VT and SCD in Adult Congenital Heart Disease

Mei-Hwan Wu, MD, PhD
National Taiwan University Children’s Hospital, Taipei, Taiwan
The ACHD population will grow with increasing medical complexity over time

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Prevalence (/1000)</th>
<th>Severe CHD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taiwan</td>
<td>2014</td>
<td>2.17</td>
<td>11.7</td>
</tr>
<tr>
<td>Canada (Quebec)</td>
<td>2000</td>
<td>4.09</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>6.12</td>
<td>10.13</td>
</tr>
<tr>
<td>Estimates from CHD incidence at birth and the survival</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other high-income countries, estimates</td>
<td>2000s</td>
<td>1.77-4.91</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>2011</td>
<td>3.93</td>
<td></td>
</tr>
</tbody>
</table>

1: Wu MH et al. JAHA 2018  
2: Marelli et al, Circulation 2014  
3: Shiina Y et al. Int J Cardiol 2011
## Epidemiology update, congenital heart disease

<table>
<thead>
<tr>
<th>Study types</th>
<th>Study population</th>
<th>Severe CHD</th>
<th>Incidence (/1000 LB)</th>
<th>% total CHD</th>
<th>Incidence (/1000LB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China: Yang</td>
<td>registry data, 83,292</td>
<td>12.8</td>
<td>0.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>China: Choa</td>
<td>Hospital bases 5,190</td>
<td>14.6</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong: Sung</td>
<td>PE/echo 2,092</td>
<td>22</td>
<td>1.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan: Ooshima</td>
<td>13 hosp. nursery echo 502</td>
<td>13.5</td>
<td>1.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Korea: Jung</td>
<td>KFMI 1,202,835</td>
<td>14.8</td>
<td>1.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taiwan: Wu</td>
<td>NHI database 1,667,001</td>
<td>10.8</td>
<td>1.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US: Reller</td>
<td>Registry data, MACDP 398,140</td>
<td>17.4</td>
<td>1.42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ACHD in 2010s: ¼ to ½ of CHD incidence in live births. In the future, 80% ? Up to the treatment outcome and adherence to FU

- Severe CHD: TOF, TGA, AVSD, tricuspid atresia, truncus arteriosus, univentricular heart, HLHS, TAPVR
Tachyarrhythmia in ACHD, Taiwan 2000-2014

Freedom from tachyarrhythmia

Wu MH el al. JAHA 2018

0.574

0.710
Adult CHD prevalence (/1000)

Wu MH el al. JAHA 2018

Tachyarrhythmia burden in various CHD

Wu MH et al. JAHA 2018
Tachy-arrhythmias in ACHD

Substrates for VT in ACHD:
- Congenital abnormalities
- Surgical scars
- Subsequent ventricular dysfunction/myocardial fibrosis

Wu MH et al. JAHA 2018
Sustained tachyarrhythmia 29.9%
  Atrial tachyarrhythmia 20.1%
  IART 11.5%, AF 7.4%
  Ventricular tachyarrhythmia 14.6%
  VT 14.2%, VF 0.5% 14.2%

At least 1 arrhythmia intervention 21.4%
  Transcatheter ablation 7.2%
  Implanted device 18.3%
    Pacemaker 7.9%
    ICD 10.4%

Sustained tachyarrhythmia and/or intervention 43.3%

Khairy et al (Alliance for Adult Research in Congenital Cardiology, AARCC): 556 adult rTOF, -- 43% (Circulation, 2010)
Ventricular arrhythmia and SD
Sudden death in ACHD

• SCD may account for 19–26% of all causes of death.
• Causes:
  Arrhythmia in 171 (80% of SD)
  • VF 62%
  • VT 11%
  • VF/VT 11%
  • SVT 8%
  • Bradycardia 8%
• Not only with severe cardiac conditions but also those with septal defects and LV outflow tract obstruction.
• Poor cardiopulmonary reserve

Koyak et al. Circulation 2012
Taiwan NHI database 2000 to 2014  
ACHD (18-59 yrs)

Oregon population study, CHD repaired < 19 years, 1958 and 1996

Sudden death
Total: 0.88/1000 patient - year

Adult TOF

Wu MH, et al. Unpublished data

Wu MH, et al. JAHA 2018

Sudden death event, VT and VF
Total: 0.88/1000 patient - year

ACHD (18-59 yrs)

Wu MH, et al. Unpublished data

Wu MH, et al. JAHA 2018

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Causes of Death} & \text{ACHD} & \text{General Population} \\
\hline
\text{Severe} & \text{Simple} & \text{Total} \\
\hline
\text{Cardiac} & 61.14\% & 37.33\% & 43.42\% & 9.35\% \\
\text{Malignancy} & 3.43\% & 12.97\% & 10.53\% & 34.53\% \\
\text{External causes} & 4.57\% & 6.68\% & 6.14\% & 18.27\% \\
\text{CVA} & 3.43\% & 4.91\% & 4.53\% & 5.24\% \\
\text{SD} & 4.57\% & 4.13\% & 4.24\% & 0.14\%* \\
\text{Labor complication} & 0.57\% & 1.57\% & 1.32\% & 0.04\% \\
\text{Out of hospital death} & 4.57\% & 6.48\% & 5.99\% & NA \\
\text{ES CPR} & 0.63\% & 0.57\% & 0.58\% & NA \\
\text{Others} & 18.85\% & 27.11\% & 25\% & 32.43\% \\
\hline
\end{array}
\]

