Heart Failure in ACHD

The Failing Systemic Right Ventricle

European Society of Cardiology
2012

SickKids
The Labatt Family Heart Centre

Toronto Congenital Cardiac Centre for Adults
I have nothing to disclose.
Heart Failure in ACHD

Is the right ventricle an inherently ‘weaker’ ventricle?

• Functionally single ventricle
• TGA (after atrial switch)
• CCTGA
RV Morphology: Functionally Single V

Surgery for Congenital Heart Disease

Predictors of outcome after the Fontan operation: Is hypoplastic left heart syndrome still a risk factor?

J. William Gaynor, MD
Nancy D. Bridges, MD
Mitchell Cohen, MD
William T. Mahle, MD
William M. DeCampli

Objective: This study was undertaken to evaluate factors in early mortality and morbidity after the Fontan procedure between January 1, 1992, and December 31, 1999.
Heart Failure in ACHD

RV morphology: Functionally Single V

Gentles et al. JTCVS 1997;114:376-91
Heart Failure in ACHD

Force-frequency relationships

Cheung et al. Heart 2005
Heart Failure in ACHD

Contemporary Outcomes After the Fontan Procedure

A Pediatric Heart Network Multicenter Study

Page A. W. Anderson, MD,* Lynn A. Sleeper, ScD,† Lynn Mahony, MD,‡ Steven D. Colan, MD,§ Andrew M. Atz, MD,¶ Roger E. Breitbart, MD,§ Welton M. Gersony, MD,¶ Dianne Gallagher, MS,† Tal Geva, MD,§ Renee Margossian, MD,§ Brian W. McCrindle, MD, MPH, Stephen Paridon, MD,** Marcy Schwartz, MD,§ Mario Stylianou, PhD,†† Richard V. Williams, MD,‡‡ Bernard J. Clark III, MD,‡‡ for the Pediatric Heart Network Investigators

Durham, North Carolina; Watertown and Boston, Massachusetts; Dallas, Texas; Charleston, South Carolina; New York, New York; Toronto, Ontario, Canada; Philadelphia, Pennsylvania; Bethesda, Maryland; and Salt Lake City, Utah

Objectives
We characterized a large cohort of children who had a Fontan procedure, with measures of functional health status, ventricular size and function, exercise capacity, heart rhythm, and brain natriuretic peptide (BNP).

Background
The characteristics of contemporary Fontan survivors are not well described.

Methods
We enrolled 546 children (age 6 to 18 years, mean 11.9 years) and compared them within pre-specified anatomic and procedure subgroups. History and outcome measures were obtained within a 3-month period.

Results
Predominant ventricular morphology was 49% left ventricular (LV), 34% right ventricular (RV), and 19% mixed. Ejection fraction (EF) was normal for 73% of subjects; diastolic function grade was normal for 28%. Child Health Questionnaire mean summary scores were lower than for control subjects; however, over 80% of subjects were in the normal range. Brain natriuretic peptide concentration ranged from <4 to 652 pg/ml (median 13 pg/ml). Mean percent predicted peak $O_2$ consumption was 65% and decreased with age. Ejection fraction and EF $Z$ score were lowest, and semilunar and atrioventricular (AV) valve regurgitation were more prevalent in the RV subgroup. Older age at Fontan was associated with more severe AV valve regurgitation. Most outcomes were not associated with a superior cavopulmonary connection before Fontan.

Conclusions
Measures of ventricular systolic function and functional health status, although lower on average in the cohort compared with control subjects, were in the majority of subjects within 2 standard deviations of the mean for control subjects. Right ventricular morphology was associated with poorer ventricular and valvular function. Effective strategies to preserve ventricular and valvular function, particularly for patients with RV morphology, are needed.  

*(J Am Coll Cardiol 2008:52:85–98) © 2008 by the American College of Cardiology Foundation*
Heart Failure in ACHD

ACE inhibition (18pts, R/DB/PC)

- No change in resting Doppler indices, HR, cardiac index or exercise duration
- Trend to reduced CI and VO$_2$
- Exercise induced increase in cardiac index significantly *reduced* with treatment

Kouatli et al. Circulation 1997
Contemporary Outcomes After the Fontan Procedure

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*Durham, North Carolina; Watertown and Boston, Massachusetts; Dallas, Texas; Charleston, South Carolina; New York, New York; Toronto, Ontario, Canada; Philadelphia, Pennsylvania; Bethesda, Maryland;

Fifty-eight percent of subjects were taking an angiotensin-converting enzyme inhibitor at enrollment. Diastolic function grade was normal in 28%. The median

