CONGENITAL CARDIOLOGY TODAY

Timely News and Information for BC/BE Congenital/Structural Cardiologists and Surgeons

Euro PCR
May 25 - 28, 2010; Paris, France
www.europcr.com

Heart Failure Congress
May 29 - June 1, 2010; Berlin, Germany
www.escardio.org/congresses

International Conference on Pulmonary Circulation
June 2-5, 2010; Prague, Czech Republic
www.pc2010.eu

Parma International Echo Meeting
June 28- 30, 2010; Parma, Italy
www.unipr.it/arpa/echomeet/home.html

APPCS 2010
July 6- 9, 2010; Tokyo, Japan
www.appcs.org/2010/

Univentricular Heart – Management and Prognosis

By Lars Idorn, MD, Research Fellow; Annette S. Jensen, MD, Research Fellow; Klaus Juul, MD, PhD; Jesper I. Reimers, MD, DMSc; and Lars Søndergaard, MD, DMSc

Abstract

Fontan-type operations in patients with functionally univentricular hearts have been performed for almost 40 years. Since the first description of the Fontan operation, short- and medium-term operative survival has been good in the current era due to careful patient selection, modifications in surgical techniques, and advances in postoperative care. However, a number of serious long-term complications affect most patients. Nonetheless, the prevalence of univentriucular patients is increasing as the number of late survivors increases. Caregivers will therefore be evermore faced with the challenge of recognizing and managing the Fontan related complications and patients with failing Fontan physiology.

This review discusses the current surgical management of patients with functionally univentricular heart (UVH) and long-term sequelae of the univentricular circulation based on literature on outcome after the Fontan procedure.

Introduction

Birth prevalence of children with a functionally univentricular heart has recently been reported to 3 to 4 per 100 of children born with congenital heart defects, yielding a birth prevalence of 0.2 to 0.3 per 1000 live births.[1] The definition of this heterogenic patient group has been much debated, using either anatomical or functional definitions. Much of the surgical literature over the last 30 years, however, uses a functional definition of UVH; namely, that UVH is characterized by hypoplasia of one of the ventricles making it incapable of independently supporting either the pulmonary or the systemic circulation or making surgical biventricular repair impossible.[2] UVH might be divided into: single left ventricle in which the right ventricle is rudimentary (e.g. double inlet left ventricle (DILV)), tricuspid atresia (TA), severe Ebstein's Anomaly, and some patients with pulmonary atresia with intact ventricular septum (PA/IVS) and single right ventricle (e.g. hypoplastic left heart syndrome (HLHS), mitral atresia (MA), and complex forms of double outlet right ventricle (DORV)).

The natural history of UVH is generally poor with a reported survival rate of less than 50% at one year and 10% at ten years.[3] However, the introduction of palliative treatment as originally described by Fontan and Baudet in 1971[4] has dramatically changed the short- and medium-term prognosis for UVH.[5] The technique has evolved and is today applied as a Total Cavo-Pulmonary Connection (TCPC).[6]

Surgical Management

The TCPC operation is generally performed in three stages.[7] The concept of staging and improved surgical techniques have reduced morbidity and mortality considerably during the past decades.[5, 7-11]
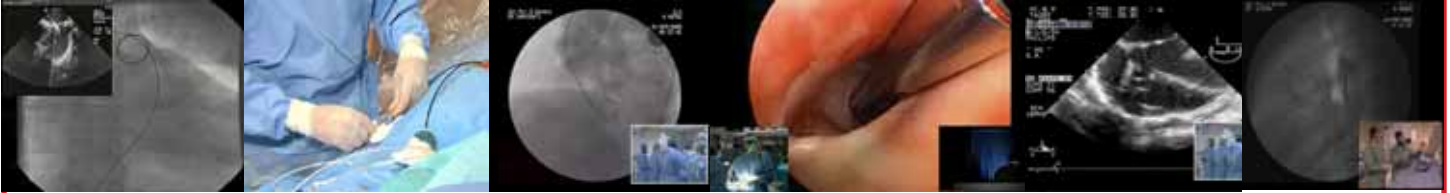

Do you or your colleagues have interesting research results, observations, human interest stories, reports of meetings, etc. that you would like to share with the Congenital Cardiology community?

Submit a brief summary of your proposed article to: RichardK@CCT.bz

The final manuscript may be between 400-4,000 words, and contain pictures, graphs, charts and tables.

First stage is in the neonatal period and aims to regulate pulmonary blood flow, either by banding of the main pulmonary artery (MPA) in children with excessive pulmonary blood flow, or by discontinuation of the MPA and insertion of an aortopulmonary shunt, i.e. modified Blalock-Taussig shunt.[12] For children with systemic outflow obstruction or HLHS the Damus-Kaye-Stansel anastomosis[12] and Norwood-type procedure[13] will augment the systemic blood flow while pulmonary blood flow is controlled by a Blalock-Taussig shunt or a right ventricular-pulmonary artery conduit.[14, 15] Furthermore, malformations such as obstruction of the aortic arch and restrictive foramen ovale have to be addressed during first stage.

Second stage is performed in order to volume unload the functional ventricle. It includes an anastomosis between the superior vena cava and the pulmonary artery (bidirectional Glenn anastomosis (BDG)), and simultaneous discontinuation of the MPA and removal of the Blalock-Taussig shunt. The importance of ventricular wall size thickness has been realized to be crucial to the success of the TCPC operation.[16] When ventricular volume overload is suddenly removed after the TCPC operation, geometric alterations occur in the face of relatively unchanging ventricular mass but considerable decrease in cavity size. These sudden changes may impair diastolic ventricular function and result in potentially lethal low cardiac output stage postoperatively.[16] The BDG is therefore performed to allow early reduction of the volume overload of the functional ventricle and a gradual remodeling of ventricular geometry before completion of the TCPC operation. Staging the TCPC operation has resulted in a decrease in morbidity and mortality.[9, 11] Timing of the BDG procedure has been discussed in several studies, with many highlighting the benefit of performing an "early" BDG procedure between two and six months of age.[17-20]

In the third and last stage the TCPC circulation is completed, which separates the systemic and pulmonary venous return and provides pulmonary blood flow without a ventricular pumping chamber. The original Fontan operation consisted of an anastomosis between the right atrium and the central pulmonary arteries (RA-PA connection).[4] Follow-up, however, revealed a high incidence of postoperative atrial

arrhythmia and thromboembolic events due to atrial enlargement.[21] The technique has evolved through a lateral tunnel procedure[8] and is today in most centres performed as an extracardiac tunnel procedure by insertion of a Gore-tex tunnel between the inferior vena cava and the pulmonary artery.[8, 22] Thereby atrial manipulation is minimized and atrial incision and suture lines eliminated. However, advocates of the lateral tunnel approach are concerned about the possible increased likelihood of thrombosis or stenosis in an external conduit and the lack of growth potential. Insufficient long-term data are available to differentiate the outcome between these two approaches, however, early and intermediate results seem to be in favor of the extracardiac conduit.[22-24] Unlike BDG, no consensus exists about the optimal timing of the TCPC operation. Some centers advocate early intervention to minimize the effect of persistent cyanosis on patient growth, those of volume overload on the ventricle, and the risk of paradoxical embolism.[25] However, very young infants have shown higher values of pulmonary vascular resistance, lower oxygen saturation and a higher prevalence of arrhythmias after TCPC than older ones.[26] Furthermore, several groups demonstrated that TCPC cannot be considered a definitive solution because of progressive, long-term attrition in terms of mortality and morbidity.[27-29] A recent study showed, that the TCPC operation can be performed safely in older patients (>7 years) without affecting operative and medium-term follow-up results.[30] However, most centers perform the TCPC operation at 2 to 3 years of age.[10]

