Congenital heart disease never goes away, even when it has been 'treated': the adult with congenital heart disease

Aarti Hejmadi Bhat and David J. Sahn

Purpose of review

As the specialties of pediatrics and pediatric cardiology continue to forge ahead with better diagnoses, medical care, and surgical results, an expanding population of patients with congenital heart disease (CHD) outgrows the pediatric age group, yet does not quite graduate to routine adult cardiology or general medicine. The adult with congenital heart disease (ACHD) faces medical, surgical, and psychosocial issues that are unique to this population and must be addressed as such. This review attempts to discuss and highlight some of the important advances and controversies brought up in the past year, in the care and management of these patients.

Recent findings

The past five to 10 years have seen dynamic interest in understanding sequelae of corrected, uncorrected, or palliated congenital heart disease. The search for the ideal surgery, optimal prosthesis, and a smooth transition to adult care continues and is reflected in the vast amount of academic work and publications in this field. Of particular interest, conduit reoperations and single ventricle pathway modifications are still an art and a science in evolution.

Summary

While all are agreed that there is a pressing need to focus on the delivery of care to the adult with congenital heart disease, this essentially requires a clearer understanding of late sequelae of CHD. The sheer heterogeneity of anatomy, age, surgery, and institutional management protocols can make it difficult to develop clear guidelines. This review attempts to give an up-to-date perspective on some of the new findings related to the more common lesions and problems faced in this group.

Keywords

adult congenital heart disease, conduit, Fontan surgery, grown-up congenital heart disease

Curr Opin Pediatr 16:500–507. © 2004 Lippincott Williams & Wilkins.

Oregon Health & Science University, Portland, Oregon, USA

Correspondence to David J. Sahn, The Clinical Care Center for Congenital Heart Disease, Oregon Health & Science University, 3181 SW Sam Jackson Park Road, L608 Portland, OR 97239-3098, USA
Tel: 503 494 2191 and 503 494 4195; fax: 503 494 2190;
e-mail: sahnd@ohsu.edu

Current Opinion in Pediatrics 2004, 16:500–507

1040-8703

Introduction

From 1940 to 2002, about 1 million patients were born with simple congenital heart disease (CHD), half a million with moderate CHD, and half a million with severe CHD. Assuming they had all been treated, there would be 750,000, 400,000, and 180,000 CHD survivors in these respective groups. Bicuspid aortic valves (BAV) would add another 300,000 cases. If left untreated, there would be 400,000, 220,000, and 30,000 CHD survivors in each group respectively [1••]. If it were to be assumed that the truth lies somewhere in between, there would be about 400,000 cases of CHD (including BAV) that reach adulthood. The 32nd Bethesda Conference estimated that there were approximately 800,000 adults with CHD (ACHD) in the USA in the year 2000, based on the New England Regional Infant Cardiac Program statistics [2].

The Congenital Cardiac Defects Committee of the AHA Section on Cardiovascular Disease in the Young estimated that in the cohort born after 1990, there would be 760,000 births with CHD, of which 200,000 would be severe. This study did not assess the pre-existing burden from previous years [3]. Presently, more than 85% of infants with CHD are expected to reach adulthood. This number will continue to increase as more children are diagnosed and treated with improving surgical and allied techniques. A 400% increase in adult CHD outpatient workload was recently reported in Canada [4].

Guidelines and recommendations have been put in place by the American College of Cardiology [5], by the Calman UK Training Advisory Committee, and the Canadian Cardiovascular Society (www.cachnet.org, www.achd-library.com, www.rbh.nthames.nhs.uk/cardiology/consensus).

Primary surgery is increasingly being undertaken at younger ages with declining postoperative mortality, yet surgical repair of most CHD is still associated with lingering cardiac mortality [6,7••]. Most of these studies exclude 'congenital' conditions such as hypertrophic and other cardiomyopathies, mitral valve prolapse, accessory conduction pathways, or channelopathies.

Pediatric cardiology arose from the fountainhead of general pediatrics to be the first boarded subspecialty in 1961, and has grown over the past four decades to be the largest subspecialty of pediatrics. As these pediatric

CHD 'graduates' enter adolescence and adulthood, their ongoing care as adults will create a new specialty on the cusp of pediatrics, pediatric cardiology, and internal medicine or adult cardiology. Effective and seamless means of transition and integration of heart diseases (congenital and acquired) of these three age groups (children, adolescents, and adults) is called for.

Late primary repair and reoperations in adult congenital heart disease

Altered rheology, hemostasis, surgical access through numerous previous sternotomies, collateral circulation, myocardial preservation, ventricular hypertrophy, arrhythmogenicity, possibly poorer ventricular function, and vascular compliance are some of the age-related additive risk factors in this group.

Mild or previously asymptomatic CHDs such as aortic valve disease, atrial septal defects, and coarctation could present for the first time in adulthood. Surgical results for these lesions are generally promising, though progressive age does add to the morbidity [8].

Reoperations are more common than primary operations in the older CHD patient. In an extensive single-center experience, only 15% of operated patients required reoperation up to 26 years postoperatively; 20-year survival was 86% [9•]. Outflow tract surgeries are most likely to require reoperations despite previous anatomic, interventional, or hybrid treatments. Aortic regurgitation and annuloaortic ectasia on the left side, and persistent stenosis or conduit failure on the right side are the commonest indications for reoperation [10•]. Cyanosis, multiple previous surgeries, and increasing age are clear risk factors for mortality ensuing first or subsequent cardiac surgeries [10•,11].

Reoperations for conduits/bioprosthesis in the pulmonary position

Stenosis of right ventricle (RV) to pulmonary artery (PA) conduit is the commonest indication for reoperation (85%). The 20-year freedom from valve or conduit replacement is 40% [12]. Pulmonary valve homografts are less likely to calcify as compared to aortic homografts. However, they are more prone to become incompetent in the face of increased pulmonary artery pressures. Pericardial monocusp valves have poor long-term competency. The jury is equally divided between cryopreserved and irradiated homografts. Cryopreserved homografts lose donor cells but do not revascularize or recellularize from the recipient. On the other hand, depopulated cryopreserved conduits do not induce immune reaction while facilitating adaptive remodeling [13••].