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Heart Failure in ACHD

Beta blockade? (151 pts R/DB/PC)

<table>
<thead>
<tr>
<th>Ventricular status</th>
<th>Placebo (%)</th>
<th>Carvedilol* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systemic left ventricle (n=116)</td>
<td>51</td>
<td>64</td>
</tr>
<tr>
<td>No left ventricle (n=41)</td>
<td>66</td>
<td>35</td>
</tr>
</tbody>
</table>

*Combined low- and high-dose groups

Shaddy R. et al JAMA Sept 2007
Heart Failure in ACHD

**CCTGA/Mustard-Senning**
- RV dilation
- Reduced resting/stressed RVEF
- Reduced exercise function
- Neurohormonal activation

‘Systemic RV’ dilated cardiomyopathy
Heart Failure in ACHD

Late RV Failure: Treatment

● **ACE inhibition?**
  - Open label, non randomised
  - No overall change in RV function (MRI) or exercise function *(Hechter et al. Am J Cardiology 2001;87:660-3)*

● **Angiotensin receptor blockade?**
  - Multicentre, randomised, placebo-controlled with Losartan
  - No change in exercise function or NT-BNP
  - ‘’implies an alternative mechanism for ventricular dysfunction and impaired ex capacity in these patients.’’ *(Dore et al. Circulation 2005;112:2411-16)*
Aetiology of RV dysfunction

Ischemia?

- 61 patients after atrial switch (7-23 years old)
- Resting and peak exercise technetium$^{99}$ tomography

Lubiszewska et al. JACC 2000;36:1365-70
Heart Failure in ACHD

**Aetiology of RV dysfunction: CCTGA**

- 20 patients
- Resting perfusion defects in all
- Correlated with RVEF

*Hornung et al. Am J Cardiol 1999*
Heart Failure in ACHD

**LV after arterial switch**

31 patients 9.0+2 years after switch

<table>
<thead>
<tr>
<th>Patient</th>
<th>Exercise myocardial perfusion defects</th>
<th>Hypokinetic segments on dobutamine stress echocardiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anterolateral</td>
<td>Apical ant, apical lat</td>
</tr>
<tr>
<td>2</td>
<td>Ant, lat</td>
<td>Ant sept, apical lat, apical sept</td>
</tr>
<tr>
<td>4</td>
<td>Ant, lat, inferolateral, basal inf</td>
<td>Ant sept, apical post, apical sept, apical lat</td>
</tr>
<tr>
<td>6</td>
<td>Anterolateral, sept, inf, apical</td>
<td>Ant sept, mid post, apical post, apical inf, mid lat, mid inf, basal inf</td>
</tr>
<tr>
<td>7</td>
<td>Anterolateral, anteroapical</td>
<td>Apical ant, mid ant, basal ant, apical inf, mid inf, basal inf</td>
</tr>
<tr>
<td>8</td>
<td>Anterolateral</td>
<td>Apical ant, apical lat</td>
</tr>
<tr>
<td>10</td>
<td>Ant, basal inferolateral</td>
<td>Mid ant, basal ant, mid inf, basal inf</td>
</tr>
<tr>
<td>12</td>
<td>Ant</td>
<td>Mid ant sept, basal ant, basal ant sept</td>
</tr>
<tr>
<td>17</td>
<td>Anteroseptal, inferolateral</td>
<td>Ant sept, apical inf, apical ant, mid ant, basal ant</td>
</tr>
<tr>
<td>18</td>
<td>Anteroseptal, ant, inferoseptal</td>
<td>Apical sept, apical inf, mid inf, basal inf, apical ant sept, mid ant sept, basal ant sept</td>
</tr>
<tr>
<td>19</td>
<td>Anterolateral, inf, inferoapical</td>
<td>Apical inf, apical ant, mid inf</td>
</tr>
<tr>
<td>20</td>
<td>Ant, anterolateral</td>
<td>Mid ant, basal ant</td>
</tr>
<tr>
<td>22</td>
<td>Anterolateral</td>
<td>Apical ant, apical lat</td>
</tr>
<tr>
<td>28</td>
<td>Ant, inf</td>
<td>Apical ant, apical inf, mid inf, basal inf</td>
</tr>
<tr>
<td>29</td>
<td>Anterolateral</td>
<td>Apical ant, mid ant, basal ant</td>
</tr>
<tr>
<td>30</td>
<td>Ant, inf</td>
<td>Apical ant, apical inf, mid inf, basal inf</td>
</tr>
<tr>
<td>31</td>
<td>Ant, inf</td>
<td>Ant sept, apical inf, mid inf, basal inf, apical ant</td>
</tr>
</tbody>
</table>

Ant, anterior; inf, inferior; sept, septal; lat, lateral; mid, middle; post, posterior.