Fenestration

A surgical fenestration between the total cavopulmonary connection and the atrium improves survival in high-risk patients.[5, 16, 31] The fenestration functions by allowing right-to-left shunt resulting in an increased cardiac index, albeit with lower than normal oxygen saturation. Besides improved survival in high-risk patients, a fenestration also reduces the duration of hospital stay, the duration and volume of chest tube drainage.[32, 33] It has been suggested that a fenestration might be a benefit for late morbidity.[34] Right-sided thrombus formation and paradoxical embolization are, theoretically, more likely to happen after a fenestrated repair. However, several reports have been unable to confirm this observation.[5] In most centers closure of the

fenestration are performed by implanting a device during cardiac catheter procedure. The necessity, proper timing, and clinical benefit of fenestration closure remain unknown. After fenestration closure, improved oxygenation, reduced need for anticongestive medication, and improved somatic growth, but higher incidence of tachyarrhythmias have been reported.[34, 35]

Mortality

Perioperative and early mortality after the TCPC operations have decreased markedly over the past three decades. In the report by Khairy et al.,[21] 82.6% of the early survivors were alive and had not had a heart transplantation 15 to 20 years later. It is of interest that the study found no significant difference in life expectancy beyond the postoperative period between the more obsolete, hemodynamic less efficient RA-PA connection and the direct cava-pulmonary artery connection. Furthermore, data from this series indicated that the three most common causes of late death were thromboembolism, heart failure and sudden death.

Survival at ten years ranges from 75 to 94% and at 20 years from 68 to 87% (Table 1). Though, most of the retrospective studies in Table 1 include relatively heterogeneous patient groups, with heterogeneous treatment strategies, one can appreciate that early and late mortality was higher for patients operated on in the earlier era than for patients operated on more recently.

Dominant Right Ventricle Compared to Left Ventricle

Several groups have reported that patients with a dominant right ventricle (RV) may be at increased risk for post-TCPC complications.[36-38] A recent study, however, found that early and intermediate results were similar between patients with a dominant RV and a dominant left ventricle (LV).[39]

Experience from congenital corrected transposition and atrial switch for D-transposition (Senning/Mustard) has shown that the systemic RV has a substantial long-term failure rate.[40, 41] Several factors may explain the generally equivalent event-free survival in TCPC patients of the dominant LV and RV. First, mortality due to rhythm disturbances, protein-losing enteropathy (PLE), stroke, and thromboembolic

Table 1: Results of the Fontan Procedure								
Author	Design	Number of patients	Year of operation	Fontan procedure	Survival	SVT	SND	Thrombo-embolism
Kim SJ[31]	Retro	200	1996-2006	Ec: 100%	10 year: 92%	5,0%	11%	6,5%
Blaufox AD[65]	Retro	521	1990-2007	RA-PA: 14% Lat: 70% Ec: 13%		9,6%		
d´Udekem Y[8]	Retro	305	1980-2000	RA-PA: 50% Lat: 34% Ec: 16%	10 year: 91% 20 year: 84%	10 year: 15,5% 15 year: 29,2%		10 years: 3,1% 15 years: 5,7%
Pace NC[30]	Retro	65	1990-2008	Lat: 20% Ec: 80%	10 year: 94%	Follow-up: 5,7 year ±5,4: 13,8%		
Tweddell JS[39]	Retro	256	1994-2007	Lat: 32% Ec: 68%	10 year: 94%			
Ocello S[69]	Retro	100	1997-2003	Ec: 100%	Follow-up 3,3 year ±1,7: 94%			
Kirklin JK[70]	Retro	112	1988-2005	Lat: 55% Ec: 46%	10 year: 83% 15 year: 71%	Lat: 15 year: 46% Ec: 15 year: 20%		15 years: 5%
Khairy P[21]	Retro	261	1973-?	RA-PA: 61% Lat: 38% Ec: 1%	10 year: 75% 20 year: 68% 25 year: 54%			
Ono M[34]	Retro	121	1984-2004	RA-PA: 23% Lat+Ec: 77%	20 year: 87%	20 years: 77% (including VT)	22%	9%
Stamm C[44]	Retro	220	1987-1991	Lat: 100%	10 years: 9%	5 years: 4% 10 years: 9%	5 years: 12% 10 years: 21%	
Haas GS[24]	Retro	45	1990-1997	Ec: 100%	Follow-up: 5,3 years: 100%	13%		
Coon PD[50]	Retro	592	1987-1999	RA-PA: 12% Lat: 82% Ec: 5%				1 year: 8% 8 years: 16% 10 years: 18%

Retro: retrospective. Prosp: prospective. RA-PA: Shunt between right atrium and pulmonary artery. Lat: Lateral tunnel. Ec: Extracardiac tunnel. SVT: supraventricular tachycardia, SND: Sinus node dysfunction; VT: ventricular tachyarrhythmia.

episodes may overwhelm the impact of ventricular morphology. Second, the staged approach to single ventricle palliation may outdo the impact of ventricular morphology. Specifically, HLHS is the most common single-ventricle diagnosis, and these patients are subject to a treatment algorithm that benefits from the increased experience with the diagnosis. Patients with HLHS undergo predictable neonatal palliation, then undergo relatively early Glenn and TCPC operation that both relieves volume overload and improves the oxygenation. These patients may be better prepared for the TCPC procedure than many patients with dominant LV, who may have variable anatomy, may present outside of the neonatal period, and consequently may be subjected to longer periods of volume overload or cyanosis. However, follow-up time in studies identifying similar behavior of the single RV or LV is relatively short. With time and accumulation of additional patients, a difference in mortality and morbidity may become apparent.

Arrhythmias

The incidence of both atrial tachy- and bradyarrhythmias increases with time[10] after TCPC completion. These arrhythmias include sinus node dysfunction (SND) as well as supraventricular tachycardias such as junctional ectopic tachycardia, atrial ectopic tachycardia, intra-atrial reentry tachycardia. The incidence of arrhythmias ranges from 5% to 77% depending on time of follow-up and type of Fontan/TCPC procedure (Table 1). Thus, the incidence of supraventricular tachycardia (SVT) following TCPC surgery increases steadily with the postoperative interval, with about 50% of patients experiencing problematic SVT by the 20th year of follow-up.[42] Arrhythmias may result from increased atrial pressure, or be incisional. Much of the research on arrhythmias after TCPC operation has focused on identifying predictors for atrial arrhythmias, and many have focused on surgical strategy as a possible critical predictor. Thus, SND following TCPC is believed caused by injury of the sinus node or disturbances of its blood supply[7, 43, 44] (Table 1). Bae et al. found that lateral tunnel repair was more likely to lead to the development of SND than the extracardiac conduit operation.[45] Junctional rhythm and loss of atrioventricular synchrony result in reduction of cardiac output, and SND may predispose patients to atrial reentry tachycardia.[7]

One of the theoretical advantages of the extracardiac TCPC operation is the minimization of incisional lines and the avoidance of atrial wall stress that may predispose the patient to SND and SVT. In a multivariate analysis Azakie et al. showed a lateral tunnel as
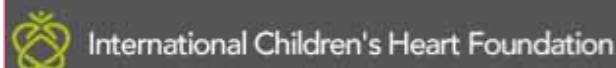
the only risk factor for early postoperative and intermediate arrhythmias.[23]

TCPC patients developing atrial tachycardia usually experience electrical problems as well as significant hemodynamic abnormalities.[46] Thus, attention to only the arrhythmia with medication or ablation, or attention to only the hemodynamic problem with TCPC revision often shows recurrent tachycardia.[46] Deal et al. showed good results in terms of low operative mortality, low risk of recurrent tachycardia, and marked improvement in functional status after TCPC revision with arrhythmia surgery (isthmus ablation, modified right atrial maze and Cox-maze III) in TCPC patients with frequent recurrence of atrial tachycardia and significant hemodynamic problem.[46]

Thromboembolic complications

Thromboembolic events (TE) (systemic venous and arterial) are a major cause of early and late mortality in TCPC patients. The reported incidence of TE in these patients varies from 3% to 25% depending on study design, the imaging technique, and the duration of the follow-up period[47-50] (Table 1). Studies with longer follow-up periods and more sensitive imaging studies suggest an incidence of at least 20%, with a mortality rate of 25%.[47-49] Although the etiology for this high risk is not well defined, possible explanations include venous stasis, coagulation abnormalities, dehydration, protein-losing enteropathy, and arrhythmias. Interestingly, there is no clustering of thromboembolic complications around a specific period after Fontan. They start to occur during the postoperative period, and the risk appears to be persistent throughout a patient´s lifetime, with no plateau.[49] Coon et al. reviewed transthoracic echocardiograms in 592 TCPC patients.[50] They found no difference in thrombus formation between atriopulmonary and lateral tunnel TCPC procedure, or between fenestrated and non-fenestrated TCPC patients. A recent study found no difference in TE between lateral tunnel and extracardiac tunnel procedures;[51] however, more results comparing these two procedures is needed.