Xenografts, such as the Hancock glutaraldehyde preserved porcine-valved Dacron conduit, have shown better long-term freedom from reoperation than homograft conduits [14••]. The "peel" technique described by this same surgical group involves reconstruction of a bovine pericardial tissue roof over the fibrous bed left over from the explanted conduit, with favorable freedom from reoperation [15•]. In this group, there was no significant difference in early or late morbidity or mortality between those who received a pulmonary valve and those who did not. Stentless porcine aortic valves treated with anti-mineralization agent alpha amino oleic acid have shown satisfactory early results in the pulmonary position, though it is too early to comment on the efficacy of this agent in preventing calcification of the implant [16•].

Bovine jugular venous conduits were believed to have theoretical advantages of reduced thrombogenicity, inherent tissue valve with resulting potential for both valve and conduit growth along with excellent handling characteristics. However, at least some studies show discouraging early results with important early complications and even mortality arising from conduit occlusion [17•, 18•]. They do not perform well in the Fontan venous position, though there does not seem to be any recent data on it [19]. When used as part of a Ross procedure, the early results have been a little more encouraging [20•]. Synthetic polyurethane valves [21] and decellularized homograft conduits [22] are newer conduit modifications on the horizon.

Percutaneous valve replacements have been attempted in pulmonary [16•,23,24] and aortic positions [25]. A novel nitinol stent device within which an additional bovine jugular valve is either inbuilt at the waist or can be separately deployed at a later time shows promise in animal experiments [26•].

Reoperations in tetralogy of Fallot

The overwhelming concern in this area arises from free pulmonary regurgitation (PR). Though hemodynamically well tolerated for the most part, long-term problems with free PR, such as RV volume overload and dilatation, fibrosis, arrhythmogenicity, and myocardial damage have been found to be cumulatively detrimental [30]. About a third to half of the late deaths in tetralogy of Fallot (TOF) are sudden. Older age at repair, severe left ventricular dysfunction, RV hypertension, prolonged QRS, and free PR are all recognized as risk factors for sudden death. Timely replacement of the pulmonary valve with a porcine bioprosthesis or a homograft is indicated in cases with severe PR causing RV dilatation, symptomatic or sustained arrhythmias so as to avoid irreversible changes. Tricuspid annuloplasty is indicated if this valve is severely regurgitant. Patients with sustained atrial flutter, atrial reentry tachycardia, or ventricular tachycardia should undergo catheter or surgical electrophysiological ablation studies along with correction of any ongoing hemodynamic issues. Patients with atrial fibrillation are shown to benefit from a biatrial Maze procedure [31].

Reoperations for conduits/ bioprosthesis in aortic position

Aortic homografts as well as mechanical prosthesis are acceptable options in the adult. Homografts carry the advantage of simultaneous root replacement and are preferred after endocarditis. Homograft and autograft long-term outcomes are fairly similar [27]. However, immune responses with homografts can hamper future cardiac transplant. After the first generation of xenografts showed a tendency for early deterioration, tissue engineering (preserving collagen crimping by glutaraldehyde preservation at low pressure) and addition of detergent/anticalcification agent such as sodium dodecyl sulphate (T6) led to the second generation of xenografts (Hancock II) in the 1980s. These valves have shown good 15-year durability in the aortic position [28•]. Dystrophic calcification is implicated in most cases and lipid insudation in some cases of structural dysfunction in this bioprosthesis [29••]. Studies to decipher associations between serum lipids and valve degradation may be able to advise on a target lipid profile for valve replacement patients; there may be scope for medical intervention.

Ross and Ross/Konno aortoventriculoplasty

This is an attractive proposition in the pediatric population, as it may preserve the growth potential of the root and valve while avoiding systemic anticoagulation [32•]. Though perioperative and early outcomes are acceptable [33•], we still await data on long-term outcome. One of the concerns in the long term is about neo-aortic root dilatation and secondary valve incompetence with numerous surgical modifications addressing this aspect [34,35•,36,37], acute onset dilatation [38], and stenosis [39•,40•]. The pulmonary trunk does not seem to be involved in structural and biomolecular degenerative changes observed in the aorta of patients with aortic aneurysm [41]. Neo-aortic root dilatation has also been worrisome in the hypoplastic left heart group into their second decade of follow-up [42••] and after arterial switch operations [43].

Pulmonary autograft as part of a Ross procedure shows better hemodynamic results on self-reported and measured exercise capacity [44,45•].

Reoperations in complete transposition of great arteries

Long-term outcome is definitely superior in the arterial as compared with atrial switch and in the Mustard versus the Senning group of atrial switches [46•]. Nonetheless, even in the exquisitely corrective approach that is the arterial switch, there are concerns about late PA stenosis, neo-aortic regurgitation, and an important rate of reintervention for conduit replacement in the Rastelli operation [46•]. Coronary artery stenosis after the arterial switch might be overlooked unless sought on coronary angiography and adult onset CAD may add to premature CAD as coronary lesions have been found to persist [47•].

As the patient population that underwent atrial switch (Senning or Mustard) enters their second or third postoperative decade, systemic RV failure becomes a substantial problem. Lack of donor hearts limits transplant options in the vast majority of these patients. In them, retraining the LV followed by an arterial switch and atrial reseptation is a viable option [48•], but challenging.

(Re)operations in corrected transposition of great arteries

Eventual systemic right ventricular failure dooms long-term outcome of this subset [49,50]. To avoid this complication, anatomic correction (irrespective of age) has become the procedure of choice in most centers, in the form of a double switch or Rastelli-Senning modification, with acceptable early and midterm results [51•].

