Long-term experience with percutaneous pulmonary valve implantation (PPVI)
Lessons we have learned

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Percutaneous valves

18, 20, and 22 mm double afoons

23 mm SAPIEN

26 mm SAPIEN

Melody TPV n >11,000

Edwards Sapien valves n >300

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PPVI Melody valve

2000 1st percutaneous pulmonary valve implantation, prototype
2003 1st PPVI with Melody in definite design
2005 1st cohort for CE mark (59 Pat.),
Khambadkone S. Circulation 2005;112(8):1189-97
2005 100. Patient
2006 CE-mark + approval in Canada
12/2006 1st Patient in München
2010 FDA-approval

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Indication for PPVI at DHM

- Severe RVOT obstruction with no or mild PR, and:
- Symptoms related to RVOT obstruction (<65% of expected or a significant decrease in exercise tolerance) plus a peak Doppler velocity at the tricuspid valve > 3.5 m/s or
- No symptoms + RV pressure > 4.3 m/s (measured at tricuspid regurgitation), > 2/3 systemic pressure in the right ventricle.
- Severe pulmonary regurgitation, with right ventricular end-diastolic volume index > 150 ml/m² by cMRI.
- Adequate RVOT conduit/vessel size to accommodate a valved stent.
- Adequate body size (no real lower limit, but usually > 20kg).

PPVI Experience DHM

12/2006-02/2018 n = 243 patients
valve-in-valve n = 4

| age median (y) | 18.5 (4.1-78.9) |
| weight (kg)    | 59.0 (19 -176) |
| Gender         | f = 85, m = 158 |
| OP             | 2 (1-6)         |
| diagnosis      | TOF/PA 121, TAC 41, TGA 20, AoVS 28, other 33 |
| conduit        | Homograft 166, none 26, Hancock 7, Shelhigh 4, Matrix 1, Contegra 11, other 28 |
| Valve position | PaV 243, (TrV 21, TCPC 1, other 1, MiV 1) |
| valve          | Melody 226, Sapien 23 n = 4 |
|                | Sapien 26 n = 9; Sapien 29 n = 4 |

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Incidents:

1. Endocarditis
   - 17 patients – 19 episodes of IE (7%)
   - Medical: 11
   - OP: 8
   - Total patient years up to now: 922 years
   - Annual incidence of IE: 1.9%/patient year

2. Stenosis
   - 11 (5%)
   - Cath.: Re balloon dilatation with valve in valve
   - OP: 4
   - Outgrowth (all non dilatable conduits): 7

3. Death
   - Periprocedural: 2/247 (0.8%)
     - Coronary: 1
     - Rvot rupture: 1
   - Heart failure: 2
   - SCD: 2

Censored by OP (15), valve-in-valve (4) or death (6); 25/247 (10%)

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**PPVI/PTVI**

247 valves/243 pts since 12/2006

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**Coronary compression**

“positive” balloon test after Ross-Konno OP

“balloon interrogation”

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Aggressive ballooning of a calcified conduit may lead to severe, uncontrollable bleeding

In severely calcified conduits completely cover the landing zone with covered stents before intending to break the calcified tube to avoid fatal rupture
Event (operation, intervention, death) free survival

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RV pressure in echo

Peak systolic pressure difference RV-RA at TrV

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cMRI – RVEDVi

Pts at risk

| 172 | 141 | 1 |

P < 0.001

VO₂max

Pts

| 156 | 147 | 109 | 67 | 2 |

P < 0.001

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• balloontest (Z-Med or BiB) with aortogram and selective coronary depiction of both coronaries. Relation to RVOT must be clear. Risk – assessment: calcified homograft vs coronary testing with high pressure balloons, tissue compliance?

• High pressure testing indicated: 14 F long-Sheath

• After balloontest exclude rupture (dye through longsheath), sheath can be advanced rapidly to deliver cCP Stents or keep NuDEL available, Eicken et al. CTY 2017 6:1-4

• After prestenting, repeated selective coronary depiction pre final dilation

• „custom made“ 55 + 65 mm 8zcCP, or 10zcCP available

<table>
<thead>
<tr>
<th>Balloon</th>
<th>8zig</th>
<th>10zig</th>
</tr>
</thead>
<tbody>
<tr>
<td>22mm</td>
<td>25%</td>
<td>9%</td>
</tr>
<tr>
<td>24mm</td>
<td>35%</td>
<td>14%</td>
</tr>
</tbody>
</table>
Surgery only if PPVI is not possible

- Coronary anatomy
- Wide RVOT
91% of our PPVI patients live with their PPVI valve

What to do in suspected IE?