Abnormalities in the haemostatic system have been found. Procoagulant factors (factors II, V, VII, IX, and X; plasminogen; fibrinogen), as well as anticoagulant factors (protein C and antithrombin III), were lower than normal controls prior to the BDG and prior to the TCPC completion.[52, 53] Increased platelet reactivity prior to the TCPC completion has also been showed.[54] A recent report, however, found no significant differences in thromboelastography (a global whole-blood assay of coagulation) in pediatric TCPC patients compared with healthy children.[55]

There is no consensus concerning the postoperative mode and duration of prophylactic anticoagulation, since no controlled randomized studies have been performed comparing different therapeutic strategies. Many centers recommend acetylsalicylic acid for uncomplicated TCPC patients, while Coumadin is reserved for patients with additional risk factors as arrhythmia, protein losing enteropathy, or ventricular dysfunction.[7]

Cardiopulmonary Function

There have been numerous studies of aerobic capacity after the TCPC operation, all showing a substantial reduction of exercise capacity measured as peak oxygen uptake (VO_2) in a cardiopulmonary exercise test (Table 2).

Giardini et al. demonstrated that exercise capacity progressively declined in TCPC patients over time.[29] They studied, longitudinally, 53 TCPC patients with cardiopulmonary exercise test (average 3.2±1.1 test for each patient). Time intervals between tests ranged from 1 to 16 years (average 7.7±4.0 years). Overall, peak Vo_2 decreased at a rate of -2.6±2.7%/year. Left ventricular morphology appeared as a predictor of the rate of decrease of peak Vo_2 at multivariate analysis (p=0.0001), thus the progressive decrease in exercise capacity is slower in patients with a morphologically LV. A similar decrease in peak Vo_2 over time was found by Müller et al in adult TCPC patients, whereas exercise capacity stayed unchanged during childhood.[56]

Minamisawa et al. showed that programmed exercise training could be safely performed to improve aerobic performance and oxygen utilization in TCPC patients. Although the improvement was a modest one, the improvement in oxygen use and participation in appropriate exercise may allow patients to lead a more active life.[57]

Protein-losing Enteropathy

PLE is a devastating complication after TCPC operation that responds poorly to present treatment protocols. PLE is defined as an abnormal loss of serum-proteins into the lumen of the gastrointestinal tract.[58] The cause of PLE is unknown, and pathophysiology is not well understood.[58, 59] Possible explanations might be decreased cardiac output, increased systemic venous pressure, inflammation and pulmonary vascular dysfunction.[58-60] Its clinical symptoms include peripheral edema, ascites, pleural- or pericardial effusion, diarrhea, and malaise. In laboratory tests a low and falling S-albumin and S-total protein and a high α1-antitrypsin in the stool is found.[58, 61] Time from TCPC operation to development of PLE is, in the literature, reported from 1 month and forward.[58] The prevalence of PLE is reported from 1-15% and increasing with age and 5-year survival rate 46-59%.[58-60] No effective treatment is available. Standard treatment includes diet (high protein, low fat), inotropic and afterload reducing agents, anti-inflammatory agents (corticosteroids), unfractionated heparin, and diuretics and albumin infusions. However, these agents have only shown sporadic effect.[58, 62, 63] Case reports suggests pulmonary vasodilation as a potential medical treatment.[64]

Despite treatment PLE is associated with a very high mortality rate. Further investigation is needed to determine the exact mechanism of the disease and to develop new therapeutic approaches.

Quality of Life and Daily Activity

Daily activity is an important lifestyle factor for both children and adults, however, studies measuring daily activity in TCPC patients are sparce. Müller et al. investigated exercise capacity, quality of life and daily activity in 57 TCPC patients.[56] Despite a reduced exercise capacity (Table 2), the patients seemed to be fairly active, many of them showing normal daily activity pattern. However, children younger than nine years were most prominently curtailed in physical activity compared to their healthy peers, perhaps due to overprotection. Later in adolescence, daily activity was mainly

Table 2. Aerobic Capacity After TCPC Operation			
Author	*n*	Vo$_{2max}$ mL/Kg/minute	% normal
Müller J[56]	50	25,0	59,7
Harrison DA[71]	30	14,8	
Ohuchi H[72]	105		59
RV morphology	33	25	55
LV morphology	47	27	63
Biventricle	15	25	55
Paridon SM[73]	411	26,3	65
Ovroutski S[74]	43		
Children (≤15 years)	28	27,9	62
Adults	15	22,9	53,5
LV: left ventricle; RV: right ventricle. Vo$_{2max}$: maximal oxygen uptake.			

related to exercise capacity that was found to decline from early adolescence on. Self-reported quality of life, concerning physical functioning did not correlate to objectively measured exercise capacity.[56] Blaufox et al. investigated quality of life in 521 TCPC patients using the Child Health Questionnaire (CHQ) Parent Report[65]. Mean CHQ physical (CHQ-p) and CHQ psychosocial (CHQ-ps) summary scores were lower than those for healthy controls: CHQ-p was 45.4 ± 11.8 versus 53.0 ± 8.8 for historical controls and CHQ-ps was 47.3 ± 10.9 versus 51.2 ± 9.1 for historical controls.

In another study, reduced habitual physical activity was associated with lower perceived general health, but no other aspects of quality of life.[66] The same authors, in a recent multicenter study, found only weak association between parent-estimated functional health status and exercise capacity and ventricular characteristics (echocardiography and magnetic resonance imaging) in 511 TCPC patients 6 to 18 years of age.[67]

Failure of the TCPC Circulation

Even after excellent early results, TCPC patients remain at risk of TCPC circulation failure. The most common manifestations of failing TCPC physiology are progressive ventricular dysfunction, PLE, arrhythmia, TE, progressive hypoxemia, and elevated pulmonary vascular resistance.[7, 68] So far there are no diagnostic tools allowing early prevention of declining univentricular circulation. Although the prognosis for UVH has changed considerably during the last decades, there still remains a continuing decrement of functional status during long-term follow-up. In failing TCPC, both TCPC takedown by conversion into BDG or orthotopic heart transplantation are possibilities.

Conclusions

Staged palliation and major improvements in the surgical techniques, have resulted in a decreasing mortality rate and increased prevalence of UVH patients. Despite these improvements, significant morbidity remains after the TCPC completion, including myocardial dysfunction, arrhythmias, TE, PLE and diminished exercise capacity. Therefore, the TCPC operation remains a palliative procedure and an imperfect solution. The persistent long-term morbidity document the obvious need for regular long-term surveillance of these patients as well as prospective follow-up studies.

Future Perspective

As the number of late survivors from the TCPC operation increases, caregivers will be evermore faced with the challenge of recognizing and managing complications secondary to the TCPC circulation. Early diagnosis and management of functional sequelae and complications associated with the TCPC physiology is required for improving the long-term outcome and quality of life.

Persistent investigations into new surgical modifications of the TCPC circulation as well as investigations into possible risk factors and treatment to TCPC failure are needed in order to continue improved outcome in the UVH patients.

