A, Jacobsen JR, Hvid-Jacobsen K, Lauridsen P. Long-term follow-up of right ventricular function after Mustard operation for transposition of the great arteries. Scand J Thorac Cardiovasc Surg 1988;22:197-202.
16. Vick GW 3rd, Murphy DJ Jr, Ludomirsky A, Morrow WR, Morriss MJ, Danford DA, et al. Pulmonary venous and systemic ventricular inflow obstruction in patients with congenital heart disease: detection by combined two-dimensional and Doppler echocardiography. J Am Coll Cardiol 1987;9:580-7.
17. Graham TP Jr, Burger J, Bender HW, Hammon JW, Boucek RJ Jr, Appleton S. Improved right ventricular function after intra-atrial repair of transposition of the great arteries. Circulation 1985;72:II45-51.
18. Ebenroth ES, Hurwitz RA, Cordes TM. Late onset of pulmonary hypertension after successful Mustard surgery for d-transposition of the great arteries. Am J Cardiol 2000; 85:127-30, A10.
19. Wyse RK, Macartney FJ, Rohmer J, Ottenkamp J, Brom AG. Differential atrial filling after Mustard and Senning repairs. Detection by transcutaneous Doppler ultrasound. Br Heart J 1980;44:692-8.
20. Reich O, Vorísková M, Ruth C, Krejcír M, Marek J, Skovránek J, et al. Long-term ventricular performance after intra-atrial correction of transposition: left ventricular filling is the major limitation. Heart 1997;78:376-81.
21. Clarkson PM, Neutze JM, Wardill JC, Barratt-Boyes BG. The pulmonary vascular bed in patients with complete transposition of the great arteries. Circulation 1976;53:539-43.
22. Kouchoukos NT, Blackstone EH, Doty DB, Hanley FL, Karp RB. Complete transposition of the great arteries. In: Kirklin/Barratt-Boyes cardiac surgery: morphology, diagnostic criteria, natural history, techniques, results, and indications. 3rd ed. Philadelphia: Churchill Livingstone; 2003. p. 1438-508.
23. Prifti E, Crucean A, Bonacchi M, Bernabei M, Murzi B, Luisi SV, et al. Early and long term outcome of the arterial switch operation for transposition of the great arteries: predictors and functional evaluation. Eur J Cardiothorac Surg 2002;22:864-73.
24. Blume ED, Wernovsky G. Long-term results of arterial switch repair of transposition of the great vessels. Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu 1998;1:129-38.
25. Karl TR, Cochrane A, Brizard CP. Arterial switch operation. Surgical solutions to complex problems. Tex Heart Inst J 1997;24:322-33.
26. Williams WG, McCrindle BW, Ashburn DA, Jonas RA, Mavroudis C, Blackstone EH. Congenital Heart Surgeon's Society. Outcomes of 829 neonates with complete transposition of the great arteries 12-17 years after repair. Eur J Cardiothorac Surg 2003;24:1-9.