_Hui et al. Heart 2005_
Heart Failure in ACHD

Tissue Doppler

Vogel et al. JACC 2004:43; 1006
The effects of ventricular asynchrony on myocardial perfusion

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b Department of Cardiology, University of Ioannina, Greece

Ono et al. Circulation 1992: 85; 1125-31
Heart Failure in ACHD

**Methods**

- Integrated catheter
  - micromanometer
  - conductance electrodes
- Thermodilution cath
- IVC occlusion balloon
- Dobutamine
  - 0, 5, 10 mcg/kg/min

*Derrick et al. Circulation 2000;102:III154-9*
Heart Failure in ACHD

Preload reduction

Systolic
- Contractility
  - ESPVR (Ees)
  - PRSW

Coupling
- Ea/Ees

Diastolic
- relaxation
  - \( \tau \)
- compliance
  - EDPVR
- Filling rate
  - \( \frac{dV}{dt} \)
Heart Failure in ACHD

Post-Mustard RV myocardial function

ESPVR

P<0.001

PRSW

P<0.001

Ea/Es

P<0.001

Heart Failure in ACHD

Post-Mustard RV myocardial function

Heart Failure in ACHD

- Sinus tachycardia poorly tolerated
- SD associated with AF?
Heart Failure in ACHD

Patients After Atrial Switch Operation for Transposition of the Great Arteries Can Not Increase Stroke Volume Under Dobutamine Stress as Opposed to Patients With Congenitally Corrected Transposition

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Sex</th>
<th>Type of surgery</th>
<th>Age at surgery (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>Senning operation</td>
<td>1.1</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>Senning operation</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>Senning operation</td>
<td>0.9</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>Senning operation</td>
<td>0.2</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>Mustard operation</td>
<td>1.8</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>Senning operation</td>
<td>0.1</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>Senning operation</td>
<td>0.1</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>Mustard operation</td>
<td>1.6</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>Senning operation</td>
<td>0.1</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>Senning operation</td>
<td>1.2</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>Senning operation</td>
<td>1.0</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>Senning operation</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Median (range) 1 (0.1–1.8)

Circ J 2008; 72: 1130–1135
CASE REPORT

Congenitally corrected transposition of the great arteries in an 80 year old woman

M Roffi, S F de Marchi, C Seiler

Abstract
Congenitally corrected transposition of the great arteries (CCTGA) is a rare form of congenital heart disease characterised by atrioventricular as well as ventriculoarterial discordance. It is usually associated with a variety of severe intracardiac defects. Few patients with this abnormality survive past 50 years. An 80 year old woman was admitted to the hospital because of mild congestive heart failure. Cardiac examination revealed a 4/6 holosystolic and a 2/6 decrescendo diastolic murmur at the left sternal border. Chest radiography revealed an absent pulmonary artery segment, a prominent right pulmonary hilus, and an enlarged cardiac silhouette (fig 1).

Echocardiography showed the aorta to arise from the morphological RV, which was identified by the three leaflet tricuspid valve that inserted more apically than the mitral valve (fig 2). The pulmonary trunk, identified by its bifurcation, arose from the morphological LV. The systemic ventricle (RV) was dilated, the walls measured 10 mm, and the systolic RV function was severely reduced (ejection frac-
Heart Failure in ACHD

Late RV Failure: CCTGA

Heart Failure in ACHD

Influence of RV geometry?

- Progressive RV dilatation
- Shifted interventricular septum
- Worsening TR
Heart Failure in ACHD

Late RV Failure: CCTGA

Heart Failure in ACHD

Tricuspid valve replacement

Van Son et al. JTCVS 1995;109: 642-52
Tricuspid valve replacement

Long-term outcome of surgically treated patients with corrected transposition of the great arteries

Hraska et al. JTCVS 2005;129: 182-91
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Retraining 1988-2002

Cardiovascular Surgery

Intention-to-Treat Analysis of Pulmonary Artery Banding in Conditions With a Morphological Right Ventricle in the Systemic Circulation With a View to Anatomic Biventricular Repair

David S. Winlaw, MBBS, MD, FRACS; Simon P. McGuirk, BMedSci, MRCS; Christian Balmer, MD; Stephen M. Langley, MD, FRCS; Massimo Griselli, MD, MS, FRCS; Oliver Stümper, MD, PhD, MRCP; Joseph V. De Giovanni, MD, FRCP, FRCPCCH; John G. Wright, MA, FRCP, FRCPCCH; Sara Thorne, MD, MRCP; David J. Barron, MD, MRCP, FRCS; William J. Brawn, FRACS, FRCS

Background—Some patients with a morphological right ventricle (mRV) in the systemic circulation require early intervention because of progressive systemic ventricular dysfunction or atrioventricular valve regurgitation. They may be eligible for anatomic repair (correction of atrioventricular and ventriculoarterial discordance) but require prior training of the morphological left ventricle (mLV).