Reference List

1. Moons P, Sluysmans T, De WD et al. Congenital heart disease in 111 225 births in Belgium: birth prevalence, treatment and survival in the 21st century. Acta Paediatr 2009;98(3): 472-477.
2. Jacobs JP, Franklin RC, Jacobs ML et al. Classification of the functionally univentricular heart: unity from mapped codes. Cardiol Young 2006;16 Suppl 1:9-21.
3. Ghanayem NS, Berger S, Tweddell JS. Medical management of the failing Fontan. Pediatr Cardiol 2007;28(6): 465-471.
4. Fontan F, Baudet E. Surgical repair of tricuspid atresia. Thorax 1971;26(3): 240-248.
5. Driscoll DJ. Long-term results of the Fontan operation. Pediatr Cardiol 2007;28(6):438-442.
6. de Leval MR, Kilner P, Gewillig M, Bull C. Total cavopulmonary connection: a logical alternative to atriopulmonary connection for complex Fontan operations. Experimental studies and early clinical experience. J Thorac Cardiovasc Surg 1988;96(5):682-695.
7. Kaulitz R, Hofbeck M. Current treatment and prognosis in children with functionally univentricular hearts. Arch Dis Child 2005;90(7):757-762.
8. d'Udekem Y, Iyengar AJ, Cochrane AD et al. The Fontan procedure: contemporary techniques have improved long-term outcomes. Circulation 2007;116(11 Suppl):I157-I164.
9. Jacobs ML, Rychik J, Rome JJ et al. Early reduction of the volume work of the single ventricle: the hemi-Fontan operation. Ann Thorac Surg 1996;62(2): 456-461.
10. Marino BS. Outcomes after the Fontan procedure. Curr Opin Pediatr 2002;14 (5):620-626.
11. Norwood WI, Jacobs ML. Fontan's procedure in two stages. Am J Surg 1993;166(5):548-551.
12. Duncan BW, Rosenthal GL, Jones TK, Lupinetti FM. First-stage palliation of complex univentricular cardiac anomalies in older infants. Ann Thorac Surg 2001;72(6):2077-2080.
13. Weldner PW, Myers JL, Gleason MM et al. The Norwood operation and subsequent Fontan operation in infants

CSI - Catheter Interventions in
Congenital & Structural Heart Diseases
July 8-10, 2010 | Frankfurt, Germany

www.csi-congress.org

CSi
Congenital & Structural Interventions

with complex congenital heart disease. J Thorac Cardiovasc Surg 1995;109(4):654-662.

14. Malec E, Januszewska K, Kolcz J, Mroczek T. Right ventricle-to-pulmonary artery shunt versus modified Blalock-Taussig shunt in the Norwood procedure for hypoplastic left heart syndrome - influence on early and late haemodynamic status. Eur J Cardiothorac Surg 2003;23(5):728-733.

15. Sano S, Ishino K, Kado H et al. Outcome of right ventricle-to-pulmonary artery shunt in first-stage palliation of hypoplastic left heart syndrome: a multi-institutional study. Ann Thorac Surg 2004;78(6):1951-1957.

16. Cilliers A, Gewillig M. Fontan procedure for univentricular hearts: have changes in design improved outcome? Cardiovasc J S Afr 2002;13(3):111-116.

17. Ghanayem NS, Tweddell JS, Hoffman GM, Mussatto K, Jaquiss RD. Optimal timing of the second stage of palliation for hypoplastic left heart syndrome facilitated through home monitoring, and the results of early cavopulmonary anastomosis. Cardiol Young 2006;16 Suppl 1:61-66.

18. Jaquiss RD, Ghanayem NS, Hoffman GM et al. Early cavopulmonary anastomosis in very young infants after the Norwood procedure: impact on oxygenation, resource utilization, and mortality. J Thorac Cardiovasc Surg 2004;127(4):982-989.

19. Petrucci O, Khoury PR, Manning PB, Eghtesady P. Outcomes of the bidirectional Glenn procedure in patients less than 3 months of age. J Thorac Cardiovasc Surg 2009.

20. Tanoue Y, Sese A, Ueno Y, Joh K, Hijii T. Bidirectional Glenn procedure improves the mechanical efficiency of a total cavopulmonary connection in high-risk fontan candidates. Circulation 2001;103(17):2176-2180.

21. Khairy P, Fernandes SM, Mayer JE, Jr. et al. Long-term survival, modes of death, and predictors of mortality in patients with Fontan surgery. Circulation 2008;117(1):85-92.

22. Ochiai Y, Imoto Y, Sakamoto M et al. Mid-term follow-up of the status of Gore-Tex graft after extracardiac conduit Fontan procedure. Eur J Cardiothorac Surg 2009;36(1):63-67.

23. Azakie A, McCrindle BW, Van AG et al. Extracardiac conduit versus lateral tunnel cavopulmonary connections at a single institution: impact on outcomes. J Thorac Cardiovasc Surg 2001;122(6):1219-1228.

24. Haas GS, Hess H, Black M, Onnasch J, Mohr FW, van Son JA. Extracardiac conduit fontan procedure: early and intermediate results. Eur J Cardiothorac Surg 2000;17(6):648-654.

25. Pizarro C, Mroczek T, Gidding SS, Murphy JD, Norwood WI. Fontan completion in infants. Ann Thorac Surg 2006;81(6):2243-2248.

26. Weber HS, Gleason MM, Myers JL, Waldhausen JA, Cyran SE, Baylen BG. The Fontan operation in infants less than 2 years of age. J Am Coll Cardiol 1992;19(4):828-833.

27. Alphonso N, Baghai M, Sundar P, Tulloh R, Austin C, Anderson D. Intermediate-term outcome following the fontan operation: a survival, functional and risk-factor analysis. Eur J Cardiothorac Surg 2005;28(4):529-535.

28. Fontan F, Kirklin JW, Fernandez G et al. Outcome after a "perfect" Fontan operation. Circulation 1990;81(5):1520-1536.

29. Giardini A, Hager A, Pace NC, Picchio FM. Natural history of exercise capacity after the Fontan operation: a longitudinal study. Ann Thorac Surg 2008;85(3):818-821.

30. Pace NC, Oppido G, Angeli E, Giardini A, Resciniti E, Gargiulo G. Results of the modified Fontan procedure are not related to age at operation. Eur J Cardiothorac Surg 2009.

31. Kim SJ, Kim WH, Lim HG, Lee JY. Outcome of 200 patients after an extracardiac Fontan procedure. J Thorac Cardiovasc Surg 2008;136(1):108-116.

32. Airan B, Sharma R, Choudhary SK et al. Univentricular repair: is routine fenestration justified? Ann Thorac Surg 2000;69(6):1900-1906.

33. Lemler MS, Scott WA, Leonard SR, Stromberg D, Ramaciotti C. Fenestration improves clinical outcome of the fontan procedure: a prospective, randomized study. Circulation 2002;105(2):207-212.

34. Ono M, Boethig D, Goerler H, Lange M, Westhoff-Bleck M, Breymann T. Clinical outcome of patients 20 years after Fontan operation--effect of fenestration on late morbidity. Eur J Cardiothorac Surg 2006;30(6):923-929.

35. Goff DA, Blume ED, Gauvreau K, Mayer JE, Lock JE, Jenkins KJ. Clinical outcome of fenestrated Fontan patients after closure: the first 10 years. Circulation 2000;102(17):2094-2099.

36. Gentles TL, Mayer JE, Jr., Gauvreau K et al. Fontan operation in five hundred consecutive patients: factors influencing early and late outcome. J Thorac Cardiovasc Surg 1997;114(3):376-391.

37. Julsrud PR, Weigel TJ, van Son JA et al. Influence of ventricular morphology on outcome after the Fontan procedure. Am J Cardiol 2000;86(3):319-323.