Recoarctation revisited

Risk factors for recurrence (10% cases) are related to age and arch anatomy [52,53••]. Median sternotomy with conduit placement from the ascending to descending aorta for recoarctation with arch hypoplasia is preferred by some [54]. Other groups would use an extended end-to-end anastomosis if the distal arch is hypoplastic and a patch enlargement of all the aortic branches if the proximal arch is also narrow [53••]. The median sternotomy approach is preferred in hypoplastic arch cases as it improves visualization with lesser incidence of late aneurysm formation.

While balloon angioplasty is the modality of choice for recoarctations, stents may be another option in adolescents and adults [55•]. Stent implantation in full-grown aortas can avoid subsequent redilations. Long-term results after stent implantation in the descending aorta are awaited with concern about the influence of relatively noncompliant metal embedded in the aortic wall. As such, stents may be reserved for situations where balloon angioplasty has been unsatisfactory (gradient > 20 mm Hg). In a study comparing balloon-expandable versus self- expanding stents for native coarctation in adults, the authors found much better handling characteristics of nitinol self-expanding stent [56••]. Beneficial remodeling was later found in this group. Avoidance of overdilation, smoother atraumatic edges, decreased migration possibility, and good intima-media contact reducing dissection and aneurysm risks are factors favoring self-expanding stents. Other groups decline any role for stent implantation in adult native coarctation [57•]. Data on redilatation safety of stents is lacking, though stent fracture has been reported. At the level of the aortic tissue, vascular injuries are more likely and more severe with balloon dilatation, and neo-intimal hyperplasia due to ingrowth was more likely with stents [58].

Fontan related procedures

It is common to be faced with late complications following Fontan surgery and the median time to reoperation is 3.6 years [59] in about 58% cases. Morbidity and mortality increase with increasing age at surgery [60••]. Arrhythmias are the commonest indication for hospitalization, reintervention, and reoperation [59,60••], besides being the commonest cause for sudden death. These risks accumulate with age [60••]. Atrial flutter is the commonest symptomatic arrhythmia [61]. In an attempt to reduce the almost inevitable long-term complication of atrial reentry tachycardias, prophylactic atrial incisions [62•], DDD epicardial pacemaker implantation [63], intraoperative radiofrequency ablation with right atrial debulking [64•], catheter-based electroanatomic mapping, and RFA [65•] or cryoablation [66•] may be done at the time of Fontan conversion or later. Amiodarone is an effective therapeutic option in responders [60••].

Experience with single ventricle surgery undertaken for the first time in adulthood, as described by a Dutch group, shows worse morbidity and mortality [60••]. This experience is countered by reports from the Mayo group [67••] and in re-do Fontans [64•], which claim the same early mortality as surgery in childhood. These latter studies lack the duration of follow-up of the Dutch study. In the absence of 'risk factors' such as atrioventricular valve regurgitation and outflow obstruction, the Mayo group does not believe in a bidirectional cavopulmonary shunt prior to Fontan surgery [68]. While pulmonary vascular resistance and transpulmonary gradient were classically considered decisive preoperative predictors of operability, a recent study found this was not the case and the tau index of ventricular relaxation a clear predictor [69••].

Prognosis for Fontan patients requiring cardiac transplantation remains poor [59,70]. Anticoagulation in a Fontan setting is controversial. While randomized long-term data is lacking, scattered observations and studies do not reach any consensus. The reported incidence of CVAs (0.28 per patient year) in a postoperative Fontan childhood cohort is less than the risk of major bleeding complications from anticoagulation (0.7% per patient year) [71•]. In an adult study with much longer follow-up, a 25% incidence of thromboembolic episodes occurred despite adequate anticoagulation (INR 2–3.5) in 50% of cases and carried a mortality of 38% [60••]. This indicates the magnitude and urgency of the problem. Perhaps Fontan anticoagulation needs an age-dependent management algorithm, with the approach being conservative in children and more liberal in adults. These questions need evidence-based answers in a well-designed, prospective study.

The extracardiac Fontan modification has some proven advantages over lateral tunnel Fontan such as surgical ease, decreased bypass and circulatory arrest time, avoidance of atrial manipulation and sutures, decreased risk of atrial distention, and lesser hydraulic energy loss. Intermediate results show decreased incidence of arrhythmias and autonomic impairment [72••]. However, the lateral tunnel Fontan, on the heels of a previous Hemi Fontan circulation may have the best hydraulic performance relative to any other combination, including the extracardiac conduit [73•], possibly due to the natural anteroposterior offset between the vena cavae and the atriopulmonary connection in this combination. Apparently minor distances and angles can exponentially influence fluid dynamics and though computational studies are essential to guide surgical preferences, each surgery is likely to be a unique model.

Ventricular septal defects

Ventricular septal defects with ongoing concerns in adulthood are residual or complicated by outflow obstruction, aortic valve distortion with progressive AR. New regurgitation occurs in about 9% of follow-up cases [74] and progression of AR from mild to severe has been observed in 5% [75]. Special care should be taken that the risk of VSD closure, which is negligible, is not replaced with the much higher risk of aortic valve surgery or the long-term morbidity of an abnormal aortic valve or prosthesis.

Sudden death/aborted sudden death episodes and other emergency episodes

The risk for late sudden death (SD) for patients surviving operation for CHD is 25 to 100 times greater than an age-matched control population, more so for cyanotic CHD and outflow obstructions and after the second decade [76]. SD is the commonest mode of death, responsible for 26% of late deaths in ACHD followed by perioperative causes and progressive heart failure [77]. In the post-TOF repair group, risk factors were believed to be increased arrhythmogenicity arising from around the ventriculotomy scar, or RV damage due to chronic cyanosis, chronic volume, or pressure overload and fibrosis [78]. But sudden death can occur in late postoperative TOFs without any of these risk factors. In fact, even low-risk anomalies such as ASD can suffer SD late after surgery. In a 21-year prospective study on SD in athletes in Italy, the overall incidence was 2.3 per 100,000 athlete years and 2.1 per 100,000 athlete years in those with CHD [79•]. This was despite rigorous preparticipation screening already in place. Arrhythmogenic RV dysplasia, premature coronary artery disease, and congenital coronary anomalies were the commonest CHDs at risk.