- Suspected IE after PPVI
  - Blood cultures 6 in 48 hours
  - TEE, ICE, CT, PET

- Hemodynamic instability severely sick
- Symptomatic patient search for thrombi (ICE, CT, PET)
- Decision: medical treatment feasible
- 6 weeks of i.v. antibiotics, then blood cultures

- i.v. antibiotics (6 weeks)

- ICU, instant surgical treatment
- 6 weeks of i.v. antibiotics, then blood cultures
PPVI for RVOT dysfunction is the preferred treatment option in many centres

Meticulous preparation of the landing zone results in optimal results (low residual gradient, less stent fractures)

Coronary compression and conduit rupture are the hazards of PPVI. If coronary anatomy is "doubtful" – no PPVI. Heavily calcified conduits ("porcellan") should be treated with cCP stents preceding PPVI

Most patients have good valve function after PPVI at medium term follow-up. So far in 90% of our patients their first percutaneous valve is still performing well in pulmonic position (since 2006)

If re-stenosis occurs a valve-in-valve procedure may be successful
Early Feasibility Study Overview

- Prospective, Non-randomized
- First FDA approved Early Feasibility Study
- Primary Objective:
  - Obtain in vivo data to confirm assumptions on loading conditions for future in vitro frame evaluations
- Secondary Objectives:
  - Characterize procedural feasibility, safety & TPV performance
- 20 patients implanted for 5 year follow-up at 3 centers (May 2013 – May 2015)
  - The Hospital for Sick Children, Toronto Canada – Dr. Lee Benson
  - Nationwide Children’s Hospital, Columbus Ohio – Dr. John Cheatham
  - Boston Children’s Hospital, Boston, MA – Dr. Lisa Bergersen
- Screening Committee to review all potential candidates
- DSMB oversight of study

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NCH Team Performed the FIM Implant of the new Native Outflow Tract TPV on May 30th, 2013
NCH Team Performed the FIM Implant of the new Native Outflow Tract TPV on May 30th, 2013

ICE pre and post implant

Courtesy John Cheatham  
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Subjects consented  
n=67

- Inappropriate anatomic criteria  
n=46
- Catheterized  
n=21
- Implant not attempted  
n=1
- Implanted  
n=20
- Explanted  
n=1
- 1-month follow-up  
n=19
- Explanted  
n=1
- 3-month follow-up  
n=18
- 6-month follow-up  
n=18
- 12-month follow-up  
n=18

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MRI Hemodynamics

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Pre-implant (n=12)</th>
<th>12-month (n=12)</th>
<th>P-value (pre-implant to 12 months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVEDV (ml)</td>
<td>280.4 ± 74.0</td>
<td>195.1 ± 57.9</td>
<td>0.001</td>
</tr>
<tr>
<td>RVEDVi (ml/m²)</td>
<td>158.4 ± 35.5</td>
<td>106.7 ± 22.1</td>
<td>0.001</td>
</tr>
<tr>
<td>RVESV (ml)</td>
<td>140.1 ± 45.3</td>
<td>103.9 ± 40.1</td>
<td>0.001</td>
</tr>
<tr>
<td>AR (%)</td>
<td>2.1 ± 2.3 (n=10)</td>
<td>0.7 ± 2.2 (n=10)</td>
<td>0.16</td>
</tr>
<tr>
<td>RVEF (%)</td>
<td>50.8 ± 8.3 (n=11)</td>
<td>48.1 ± 9.5 (n=11)</td>
<td>0.34</td>
</tr>
<tr>
<td>PR (%)</td>
<td>48.9 ± 10.3 (n=11)</td>
<td>2.1 ± 3.4 (n=11)</td>
<td>0.001</td>
</tr>
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### Mean RVOT Gradient

![Graph showing mean RVOT gradient over time](image)

**Pre-Implant (n=20)**
- **Discharge (n=20)**
- **1 month (n=19)**
- **3 months (n=18)**
- **6 months (n=18)**
- **12 months (n=16)**

**Mean RVOT Gradient (mmHg)**

**Pre-implant to 12 months (paired data, n=16), P<0.001**

### Reintervention & Reoperation

- **2 reoperations**
  - Both involved TPV explant and surgical PVR and resolved without sequelae
    - **1: Stent fracture, valve dysfunction: stenosis, valve frame collapse** – identified at 1 mo. Visit
    - **2: Migration, PVL (major & minor), “erosion”** – identified at discharge

- **No catheter reinterventions but 1 diagnostic catheterization**
What is planned next?

• Continue 5 year follow up on EFS implanted patients
• Analyze an additional 160 CMRs to better understand the complex anatomy of the RVOT
• Leveraging engineering analysis and additional anatomical data for inputs into additional Harmony TPV sizes and optimized delivery system – development underway!
• Harmony TPV IDE approved Oct. 26th, 2016
  – 40 additional patients at 10 centers
  – Slightly modified screening process to be used
  – Slightly modified delivery system
  – Training course completed in November 2016
  – Actively enrolling - 1st implant March 2017
Thank you!