38. McGuirk SP, Winlaw DS, Langley SM et al. The impact of ventricular morphology on midterm outcome following completion total cavopulmonary connection. Eur J Cardiothorac Surg 2003;24(1):37-46.

39. Tweddell JS, Nersesian M, Mussatto KA et al. Fontan palliation in the modern era: factors impacting mortality and morbidity.

40. Siebenmann R, von SL, Schneider K, Schneider J, Senning A, Turina M. Late failure of systemic ventricle after atrial correction for transposition of great arteries. Eur J Cardiothorac Surg 1989;3(2):119-123.

41. Termignon JL, Leca F, Vouhe PR et al. "Classic" repair of congenitally corrected transposition and ventricular septal defect. Ann Thorac Surg 1996;62(1):199-206.

42. Weipert J, Noebauer C, Schreiber C et al. Occurrence and management of atrial arrhythmia after long-term Fontan circulation. J Thorac Cardiovasc Surg 2004;127(2):457-464.

43. Cohen MI, Wernovsky G, Vetter VL et al. Sinus node function after a systematically staged Fontan procedure. Circulation 1998;98(19 Suppl):II352-II358.

44. Stamm C, Friehs I, Mayer JE, Jr. et al. Long-term results of the lateral tunnel Fontan operation. J Thorac Cardiovasc Surg 2001;121(1):28-41.

45. Bae EJ, Lee JY, Noh CI, Kim WH, Kim YJ. Sinus node dysfunction after Fontan modifications--influence of surgical method. Int J Cardiol 2003;88(2-3):285-291.

46. Deal BJ, Mavroudis C, Backer CL. Arrhythmia management in the Fontan patient. Pediatr Cardiol 2007;28(6):448-456.

47. Kaulitz R, Luhmer I, Bergmann F, Rodeck B, Hausdorf G. Sequelae after modified Fontan operation: postoperative haemodynamic data and organ function. Heart 1997;78(2):154-159.

48. Monagle P, Cochrane A, McCrindle B, Benson L, Williams W, Andrew M. Thromboembolic complications after fontan

procedures--the role of prophylactic anticoagulation. J Thorac Cardiovasc Surg 1998;115(3):493-498.

49. Rosenthal DN, Friedman AH, Kleinman CS, Kopf GS, Rosenfeld LE, Hellenbrand WE. Thromboembolic complications after Fontan operations. Circulation 1995;92(9 Suppl):II287-II293.

50. Coon PD, Rychik J, Novello RT, Ro PS, Gaynor JW, Spray TL. Thrombus formation after the Fontan operation. Ann Thorac Surg 2001;71(6): 1990-1994.

51. Fu S, Valeske K, Muller M, Schranz D, Akinturk H. Total cavopulmonary connection: lateral tunnel anastomosis or extracardiac conduit?--an analysis of 114 consecutive patients. Chin Med Sci J 2009;24(2):76-80.

52. Odegard KC, McGowan FX, Jr., DiNardo JA et al. Coagulation abnormalities in patients with single-ventricle physiology precede the Fontan procedure. J Thorac Cardiovasc Surg 2002;123(3):459-465.

53. Odegard KC, McGowan FX, Jr., Zurakowski D et al. Coagulation factor abnormalities in patients with single-ventricle physiology immediately prior to the Fontan procedure. Ann Thorac Surg 2002;73(6):1770-1777.

54. Ravn HB, Hjortdal VE, Stenbog EV et al. Increased platelet reactivity and significant changes in coagulation markers after cavopulmonary connection. Heart 2001;85(1):61-65.

55. Raffini L, Schwed A, Zheng XL et al. Thromboelastography of patients after fontan compared with healthy children. Pediatr Cardiol 2009;30(6):771-776.

56. Muller J, Christov F, Schreiber C, Hess J, Hager A. Exercise capacity, quality of life, and daily activity in the long-term follow-up of patients with univentricular heart and total cavopulmonary connection. Eur Heart J 2009;30(23): 2915-2920.

57. Minamisawa S, Nakazawa M, Momma K, Imai Y, Satomi G. Effect of aerobic training on exercise performance in patients after the Fontan operation. Am J Cardiol 2001;88(6):695-698.

58. Rychik J. Protein-losing enteropathy after Fontan operation. Congenit Heart Dis 2007;2(5):288-300.

59. Ostrow AM, Freeze H, Rychik J. Protein-losing enteropathy after fontan operation: investigations into possible pathophysiologic mechanisms. Ann Thorac Surg 2006;82(2):695-700.

60. Silvilairat S, Cabalka AK, Cetta F, Grogan M, Hagler DJ, O'Leary PW. Protein-losing enteropathy after the Fontan operation: associations and predictors of clinical outcome. Congenit Heart Dis 2008;3(4):262-268.

61. Fujii T, Shimizu T, Takahashi K et al. Fecal alpha1-antitrypsin concentrations as a measure of enteric protein loss after modified fontan operations. J Pediatr Gastroenterol Nutr 2003;37(5): 577-580.

62. Ryerson L, Goldberg C, Rosenthal A, Armstrong A. Usefulness of heparin therapy in protein-losing enteropathy associated with single ventricle palliation. Am J Cardiol 2008;101(2): 248-251.

63. Therrien J, Webb GD, Gatzoulis MA. Reversal of protein losing enteropathy with prednisone in adults with modified fontan operations: long term palliation or bridge to cardiac transplantation? Heart 1999;82(2):241-243.

64. Uzun O, Wong JK, Bhole V, Stumper O. Resolution of protein-losing enteropathy and normalization of mesenteric Doppler flow with sildenafil after Fontan. Ann Thorac Surg 2006;82 (6):e39-e40.

65. Blaufox AD, Sleeper LA, Bradley DJ et al. Functional status, heart rate, and rhythm abnormalities in 521 Fontan patients 6 to 18 years of age. J Thorac Cardiovasc Surg 2008;136(1):100-7, 107.

66. McCrindle BW, Williams RV, Mital S et al. Physical activity levels in children and adolescents are reduced after the Fontan procedure, independent of exercise capacity, and are associated with lower perceived general health. Arch Dis Child 2007;92(6):509-514.

67. McCrindle BW, Zak V, Sleeper LA et al. Laboratory measures of exercise capacity and ventricular characteristics and function are weakly associated with functional health status after Fontan procedure. Circulation 2010;121 (1):34-42.

68. Corno A, Becker AE, Bulterijs AH et al. Univentricular heart: can we alter the natural history? Ann Thorac Surg 1982;34(6):716-727.

69. Ocello S, Salviato N, Marcelletti CF. Results of 100 consecutive extracardiac conduit Fontan operations. Pediatr Cardiol 2007;28(6):433-437.

70. Kirklin JK, Brown RN, Bryant AS et al. Is the "perfect Fontan" operation routinely achievable in the modern era? Cardiol Young 2008;18(3):328-336.

71. Harrison DA, Liu P, Walters JE et al. Cardiopulmonary function in adult patients late after Fontan repair. J Am Coll Cardiol 1995;26(4):1016-1021.

72. Ohuchi H, Yasuda K, Hasegawa S et al. Influence of ventricular morphology on aerobic exercise capacity in patients after the Fontan operation. J Am Coll Cardiol 2001;37(7):1967-1974.

73. Paridon SM, Mitchell PD, Colan SD et al. A cross-sectional study of exercise performance during the first 2 decades of life after the Fontan operation. J Am Coll Cardiol 2008;52(2):99-107.

74. Ovroutski S, Ewert P, Miera O et al. Long-term cardiopulmonary exercise capacity after modified Fontan operation. Eur J Cardiothorac Surg 2010;37(1):204-209.