In a prospective study, 20% of all urgent admissions of adults with CHD resulted in mortality or transplant in the next 3 years after initial admission [80••]. In spite of a number of methods, no single risk factor has been convincingly identified to predict VT and sudden death

in TOF, though each might give some indication of risk [81•]. Similarly, no risk factors could be identified retrospectively in groups that had AICD implantations after near SD episodes [82••].

Lifestyle issues

As this group of patients enters adulthood, they acquire the additional risk of acquired heart disease. In fact, systemic hypertension, atherosclerotic disease, age-related valve degenerations, and calcifications will compound their problems. Unfortunately, this group is also less likely to be gainfully employed, more likely to be sedentary, and is almost as likely to indulge in risk-taking behavior. While it is well known that depression is common in patients with CHD, there are no randomized controlled trials to date about the efficacy or effects of available pharmacological and nonpharmacological interventions [83]. A moderate level of exercise training has been found to improve aerobic capacity in postoperative TOF patients [84] and these encouraging results could easily be translated across all other hemodynamically stable lesions too. While most post-Fontan patients are in NYHA class I or II in the first postoperative decade, this diminishes with age, as does their self perception [60••]. This general outcome in palliated Fontan cases is understandably poorer than in groups that have undergone definitive repair [85•] or in those who underwent late corrective surgery [86•]. Insurance issues require accurate prognostication, based on ongoing reporting and constant updating of long-term survival data in CHD [87].

Policy and implementation

Policy and implementation need political will and commitment. Specialties and sub-boards need to plan and execute an integrated model of health care targeting this core group. Training a group of professionals specifically for ACHD is one approach, the other being a more informal combination of specialists from different fields with care convergence. While there are numerous examples of the success of the latter approach, a system is needed to broaden the scope across the country and indeed internationally. Discussing and preparing the patient and family for a transition to such a clinic is critical and should be done in a timely fashion to ensure continuity of care.

Conclusion

Adult congenital heart disease is a complex and challenging field that needs specialized expertise and a dedicated infrastructure to train, equip, and manage. While there have been major advances, we continue to have more questions than answers about strategies for care. We must hope that, even though many of these conditions are uncommon in the general population, large multicentered clinical trials will be added to the tools used to refine our knowledge and support our management.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

- • Of special interest
- •• Of outstanding interest

1 • Hoffman JIE, Kaplan S, Liberthson RR: Prevalence of congenital heart disease. Am Heart J 2004, 147:425–439.

Specific CHDs or fractions thereof are categorized as mild, moderate, or severe to reflect the survival probability in 5-year age increments. Such data was intended to help projections of training requirements and resource allocation. This impressive compilation is certainly going to be central to policy decisions in the field.

2 Warnes CA, Liberthson R, Danielson GK, et al.: Task force1: The changing profile of congenital heart disease in adult life. J Am Coll Cardiol 2001, 37: 1170–1175.

3 Webb CL, Jenkins KJ, Karpawich PP, et al.: Collaborative care for adults with congenital heart disease. Circulation 2002, 105:2318–2323.

4 Gatzoulis MA, Hechter S, Siu SC, Webb GD: Outpatient clinics for adults with congenital heart disease: increasing workload and evolving patterns of referral. Heart 1999, 81:57–61.

5 Webb GD, Williams RG, et al.: 32nd Bethesda Conference: care of the adult with congenital heart disease. J Am Coll Cardiol 2001, 37:1161–1198.

6 Morris CD, Menashe VD: 25 year mortality after surgical repair of congenital heart defect in childhood. A population based cohort study. JAMA 1991, 266: 3447–3452.

7 •• Therrien J, Webb G: Clinical update on adults with congenital heart disease. Lancet 2003, 362:1305–1313.

A must read for all of us in the field, this review rounds up the authors' expertise with all the evidence that is required for up-to-date management of this diverse medical population.

8 Murphy JG, Gersh BJ, McGoon MD, et al.: Long term outcome after surgical repair of isolated atrial septal defect: follow-up at 27 to 32 years. N Engl J Med 1990, 323:1645–1650.

9 • Monro JL, Alexiou C, Salmon AP, Keeton BR: Reoperations and survival after primary repair of congenital heart defects in children. J Thorac Cardiovasc Surg 2003, 126:511–520.

Large retrospective analysis of single surgeon outcomes spanning 16 years of planned, inevitable, or unexpected cardiac surgeries. The freedom from surgery was 77% at 10 years for the group undergoing aortic valvotomy. Surgical rather than balloon valvotomy was the choice in this center and the authors feel that the more controlled open commissurotomy reduces regurgitation risk and eventual reoperation.

10 • Berdat PA, Immer F, Pfammatter J, Carrel T: Reoperations in adults with congenital heart disease: analysis of early outcome. Int J Cardiol 2004, 93:239–245.

This retrospective analysis of adults with known CHD, who require reoperations showed that LV outflow tract obstruction was the commonest indication for reoperation. Early postoperative mortality was 7.6% in this series; cyanosis was the prime risk factor.

11 Dore A, Glancy L, Stone S, et al.: Cardiac surgery for grown up congenital heart patients: Survey of 307 consecutive operations from 1991 to 1994. Am J Cardiol 1997, 80:906–913.

12 Caldarone CA, McCrindle BW, Van Arsdell GS, et al.: Independent factors associated with longevity of prosthetic pulmonary valves and valved conduits. J Thorac Cardiovasc Surg 2000, 120:1021–1031.

13 •• Wells W, Malas M, Baker CJ, et al.: Depopulated vena caval homograft: A new venous conduit. J Thorac Cardiovasc Surg 2003, 126:498–503.

This large-animal study documents the preparation of the depopulated venous graft they used in the superior vena caval position in 8 minipigs. The study duration of 6 months, after which the conduits were removed and analyzed for important endothelial and subendothelial markers, may seem a little short to determine the prolonged outcome.