Methods and Results—Forty-one patients with congenitally corrected transposition of the great arteries or a previous atrial switch procedure embarked on a protocol of pulmonary artery (PA) banding with a view to anatomic repair. All had an mRV in the systemic circulation and a subpulmonary mLV that was not conditioned by either volume or pressure load.

Winlaw et al Circulation 2005:111; 405-11
Retraining 1988-2002

...tion after previous atrial switch. Young patients train quickly, and in infants, the response to banding is very fast, with a doubling of LV mass in only 1 week, although some of this may represent myocardial edema. At the other end of the spectrum, there may be a point at which it is no longer possible to effectively train the ventricle.

Winlaw et al Circulation 2005:111; 405-11
Retraining

• CCTGA vs Atrial switch (p=0.91)
• Pre-existing or induced LV dysfunction (p<0.004)
• Age >16 (n=12) not an independent risk factor for outcome (p=0.95)

Winlaw et al Circulation 2005:111; 405-11
Heart Failure in ACHD

PV relations during PA Band

Pulmonary Artery Band applied
Heart Failure in ACHD

PV relations during PA Band

Adaptation  Failure

Pulmonary Artery Band applied
Retraining

- 8 patients over aged 18 (18-56)
- All had LV pressures <50% systemic
- 1-3 bandings, 2-32 weeks between procedures
- 2 of 7 patients had significant TnI release
- 1 double switch
Septal shift

Intraoperative PA banding
Heart Failure in ACHD

Retraining
CCTGA – *Destination therapy*?

- 56 year old, unoperated CCTGA
- Asymptomatic until age 50
- Severe TR
- Banded to 45%, 60%, then 85-90% systemic
Conclusions

- Little evidence for ‘intrinsic’ RV systolic failure
- Lower tolerance of additional load?
- The late outcomes of CCTGA are influenced by degree of TR
- Poor outcomes of LV retraining may be 2° to training protocol
- PA band as destination therapy?
Heart Failure in ACHD

Retraining

- 8 patients over aged 18 (18-56)
- All had LV pressures <50% systemic
- 1-3 bandings, 2-32 weeks between procedures
- 2 of 7 patients had significant TnI release
- 1 double switch
The morphologic left ventricle that requires training by means of pulmonary artery banding before the double-switch procedure for congenitally corrected transposition of the great arteries is at risk of late dysfunction.
Retraining: 17 1/2 years old Before Banding
Retraining: After 1st Banding
Systemic RV: Assessment and Treatment

Retraining: 4 days after 2nd Banding
Systemic RV: Assessment and Treatment

Retraining: 13 days after 2\textsuperscript{nd} banding
Retraining: Pre-double switch
Systemic RV: Assessment and Treatment

Retraining: 11 days after double switch
Systemic RV: Assessment and Treatment

Retraining: 3 months after double switch
A pilot study on the effects of carvedilol on right ventricular remodelling and exercise tolerance in patients with systemic right ventricle

Alessandro Giardini a,*, Luigi Lovato b, Andrea Donti a, Roberto Formigari a, Gaetano Gargiulo c, Fernando Maria Picchio a, Rossella Fattori b
Right Ventricular Function in CCTGA

Outcome of the Unoperated Adult Who Presents With Congenitally Corrected Transposition of the Great Arteries

Luc M. Beauchesne, MD, FRCPC,* Carole A. Warnes, MD, MRCP, FACC,* Heidi M. Connolly, MD, FACC,* Naser M. Ammash, MD, FACC,* A. Jamil Tajik, MD, FACC,* Gordon K. Danielson, MD, FACC†

Rochester, Minnesota

44 patients with unoperated CTGA and ≥ 18 years old referred for evaluation

- 30 patients required surgical intervention
- 14 patients unoperated

29 patients alive at last follow-up
1 patient dead noncardiovascular cause
13 patients alive at last follow-up
1 patient with sudden death

P = 0.006

Pre-op Mean 40 ± 10%
Post-op Mean 34 ± 11%