CCT

Corresponding Author

Lars Idorn, MD, Research Fellow
Department of Pediatrics
Department of Cardiology
Rigshospitalet, Denmark
Rigshospitalet, 3.11.2
Blegdamsvej 9
DK-2100 Copenhagen East, Denmark
Tel: 0045 3545 0807
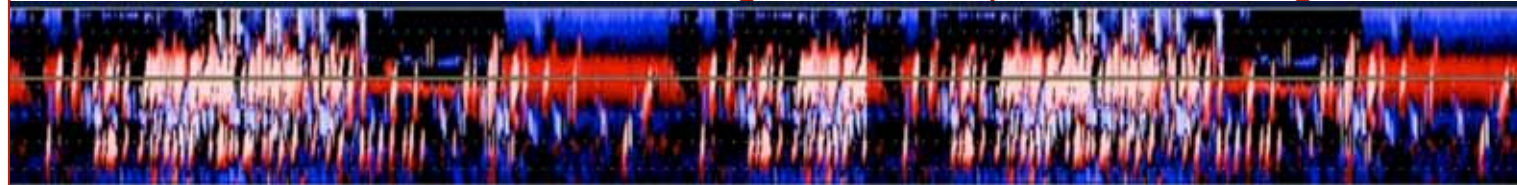*Fax: 0045 3545 2341*
lars.idorn@rh.regionh.dk

Annette S. Jensen, MD, Research Fellow
Department of Cardiology
Rigshospitalet, Denmark

Klaus Juul, MD, PhD
Department of Pediatrics
Rigshospitalet, Denmark

Jesper I. Reimers, MD, DMSc
Department of Pediatrics,
Rigshospitalet, Denmark

Lars Søndergaard2, MD, DMSc
Department of Cardiology
Rigshospitalet, Denmark

Abstracts from "Evolving Concepts in the Management of Complex Congenital Heart Disease II" - Part II

"Abstracts from 'Evolving Concepts in the Management of Complex Congenital Heart Disease II' - Part II" includes the following topics and presenters:

- Late Challenges in Adult CHD – A Case-Based Approach by John S. Child, MD
- Surgery for Ebstein's Anomaly by Joseph A. Dearani, MD
- Starting a Hybrid Program by Howaida G. El-Said, MD
- Management Of Patients With Aorto-Pulmonary Collaterals by Frank L Hanley, MD
- Update on Medical Management of Severe Pediatric Pulmonary Hypertension by D. Dunbar Ivy, MD

See Part I in the April issue of Congenital Cardiology Today

Abstract Title: Late Challenges in Adult CHD – A Case-Based Approach
Presenter: John S. Child, MD; Adult Cardiologist, Ronald Reagan U.C.L.A. Medical Center, Los Angeles, CA

Objective

- Case presentations of representative adult CHD first diagnosed as an adult
- Case presentations of adults with CHD with postoperative issues
- Review the modern outlook and management of Eisenmenger Syndrome

Abstract

Surgical advances in CHD over the past 60+ years allowed >85% survival into adulthood. Adults with CHD now exceed 1 million in the U.S. of which >1/3rd are moderate-to-complex. Operation does not imply cure. Residua and sequelae (separate from complications), whether mild or severe are common. Residua (defects not addressed at the time of surgery) include long-term systemic RV or single ventricle function. Sequelae (abnormalities resulting from intervention) include severe pulmonary regurgitation or arrhythmias in tetralogy of Fallot, longevity of conduits and valves, or atrial arrhythmias in atrial baffle or Fontan patients. Myocardial dysfunction due to inadequate myocardial protection, extensive patches or incisions, or long-standing pressure or volume overload is a common concern.

Not all have been or will be operated. Some may not be recognized until the natural history results in symptomatic presentation in the adult years (e.g. CCTGA, Ebstein). In those that were inoperable, Eisenmenger Syndrome (ES) was more common in the earlier eras. Survival of ES is determined by the type of underlying CHD and the medical complications of cyanosis. Cyanosis has profound hematologic consequences and is a multi-system disorder.

References

1. Warnes, Williams, Bashore, Child, et al: ACC/AHA 2008 Guidelines for the Management of Adults With Congenital Heart Disease. JACC published online Nov 7, 2008; doi:10.1016/j.jacc.2008.10.001
2. Webb GD: Challenges in the care of adult patients with congenital heart defects. Heart 2003; 89:465-469.
3. Warnes CA: The adult with congenital heart disease: Born to be bad? JACC 2005;46:1-8.
4. Oechslin E: Hematologic management of the cyanotic adult with congenital heart disease. Int J Cardiol 2004; 97:109-115.
5. Perloff, Child, Aboulhosn: Congenital Heart Disease in Adults. 3rd Ed. Saunders-Elsevier, Philadelphia.2009. pp 488.

Abstract Title: Surgery for Ebstein's Anomaly
Presenter: Joseph A. Dearani, MD; Professor of Surgery; Program Director, Thoracic Surgery Residency; Mayo Clinic, Rochester, MN

CCT

Objective

The goal of this presentation is to provide an outline or strategy that will help guide patient selection for operation and help the surgeon recognize which procedure is best for which patients.

Abstract

Ebstein's Anomaly is a rare congenital heart malformation with a seemingly infinite range of anatomic variability. In addition, the clinical presentation is also widely variable, ranging from the symptomatic neonate needing urgent operation to an incidental finding in an asymptomatic adult patient on a routine medical examination.

The rarity of this anomaly and the numerous repair techniques described in the literature have resulted in uncertainty as to the best approach - operative technique or even optimal timing of operation - even among those centers with a large experience in the condition. Consequently, it is a particular challenge for the surgeon with modest experience to develop a consistent method with reproducible and reliable results.

In general, management strategies can be applied to 3 groups of patients with Ebstein's Anomaly:
1. the symptomatic neonate or infant,
2. the child, adolescent, and young adult, and
3. the older adult patient.

There are two main treatment algorithms for the symptomatic neonate – the biventricular repair and the single ventricle pathway. In the current era, both surgical strategies continue to have high early mortality (10-30%) even in the most experienced hands, when compared to the majority of other complex congenital heart anomalies operated on in the first year of life, where the early mortality has been uniformly reduced to <5%.

There is general agreement that management of the child, adolescent and young adult should be focused on tricuspid valve repair (as opposed to replacement); almost always this operation is elective and early mortality is and should be low. While there is no general agreement as to the ideal method of repair, it is my impression that the "cone reconstruction" provides the most anatomic repair and should be applied in the majority of circumstances.

Management of the older adult (>50 years) with Ebstein's Anomaly has its own set of technical challenges – often markedly enlarged hearts with concomitant atrial tachyarrhythmias, possible atherosclerotic coronary artery disease, or other acquired valve abnormalities. In addition, the presence of medical comorbidities such as diabetes or hypertension is also common, making perioperative management more difficult. The durability of the porcine bioprosthesis in this age bracket makes tricuspid valve replacement a reasonable alternative when valve repair is not possible, since durability and freedom from reoperation has been shown to be very good. The need for concomitant procedures such as the maze procedure, coronary artery bypass grafting, etc. also needs to be considered.

References

1. Brown ML, Dearani JA, Danielson GK, Cetta F, Connolly HM, Warnes, CA, Zhuo LI, Hodge, DO, Driscoll, DJ. The outcomes of operations for 539 patients with Ebstein anomaly. J Thorac Cardiovasc Surg. 2008;135:1120-36.
2. Quinonez LG, Dearani JA, Puga FJU, Driscoll DJ, Connolly HM, O'Leary PW, et. Al Results of the 1.5 ventricle repair for Ebstein's anomaly and the failing right ventricle. J. Thorac Cardiovasc Surg. 2007;133:1303-10.
3. Da Silva JP, Baumgratz FJ, Fonseca L, Franchi SM, Lopes LM, Tavares GM. The cone reconstruction of the tricuspid valve in Ebstein's anomaly, the operation: early and midterm results. J Thorac Cardiovasc Surg. 2007;133:215-23.
4. Knott-Craig CJ, Goldberg SP, Overholt ED, Colvin EV, Kirklin JK. Repair of neonates and young infants with Ebstein's anomaly and related disorders. Ann Thorac Surg. 2007 Aug;84 (2):587-92; discussion 592-3.
5. Watanabe M, Harada Y, Takeuchi T, Satomi G, Uasukouchi S. Modified Starnes operation for neonatal Ebstein's anomaly. Ann Thorac Surg. 2002 Sep;74(3):916-7.
6. Starnes VA, Pitlick PT, Bernstein D, Griffin ML, Choy M, Shumway NE. Ebstein's anomaly appearing in the neonate. A new surgical approach. J Thorac Cardiovasc Surg. 1991 Jun; 101(6):1082-7.