14 •• Dearani JA, Danielson GK, Puga FG, et al.: Late follow up of 1095 patients undergoing operation for complex congenital heart disease utilizing pulmonary ventricle to pulmonary artery conduits. Ann Thorac Surg 2003, 75:399–411.

This large patient cohort from Mayo, operated prior to July 1992, provides survival and freedom from reoperation data for CHDs requiring conduits. The Hancock porcine valve fared better than any of the other homograft valves in this series and this finding has been well defended by the authors as a reflection of the patient population and conduit type used.

15 Bermudez CA, Dearani JA, Puga FJ: Late results of the peel operation for
• replacement of failing extracardiac conduits. Ann Thorac Surg 2004, 77: 881–888.
The authors have described an autologous tissue reconstruction technique for extracardiac conduits in the right ventricle to pulmonary artery position. Follow-up over a mean 7.6 years shows greater freedom from reoperation than conventional or homograft conduits.

16 Kanter KR, Fyfe DA, Mahle WT, et al.: Results with the freestyle porcine aortic
• root for right ventricular outflow tract reconstruction in children. Ann Thorac Surg 2003, 76:1889–1895.
Fifty six children and adolescents underwent RVOT reconstruction using a Freestyle stentless porcine aortic root graft with good early and intermediate results.

17 Boudjemline Y, Bonnet D, Massih TA, et al.: Use of bovine jugular vein to
• reconstruct the right ventricular outflow tracts: Early results. J Thorac Cardiovasc Surg 2003, 126:490–497.
Early complications within a 3-month postoperative follow-up in a cross-section of cases 0 to 21 years old requiring right ventricle to pulmonary artery conduits showed an alarming incidence of thrombosis, occlusion, obstruction, valve incompetence.

18 Bottio T, Thiene G, Vida V, et al.: The bovine jugular vein conduit for right
• ventricular outflow tract reconstruction: A feasible alternative to homograft conduits? J Thorac Cardiovasc Surg 2004, 127:1204–1207.
The high early surgical mortality (3/10) in this group might be more specific to the anatomy or surgery rather than significant degradation of the bovine conduit, but adds to other concerns about the suitability of this prosthesis.

19 Schoof PH, Koch AD, Hazekamp MG, et al.: Bovine jugular vein thrombosis in the Fontan circulation. J Thorac Cardiovasc Surg 2002, 124:1038–1040.

20 Purohit M, Kitchiner D, Pozzi M: Contegra bovine jugular vein right ventricle to
• pulmonary artery conduit in Ross procedure. Ann Thorac Surg 2004, 77: 1707–1710.
Though the mean age of 14 years is more representative of the young adult, a follow-up of 14 months is certainly inadequate to consider the long-term outcome of the conduit.

21 Robin J, Martinot S, Curtil A, et al.: Experimental right ventricle to pulmonary artery discontinuity: outcome of polyurethane valved conduits. J Thorac Cardiovasc Surg 1998, 115:898–903.

22 Goldstein S, Clarke DR, Walsh SP, et al.: Transspecies heart valve transplant; advanced studies of a bioengineered xeno-autograft. Ann Thorac Surg 2000, 70:1962–1969.

23 Bonhoeffer P, Boudjemline Y, Saliba Z, et al.: Percutaneous replacement of pulmonary valve in a right ventricle to pulmonary artery prosthetic conduit with valve dysfunction. Lancet 2000, 356:1403–1405.

24 Bonhoeffer P, Boudjemline Y, Qureshi SA, et al.: Percutaneous insertion of the pulmonary valve. J Am Coll Cardiol 2002, 39:1664–1669.

25 Boudjemline Y, Bonhoeffer P: Steps towards percutaneous aortic valve replacement. Circulation 2002, 105:775–778.

26 Boudjemline Y, Agnoletti G, Bonner D, et al.: Percutaneous pulmonary valve
• replacement in a large right ventricular outflow tract. An experimental study. J Am Coll Cardiol 2004, 43:1082–1087.
A novel stent design, coupled with a bovine jugular vein valve in the pulmonary position has been described. The animal-based experiment tried to simulate the real situation of dilated outflow tracts as seen with transannular patch repair of tetralogy of Fallot. This study is relevant since dilated outflows can often confound deployment of prosthesis.

27 Knott-Craig CJ, Elkins RC, Santangelo K, et al.: Aortic valve replacement: Comparison of late survival between autografts and homografts. Ann Thorac Surg 2000, 69:1327–1332.

28 Rizzoli G, Bottio T, Thiene G, et al.: Long term durability of the Hancock II
• porcine bioprosthesis. J Thorac Cardiovasc Surg 2003, 126:66–74.
This detailed study of long-term outcomes in 212 patients age 63 ± 9 years, to a median of 9 years shows acceptable results, and recommends the Hancock II bioprosthesis in adults over 65 years.

29 Bottio T, Thiene G, Pettenazzo E, et al.: Hancock II prosthesis: A glance at the
•• microscope in mid-long-term explants. J Thorac Cardiovasc Surg 2003, 126: 99–105.
An interesting pathological study gives valuable insight into the possible tissue mechanisms of valve degradation. While dystrophic calcification is of established significance in valve deterioration, the overwhelming prevalence of lipid insudation in explanted valves is a track worth pursuing. Is there a correlation between serum lipid levels and valve degradation in these patients; should we then have a lower threshold for statin therapy in this group of patients?

30 Therrien J, Siu SC, McLaughlin PR, et al.: Pulmonary valve replacement in adults late after repair of Tetralogy of Fallot: are we operating too late? J Am Coll Cardiol 2000, 36:1670–1675.

31 Therrien J, Siu S, Harris L, et al.: Impact of pulmonary valve replacement on arrhythmia propensity late after repair of tetralogy of Fallot. Circulation 2001, 103:2489–2494.