CCT

Abstract Title: Starting a Hybrid Program **Presenter:** Howaida G. El-Said, MD; Pediatric Cardiologist, Rady Children's Hospital, San Diego, CA

Objective

1. Overview of the issues involved in starting a Hybrid program.
2. Review of patients that underwent Hybrid at Rady Children's Hospital including patient selection and outcome.

Abstract

Specific Aims: To conduct a retrospective chart review of all patients from September 2007-December 2009 to determine the outcome of the Hybrid procedure.

The aim of this study is to evaluate the outcome of the Hybrid procedure in high risk patient with HLHS and compare them with patients who underwent the Norwood Sano procedure.

Specific goals for this project include:
- Evaluate the outcome of the Hybrid procedure in the high risk HLHS patients
- Evaluate the role of serial Tropnin measurements in the Hybrid group to determine need for early intervention
- Evaluate intermediate term follow-up of the Hybrid group particularly pulmonary artery dilation

Background and Significance: Hypoplastic Left Heart Syndrome (HLHS) is a combination of congenital abnormalities of the left side of the heart, characterized by left ventricular outflow tract dysfunction with resulting underdeveloped left ventricle and aorta. Other abnormalities include hypoplastic or atretic aortic and mitral valve. It is associated with an atrial septal defect (ASD) that allows the blood to bypass the left side of the heart from the left atrium to the right atria. Without surgical intervention the condition is fatal in the first 2 weeks of life.[1] Despite progressive improvement in surgical results, HLHS remains one of the congenital heart abnormalities with the greatest morbidity and mortality. As a result heart specialists have worked together to develop a new approach, called "Hybrid surgery," for treatment of newborns with HLHS. Instead of a series of major operations that pose considerable risk, the hybrid approach combines non-surgical interventions with a less drastic operation. Although still being tested and refined, it appears to offer better results.[4]

The advantages of development of a less invasive approach, so called 'Hybrid,' is postponing the major surgery outside the neonatal period, therefore reducing the immediate and late surgical burden on these patients.[3]

References

1. Atrip J, Campbell D, Ivy D et al. Birth weight and complexity are significant factors for the management of hypoplastic left heart syndrome. Annals of Thoracic Surgery;2006;82:1252-9.

2. Bacha E. The Hybrid Stage I Operation in Hypoplastic left Heart Syndrome: a new alternative. Heart Views;2006;2006:105-110.
3. Pilla CB, Pedra CA, Nogueira AJ. Hybrid management for hypoplastic left heart syndrome: an experience from Brazi. Pediatr Cardiol;2008;29(3):498-506
4. Gutgesell Hp & Lim DS. Hybrid palliation in hypoplastic left heart syndrome. Curr Opin Cardiol;2007:22(2):55-59.

CCT

Abstract Title: Management of Patients With Aorto-Pulmonary Collaterals
Presenter: Frank L. Hanley, MD; Director of Children's Heart Center; Lucile Packard Children's Hospital, Stanford University, Palo Alto, CA

Since July 1992 we have prospectively applied a complex and formal surgical protocol to patients with major aortopulmonary collaterals (MAPCAs). The protocol is designed primarily to achieve the largest, healthiest pulmonary microvascular bed possible. Priorities include early removal of all MAPCAs from the systemic circulation, and complete unifocalization using native tissue anastomoses. Intracardiac repair is performed as early as possible, but only when low right ventricular pressure is assured.

Our total experience involves 507 patients. There were 3.8 +/- 1.4 MAPCAs per patient. The median diameter of the central pulmonary arteries (PAs) was 1.5 mm. PAs were absent in 23%. Cardiac morphology was pulmonary atresia with VSD in 94%. Median age at first surgery was 8 months. Initial operation was complete bilateral unifocalization via sternotomy in 85%. Intracardiac repair was also achieved at initial operation in 56%, and in 83% within 2 yrs. Alternative initial operations, such as creation of main PA to aortic anastomosis, or staged unifocalization via thoracotomy, were performed in a minority of patients, according to strict morphologic and physiologic criteria.

Early mortality was 9.7% in the first half of the experience, and 2.0% in the second. In patients achieving intracardiac repair, the median RV/LV pressure was 0.44 in the first half, and 0.35 in the second half. Late follow-up was 81% complete up to 12 yrs with 6.3% mortality. Kaplan-Meier survival at 1, 5, and 10 yrs was 91%, 86%, and 86%. RV/LV pressure did not rise over time, and growth of unifocalized MAPCAs is well documented. Documented occlusion of unifocalized MAPCAs was rare.

Ongoing evaluation of the pulmonary vasculature with appropriate use of both surgical and interventional techniques is an important component of the overall management. Surgical creation of a single compartment pulmonary artery system that includes as many lung segments as possible and is achieved early in infancy promotes low pulmonary vascular resistance, allowing a high rate of intracardiac repair with low right ventricular pressure. Under this management, growth of both hypoplastic pulmonary arteries and MAPCAs keeps up with somatic development. Using current techniques surgical mortality for these complex operations is acceptable at 2%.

CCT

Abstract Title: Update on Medical Management of Severe Pediatric Pulmonary Hypertension
Presenter: D. Dunbar Ivy, MD; Section Head, Cardiology Director, Pulmonary Hypertension Program; Children's Hospital, Denver, CO

Objectives

- Improve the understanding of mechanisms of action of medications used to treat pulmonary hypertension in children
- Understand an algorithm to treat pediatric pulmonary hypertension
- Understand the classification of pulmonary hypertension

Abstract

Pulmonary arterial hypertension (PAH) is a life-threatening disease characterized by progressive obliteration of the pulmonary vasculature leading to right heart failure and death. Prior to the current treatment era, PAH carried a poor prognosis, which has changed over the past decades in relation to the introduction of new therapeutic agents. A revision of the pulmonary hypertension classification was proposed at the WHO Dana Point meeting in 2008 and has recently been published. There are no evidence-based treatment recommendations for children with PAH, primarily because of the lack of results from randomized clinical trials in pediatric patients or including pediatric patients. Initial evaluation includes acute vasodilator testing at cardiac catheterization, which is crucial in determining initial and long-term therapy. Acute responders with PAH associated with congenital shunt lesions are considered candidates for surgical repair, whereas the rare "responder" patient with other forms of PAH can be treated initially with calcium channel blockers. In the "non responder" with right heart failure, the first line treatment consists of continuous intravenous prostacyclin, whereas in the absence of right heart failure, other targeted therapies (endothelin receptor antagonists, phosphodiesterase inhibitors or prostacyclin analogues) may be tried first.

References

1. Rosenzweig EB, Feinstein J, Humpl T, and Ivy DD. Pulmonary Arterial Hypertension in Children: Diagnostic work-up and challenges. Progress in Pediatric Cardiology 27: 7-11, 2009.
2. Ivy DD, Feinstein JA, Humpl T, Rosenzweig E. Non congenital heart disease associated pediatric pulmonary arterial hypertension. Progress in Pediatric Cardiology 27: 13-23, 2009.
3. Kulik T, Mullen M, Adatia I. Pulmonary arterial hypertension associated with congenital heart disease. Progress in Pediatric Cardiology 27: 25-33, 2009.
4. Adatia I, Kulik T, Mullen M. Pulmonary venous hypertension or pulmonary hypertension due to left heart disease. Progress in Pediatric Cardiology 27: 35-42, 2009.