32 Sai Sudhakar CB, Davis T, Weinstein S: Technical aspects of the Ross op-
• eration in children and adults. Prog Pediatr Cardiol 2003, 16:125–132.
A surgical review of the technique and some modifications.

33 Wernovsky G, Marino BS, Spray TL: Immediate outcomes after the Ross
• operation in children and adults. Prog Pediatr Cardiol 2003, 16:141–147.
Early reintervention was required in 20% of this case series of 97 patients undergoing Ross procedure and modifications, and draws attention to frequent postoperative bleeding in this scenario.

34 Ishizaka T, Devaney EJ, Ramsburgh SR, et al.: Valve sparing aortic root replacement for dilatation of the pulmonary autograft and aortic regurgitation after the Ross procedure. Ann Thorac Surg 2003, 75:1518–1522.

35 Luciani GB, Casali G, Favaro A, et al.: Fate of the aortic root late after Ross
• operation. Circulation 2003, 108(suppl II):61–67.
This study showed that the diameters of the sinotubular junction and proximal aorta tend to equalize with the sinus of Valsalva as part of a root remodeling process after the Ross procedure. A root reduction technique may still not avoid autograft dilatation.

36 Roux PM, Saad N: Modified Ross procedure for dysplastic ascending aorta. Ann Thorac Surg 2003, 76:1754–1756.

37 Hraska V, Krajci M, Haun C, et al.: Ross and Ross-Konno procedure in children and adolescents: mid term results. Eur J Cardiothorac Surg 2004, 25: 742–747.

38 Villavicencio RE, Humes RA, Epstein ML, et al.: Abrupt aortic root dilatation after the Ross procedure-is this a progressive phenomenon? J Card Surg 2003, 18:384–389.

39 Sievers Hans-H, Dahmen G, Graf B, et al.: Midterm results of the Ross pro-
• cedure preserving the patients aortic root. Circulation 2003, 108(suppl II): 55–60.
A follow-up of about 550 patient years in an age group between 15 and 70 years using the subcoronary of root inclusion techniques as originally described, shows that this modification may decrease the incidence of distant aortic root dilatation. The relatively older age group of these patients at the time of the Ross surgery as compared to other studies with younger patients raises the question of functional deterioration of the pulmonary autograft as a function of age at time of surgery, as well as possible root-sparing modifications.

40 Fullerton DA, Fredericksen JW, Sundaresan S, Horvath KA: The Ross proce-
• dure in adults: Intermediate–term results. Ann Thorac Surg 2003, 76:471–477.
Standardized strategies to ensure geometric matching at the annular, sinotubular junction, and the distal aortic root were used in this series so as to effectively minimize autograft dysfunction.

41 Schmid FX, Bielenberg K, Holmer S, et al.: Structural and biomolecular changes in aorta and pulmonary trunk of patients with aortic aneurysm and valve disease: implications for the Ross procedure. Eur J Cardiothorac Surg 2004, 25:748–753.

42 Cohen MS, Mariono BS, McElhinney DB, et al.: Neo aortic root dilation and
•• valve regurgitation up to 21 years after staged reconstruction for hypoplastic left heart syndrome. J Am Coll Cardiol 2003, 42:533–540.
Pulmonary transection procedures (Norwood, arterial switch, and Ross operation) interrupt the vasa vasorum of the pulmonary trunk. This may predispose to neo aortic root dilatation in these groups. Somewhat counter-intuitively, early volume unloading of the single ventricle heart did not seem to decrease the incidence or severity of neoAR.

43 Hutter PA, Thomeer BJM, Jansen P, et al.: Fate of the aortic root after arterial switch operations. Eur J Thorac Cardiovasc Surg 2001, 20:82–88.

44 Wang A, Jaggers J, Ungerleider RM, et al.: Exercise echocardiographic comparison of pulmonary autograft and aortic homograft replacements for aortic valve disease in adults. J Heart Valve Dis 2003, 12:202–208.

45 Lupinetti FM, Duncan BW, Lewin M, et al.: Comparison of autograft and al-
• lograft aortic valve replacement in children. J Thorac Cardiovasc Surg 2003, 126:240–246.
Though the oldest patient was 22 years in this series, their findings of equally good intermediate outcomes with the autograft and the allograft in the aortic position are interesting, despite echocardiographic findings of a greater decrease in LVOT Vmax and LVPW thickness in the autograft group.

46 Williams WG, McCrindle BW, Ashburn DA, et al.: Outcome of 829 neonates
• with complete transposition of the great arteries 12–17 years after repair. Eur J Cardiothorac Surg 2003, 24:1–9.
Prospective multicentered long-term data straddling the surgical transition from the atrial to the arterial switch highlights some important differences between outcomes of these groups and also within the atrial switch group.

47 Legendre A, Losay J, Touchot-Kone A, et al.: Coronary events after arterial
• switch operation for transposition of the great arteries. Circulation 2003, 108(suppl II):186–190.
Delayed coronary artery lesions occurred in about 7% of cases late into their follow-up, and noninvasive tests were not found to be predictive of coronary events.

48 Poirier NC, YU J, Brizard C, Mee RBB: Long-term results of left ventricular reconditioning and anatomic correction for systemic right ventricular dysfunction after atrial switch procedures. J Thorac Cardiovasc Surg 2004, 127:975–981.
Interesting and important work coming from the pioneers of the two-staged arterial switch.

49 van Son JA, Danielson GK, Huhta JC, et al.: Late results of systemic atrioventricular valve replacement in corrected transposition. J Thorac Cardiovasc Surg 1995, 109:642–653.

50 Yeh T Jr, Connelly MS, Coles JG, et al.: Atrioventricular discordance: results of repair in 127 patients. J Thorac Cardiovasc Surg 1999, 117:1190–1203.

51 Langley SM, Winlaw DS, Stumper O, et al.: Midterm results after restoration
• of the morphologically left ventricle to the systemic circulation in patients with congenitally corrected transposition of the great arteries. J Thorac Cardiovasc Surg 2003, 125:1229–1241.
Through the decade-long experience of this group, they have divided the particular anatomical types within this subset and developed a management algorithm for them, with acceptable early and midterm results.

52 Ralph-Edwards AC, Williams WG, Coles JC, et al.: Reoperation for recurrent aortic coarctation. Ann Thorac Surg 1995, 60:1303–1307.

53 Zoghbi J, Serraf A, Mohammadi S, et al.: Is surgical intervention still indicated
•• in recurrent aortic arch obstruction? J Thorac Cardiovasc Surg 2004, 127:203–212.
Detailed paper on intermediate results and comparison between balloon angioplasty and surgical correction of recoarctation, advises that presence of arch hypoplasia should indicate surgical correction rather than angioplasty and the approach should preferably be through median sternotomy.

54 Connolly HM, Schaff HV, Izhar U, et al.: Posterior pericardial ascending-to-descending aortic bypass; an alternative surgical approach for complex coarctation of the aorta. Circulation 2001, 104(suppl 1):1133–1137.

55 Piechaud J: Stent implantation for coarctation in adults. J Interv Cardiol 2003,
• 16:413–418.
A review article clarifying case selection and procedural approach.

56 Tyagi S, Singh S, Mukhopadhyay S, Kaul UA: Self- and balloon- expandable
•• stent implantation for severe native coarctation of aorta in adults. Am Heart J 2003, 146:920–928.
This study found interesting differences in the handling of these types of stents in patients who had a failed balloon angioplasty in the setting of native coarctation. Beneficial late remodeling in the nitinol stent group is intriguing and no theoretical mechanism has been forwarded, but it deserves further longer-term studies.

57 Fawzy ME, Awad M, Hassan W, et al.: Long-term outcome (up to 15 years) of
• balloon angioplasty of discrete native coarctation of the aorta in adolescents and adults. J Am Coll Cardiol 2004, 43:1062–1067.
Cardiac catheterization a year after balloon angioplasty and MRI done annually after the first postprocedure year in this follow-up group of 44 patients from 15 to 55 years makes it an important, prospective follow-up study.

58 Ohkubo M, Takahashi K, Kishiro M, et al.: Histological findings after angioplasty using conventional balloon, radiofrequency thermal ablation and stent for experimental aortic coarctation. Pediatr Int 2004, 46:39.

59 Petko M, Myung RJ, Wernovsky G, et al.: Surgical reinterventions following the Fontan procedure. Eur J Cardiothorac Surg 2003, 24:255–259.

60 Van den Bosch AE, Roos-Hesselink J, van Domburg R, et al.: Long term out-
•• come and quality of life in adult patients after the Fontan operation. Am J Cardiol 2004, 93:1141–1145.
This retrospective cohort of the Dutch experience with Fontan patients highlights the large burden of morbidity and mortality attributable to arrhythmia alone. The high incidence of thromboembolic complications (25%) despite at least 50% of them being on adequate anticoagulation (INR between 2 and 3.5), though higher than other series, is accompanied by a substantial mortality (38%).

61 Li W, Somerville J: Atrial flutter in grown-up congenital heart (GUCH) patients. Clinical characteristics of affected population. Int J Cardiol 2000, 75: 129–137.

62 Collins KK, Rhee EK, Delucca JM, et al.: Modification to the Fontan procedure
• for the prophylaxis of intra-atrial re-entrant tachycardia: short term results of a prospective randomized blinded trial. J Thorac Cardiovasc Surg 2004, 127: 721–729.
This article is to be commended in its prospective randomized blinded design. Atrial incisions at the time of a lateral tunnel Fontan were found to increase conduction time and decrease incidence of early intra-atrial reentry tachycardia besides being feasible and safe.

63 Heineman MK, Gass M, Breuer J, Ziemer G: DDD pacemaker implantation after Fontan type operations. Pacing Clin Electrophysiol 2003, 26:492–495.

64 Mott AR, Feltes TF, McKenzie D, et al.: Improved early results with the Fontan
• operation in adults with functional single ventricle. Ann Thorac Surg 2004, 77:1334–1340.
Role of right atrial radio frequency ablation in combination with right atrial debulking in redo Fontans has been found to eliminate arrhythmia in this study.

65 Weipert J, Noebauer C, Schreiber C, et al.: Occurrence and management of
• atrial arrhythmia after long term Fontan circulation. J Thorac Cardiovasc Surg 2004, 127:457–464.
Though it is hard to believe that this group did not experience any Fontan failures due to arrhythmia, they have realized a satisfactory institutional outcome with catheter-based electroanatomic mapping and ablation.

66 Weinstein S, Cua C, Chan D, Davis JT: Outcome of symptomatic patients
• undergoing extracardiac Fontan conversion and cryoablation. J Thorac Cardiovasc Surg 2003, 126:529–536.
Though this limited study concluded that protein losing enteropathy should not be considered a contraindication, their conclusion is based on experience with only two cases and one mortality within that subset.

67 Burkhart HM, Dearani JA, Mair DD, et al.: The modified Fontan procedure:
•• Early and late results in 132 adult patients. J Thorac Cardiovasc Surg 2003, 125:1252–1259.
Detailed review of modified Fontan procedures performed in a cohort above 18 years of age, of which 31 patients had previous Glenn surgeries. Early morbidity and mortality were similar regardless of age at surgery.

68 Dearani JA, Puga FJ, Danielson GK: In reply to the editor. J Thorac Cardiovasc Surg 2004, 127:609.

69 Border WL, Syed AU, Michelfelder EC, et al.: Impaired systemic ventricular
•• relaxation affects postoperative short term outcome in Fontan patients. J Thorac Cardiovasc Surg 2003, 126:1760–1764.
Hemodynamic catheterization data was validated and tau index was the only significant preoperative invasive predictor. Pulmonary venous resistance and transpulmonary gradient were not predictive of short-term results in this group; this bears further study as they are widely used criterion for deciding suitability for a Fontan surgery.