CCT

Medical News, Products and Information

Request for Research Applications on Pediatric Cardiomyopathy

The Children's Cardiomyopathy Foundation (CCF) is pleased to announce the availability of one-year research grants for studies focused on pediatric cardiomyopathy. The purpose of CCF's Annual Research Grant Program is to advance knowledge of the basic mechanism of the disease and to develop more accurate diagnostic methods and improved therapies for children affected with cardiomyopathy. Please visit CCF's website www.childrenscardiomyopathy.org (click on Research/Grants & Awards) for guidelines and to view past grant awards.

Opportunity: The Children's Cardiomyopathy Foundation (CCF) is inviting investigator-initiated research proposals for innovative basic, clinical, population, or translational studies related to the cause, diagnosis, or treatment of primary cardiomyopathy in children under the age of 18 years. CCF's grant program is designed to provide seed funding to investigators for the testing of initial hypotheses and collecting of preliminary data to help secure long-term funding by the NIH and/or other major granting institutions.

Eligibility: Principal investigator must hold an MD, PhD or equivalent degree and reside in the United States or Canada. The investigator must have a faculty appointment at an accredited US or Canadian institution and have the proven ability to pursue independent research as evidenced in publications in peer-review journals.

Funding: Funding is available in the range of US$25,000 to US$50,000 for one year of total direct costs. Following the completion of the proposed study, a second year of funding may be an option for relevant study extensions.

Application Process: CCF grant guidelines and application forms are downloadable off the website. The 2010 deadline for application submission is September 3, 2010 with final award decisions to be made by January 2011.

Selection Process: Grant award decisions are made through a careful peer-review process led by CCF's Medical Advisors and reviewed by CCF's Board of Directors. Scientific excellence and relevance to primary forms of pediatric cardiomyopathy are the main criteria for selecting research projects to support.

Bypass Procedure Used During Infant Heart Surgery Does Not Impair Later Neurological Outcomes

Congenital heart defects (CHD) are the most common birth defects in humans, affecting 8 per 1000 live births with one third of affected children requiring intervention in early infancy. Increasing numbers of survivors combined with developmental expectations for independence, behavioral self-regulation and academic achievement have led to a growing identification of neurobehavioral symptoms in some survivors. A study now suggests that a cooling technique often used in heart operations does not impair neurological outcomes.

Congenital heart disease and its treatment were originally thought to potentially increase neurologic injury in these patients. The technique of deep hypothermic circulatory arrest (DHCA) is used in order to repair these congenital cardiac defects by providing a bloodless surgical field, which may facilitate completion of the best physiologic repair, and decrease the duration of blood exposure to the bypass circuit. However, it involves a period of reduced blood flow in the brain. Cooling is a protective mechanism to reduce metabolism of the brain and other organs during periods of low blood flow.

Stephanie Fuller, MD, a cardiothoracic surgeon at The Children's Hospital of Philadelphia, presented these research findings in the prestigious J. Maxwell Chamberlain Lecture at the annual meeting of the Society of Thoracic Surgeons in Fort Lauderdale, Fla. According to the study, DHCA does not impair language skills, attention, and other neurocognitive abilities in school-age children.

Dr. Fuller and colleagues from Children's Hospital and the University of Washington assessed the use of DHCA as a predictor of neurodevelopmental outcomes in children who had cardiac surgery as infants. The infants were enrolled in a prospective study of apolipoprotein-E (APOE) polymorphisms and neurodevelopmental outcome after cardiac surgery and underwent formal neurodevelopmental testing at four years of age.

Neurodevelopmental testing was completed in 238 out of 307 eligible patients. The surgeons used DHCA in 92 of those infants as deemed necessary to provide better operative exposure with a bloodless and less cluttered surgical field and therefore a shorter total cardiopulmonary support time. Use of DHCA was not predictive of worse performance for any neurodevelopmental outcome. Significant predictors of worse outcome included lower socioeconomic status, preoperative mechanical ventilation and babies that were younger and smaller at the time of first operation. Neurodevelopmental assessment included cognition, language skills, attention, impulsivity, executive function, social competence, and visual-motor and fine-motor skills.

"Selective use of DHCA during cardiac surgery in infancy may facilitate operative repair and is not associated with impaired neurodevelopmental outcomes," said Dr. Fuller. "Despite added risk factors, the selective use of DHCA during infancy for repair of congenital heart disease without an obstruction in the aorta was not predictive of worse performance at four years of age."

Dr. Fuller added "use of DHCA as a support technique during cardiac surgery in infancy has many advantages; it is not necessary to sacrifice these advantages merely to avoid use of DHCA. Our study adds to the growing literature showing no adverse influence of limited periods of DHCA. New support techniques must be carefully evaluated prior to wide-spread acceptance to confirm they are not inferior to conventional management strategies."

For more information, visit www.chop.edu.

Silver Nanoparticles May One Day be Key to Devices That Keep Hearts Beating Strong and Steady

Diamonds and gold may make some hearts flutter on Valentine's Day, but in a University

at Buffalo laboratory, silver nanoparticles are being designed to do just the opposite.

The nanoparticles are part of a new family of materials being created in the laboratory of SUNY Distinguished Professor and Greatbatch Professor of Advanced Power Sources Esther Takeuchi, PhD, who developed the lithium/silver vanadium oxide battery. The battery was a major factor in bringing implantable cardiac defibrillators (ICDs) into production in the late 1980s. ICDs shock the heart into a normal rhythm when it goes into fibrillation.

Twenty years later, with more than 300,000 of these units being implanted every year, the majority of them are powered by the battery system developed and improved by Takeuchi and her team. For that work she has earned more than 140 patents, believed to be more than any other woman in the United States. Last fall, she was one of four recipients honored in a White House ceremony with the National Medal of Technology and Innovation.

ICD batteries, in general, now last five to seven years. But she and her husband and co-investigator, SUNY Distinguished Teaching Professor of Chemistry Kenneth Takeuchi, PhD, and Amy Marschilok, PhD, UB Research Assistant Professor of Chemistry, are exploring even-better battery systems, by fine-tuning bimetallic materials at the atomic level.

Their research investigating feasibility for ICD use is funded by the National Institutes of Health, while their investigation of new, bimetallic systems is funded by the US Department of Energy (DOE).

So far, their results show that they can make their materials 15,000 times more conductive upon initial battery use due to in-situ (that is, in the original material) generation of metallic silver nanoparticles. Their new approach to material design will allow development of higher-power, longer-life batteries than was previously possible.

These and other improvements are boosting interest in battery materials and the revolutionary devices that they may make possible.

"We may be heading toward a time when we can make batteries so tiny that they -- and the devices they power -- can simply be injected into the body," Takeuchi says. Right now, her team is exploring how to boost the stability of the new materials they are designing for ICDs. The materials will be tested over weeks and months in laboratory ovens that mimic body temperature of 37 degrees Celsius.

"What's really exciting about this concept is that we are tuning the material at the atomic level," says Takeuchi. "So the change in its conductivity and performance is inherent to the material. We didn't add supplements to achieve that, we did it by changing the active material directly."

Even though batteries are an historic technology, they are far from mature, Takeuchi notes.

Do you or your colleagues have interesting research results, observations, human interest stories, reports of meetings, etc. that you would like to share with the congenital cardiology community?

Submit a brief summary of your proposed article to: RichardK@CCT.bz

The final manuscript may be between 400-4,000 words,and contain pictures, graphs, charts and tables.

TINY HEARTS
INSPIRED
HYBRID LABS
WITH ACCESS
FOR BIG TEAMS.

Fixing a heart from birth through adulthood takes big teams working together. So we examined the needs of leading clinicians when designing our hybrid solutions. The result: our Infinix™-i with 5-axis positioners and low profile detectors, stays out of the way, but right where needed, providing the best possible access to patients. To lead, you must first listen.

medical.toshiba.com

TOSHIBA
Leading Innovation >>>