70 Gamba A, Merlo M, Fiocchi R, et al.: Heart transplantation in patients with previous Fontan operations. J Thorac Cardiovasc Surg 2004, 127:555–562.

71 Mahnke CB, Boyle GJ, Janosky JE, et al.: Anticoagulation and incidence of
• late cerebrovascular accidents following the Fontan procedure. Pediatric Cardiology 2004 March 4 [Epub ahead of print].
Retrospective and multi-institutional data collection about incidence of cerebrovascular (CVA) incidents is far from ideal. Also, CVA is not defined for the purposes of this paper and the statistic of 0.28% per patient year incidence of CVA does not appear reproducible, although the total number of 132 patients is a good size.

72 Nakano T, Kado H, Ishikawa S, et al.: Midterm surgical results of total cavo-
•• pulmonary connection: Clinical advantages of the extracardiac conduit method. J Thorac Cardiovasc Surg 2004, 127:730–737.
Progressive increase in dimensions and inferred volume of the intra-atrial baffle of the lateral tunnel modification as determined on cardiac catheterization in this study is accompanied by increased atrial natriuretic peptide. This supports the view that atrial distention, atrial suturing, as well as sinus node and artery damage in the lateral tunnel modification make it less attractive than the extracardiac conduit option. Though the mathematical algorithm used by the authors is not entirely reflective of a true volume change, it is a simplistic measure of dimension or shape change.

73 Bove EL, de Leval MR, Migliavacca F, et al.: Computational fluid dynamics in
• the evaluation of hemodynamic performance of cavopulmonary connections after the Norwood procedure for hypoplastic left heart syndrome. J Thorac Cardiovasc Surg 2003, 126:1040–1047.
The art of realistic modeling and the science of fluid dynamic computations are skillfully brought together in this work. While it is well known that each anatomy is unique, and that outcomes are decided on technical modification and surgical expertise, this article brings more scientific thought to the design and construction of the systemic venous conduits and connections in the Fontan pathway.

74 Otterstad JE, Froysaker T, Erikssen J, Simonsen S: Long term results in isolated ventricular septal defect surgically repaired after age 10: Comparison with the natural course in similarly aged patients. Scand J Thorac Cardiovasc Surg 1985, 19:221–229.

75 Neumayer U, Stone S, Somerville J: Small ventricular septal defects in adults. Eur Heart J 1998, 19:1573–1582.

76 Silka MJ, Hardy BG, Menashe VD, Morris CD: A population based prospective evaluation of risk of sudden cardiac death after operation for common congenital heart defects. J Am Coll Cardiol 1998, 32:245–251.

77 Oechslin EN, Harrison DA, Connolly MS, et al.: Mode of death in adults with congenital heart disease. Am J Cardiol 2000, 86:1111–1116.

78 Deanfield JE, Ho SY, Anderson RH, et al.: Late sudden death after repair of tetralogy of Fallot: a clinicopathological study. Circulation 1983, 67:626–631.

79 • Corrado D, Basso C, Rizzoli G, et al.: Does sports activity enhance the risk of sudden death in adolescents and young adults? J Am Coll Cardiol 2003, 42:1959–1963.
This study is outstanding by the simple feature that it is a 21-year prospective study on sudden deaths in athletes who have already undergone preparticipation screening.

80 •• Kaemmerer H, Fratz S, Bauer U, et al.: Emergency hospital admission and three-year survival of adults with and without cardiovascular surgery for congenital heart disease. J Thorac Cardiovasc Surg 2004, 126:1048–1052.
This paper gives an insight into the patient load and distribution in referral centers in Germany; 25% of all admissions (mean 36 years) at this specialized adult CHD center were urgent and unscheduled, 83% for cardiovascular complications. A 3-year follow-up revealed 20[ref]mortality or transplant after the index emergency admission. Improvements must be made in staffing and training in the ER setting to diminish this unforeseen source of mortality.

81 • Steeds RP, Oakley D: Predicting late sudden death from ventricular arrhythmia in adults following surgical repair of tetralogy of Fallot. Review. Q J Med 2004, 97:7–13.
This review article pools numerous studies and techniques predictive of risk of sudden death in TOF and highlights the difficulties of teasing out specific risk markers for adverse events.

82 •• Dore A, Santagata P, Dubuc M, Mercier L: Implantable cardioverter defibrillators in adults with congenital heart disease: A single center experience. Pacing Clin Electrophysiol 2004, 27:47–51.
This 7-year retrospective review of cases brings to light an important unpredictable subset of patients who required AICD after aborted sudden death despite normal QRS durations and normal ventricular function.

83 Lip GY, Lane DA, Millane TA, Tayebjee MH: Psychological interventions for depression in adolescent and adult congenital heart disease. Cochrane Database Syst Rev 2003, 3:CD004394.

84 Therrien J, Fredriksen P, Walker M, et al.: A pilot study of exercise training in adult patients with repaired tetralogy of Fallot. Can J Cardiol 2003, 19:685–689.

85 • van Rijem EHM, Utens EMWJ, Roos-Hesselink JW, et al.: Psychosocial functioning of the adult with congenital heart disease: a 20-33 years follow-up. Eur Heart J 2003, 24:673–683.
Adults with operated ASD, VSD, TGA, TOF, and PS were analyzed. Overly optimistic results in this group may be a function of denial or coping mechanisms as the authors have suggested, but the highest educational level was lower than the reference population even though career possibilities were rated equally by them in questionnaires. At least 85% had a paid job and CHD was quoted as a cause in only 8% sick leave episodes.

86 • Nieminen H, Sairanen H, Tikanoja T, et al.: Long-term results of pediatric cardiac surgery in Finland: Education, employment, marital status, and parenthood. Pediatrics 2003, 112:1345–1350.
Educational level in nonsyndromic CHD was higher than the normal population; a high value of employment and as normal a lifestyle as they can achieve motivates this finding.

87 Vonder Mull I, Cumming G, Gatzoulis MA: Risky business: insuring adults with congenital heart disease. Eur Heart J 2003, 24:1595–1600.