CVA indicates cerebrovascular accident; ES CPR, cardiopulmonary resuscitation in emergency service; SD, sudden death.
Ventricular tachyarrhythmias (SD)

✧ Optimize hemodynamics
✧ Management of VA:
  ✧ Drugs:
    ✧ β-blocker: first-choice
    ✧ Amiodarone c/s β-blocker
    ✧ Sotalol
  ✧ Not Class I drugs: ACHD frequently have residual hemodynamic disturbances, incisional scars, intracardiac baffles, conduits, and/or extensive myocardial fibrosis that may predispose to potentially fatal proarrhythmic effects from Class I agents
  ✧ Ablation
  ✧ Cardiac rhythm management devices

<table>
<thead>
<tr>
<th>Device</th>
<th>Purposes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICD</td>
<td>Covert tachycardia, Defibrillation</td>
</tr>
<tr>
<td>Pacemaker</td>
<td>HR support, antitachycardia pacing</td>
</tr>
<tr>
<td>CRT</td>
<td>Improve dysynchrony-related LV dysfunction</td>
</tr>
</tbody>
</table>
Amiodarone induced thyroid dysfunction

- An iodine-rich agent containing 39% iodine weight.
- Thyrotoxicosis is associated with an increased risk of death and adverse cardiovascular events (worsening arrhythmia).
- Hypothyroidism presents with nonspecific symptoms and signs such as fatigue, cold intolerance, mental sluggishness, and dry skin, similar to the symptoms of spontaneous hypothyroidism.
- Risk factors: female sex, complex cyanotic heart disease, AMD dose >200 mg/day, iodine intake, ethnicity.

<table>
<thead>
<tr>
<th></th>
<th>Thyrotoxicosis</th>
<th>Hypothyroidism</th>
<th>Dosage range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western ACHD</td>
<td>13.6–21%</td>
<td>15%</td>
<td>Mean: 194-200 mg</td>
</tr>
<tr>
<td>Japan ACHD</td>
<td>18%</td>
<td>12%</td>
<td>125 ± 58</td>
</tr>
<tr>
<td>Japan cardiac patients</td>
<td>12.5%</td>
<td>10.8%</td>
<td></td>
</tr>
</tbody>
</table>
Catheter Ablation of ventricular arrhythmias

- 8 m/o diagnosed TOF
- 16 y/r total repair
- 46 y/o syncope, pulseless polymorphic VT
- 47 y/o Surgical PVR, TVP and Cryo-ablation, postop VT–ICD
- 50 y/o ICD shocks, AA
- 51 y/o 3 D Electroanatomical guide, Scar homogenization (voltage mapping < 0.3 mV, pace-mapping), RVOT ventriculotomy-TV isthmus ablation
- 52 y/o quit AA
**Electroanatomical, Non-fluoroscopic imaging for all ablation in NTUCH**

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Study Group</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient numbers (M:F)</strong></td>
<td>75 (43:32)</td>
<td>50 (30:20)</td>
<td></td>
</tr>
<tr>
<td><strong>Procedures (times)</strong></td>
<td>82</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td><strong>Age at ablation (yr)</strong></td>
<td>14.2 ± 3.07</td>
<td>12.2 ± 3.19</td>
<td>.583</td>
</tr>
<tr>
<td><strong>Body Weight (kg)</strong></td>
<td>158.5 ± 14.6</td>
<td>151.1 ± 15.7</td>
<td>.432</td>
</tr>
<tr>
<td><strong>Body Height (cm)</strong></td>
<td>52.2 ± 13.9</td>
<td>47 ± 16.4</td>
<td>.117</td>
</tr>
<tr>
<td><strong>Procedure Time (min.)</strong></td>
<td>100.52 ± 65.24</td>
<td>91.82 ± 55.08</td>
<td>.414</td>
</tr>
<tr>
<td><strong>Fluoroscopic Time (min.)</strong></td>
<td>28.64 ± 23.47</td>
<td>0.38 ± 2.01</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Acute Success Rate (%)</strong></td>
<td>98.78 (81/82)</td>
<td>98 (49/50)</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Zero-fluoroscopy</strong></td>
<td>-</td>
<td>84% (42/50)</td>
<td>-</td>
</tr>
</tbody>
</table>

- No ZF technique related, catheter-induced complications.
Catheter Ablation of ventricular arrhythmias

Hemodynamic stable:
Activation/voltage mapping, Entrainment mapping (critical isthmus: entrainment with concealed QRS fusion and post pacing interval minus TCL <30 ms), Pace-mapping
Non-sustained, hemodynamic unstable:
Pace-mapping, voltage mapping fragmentation, late/ mid-diastolic potential

Scar-related reentrant VT: Non-scar: (20-33%)

Isthmus for reentrant VT in TOF or other CHD
1A: ventriculotomy-to-tricuspid annulus
1B: ventriculotomy-to-VSD patch
2: ventriculotomy-to-pulmonary annulus
3: pulmonary annulus-to-VSD patch
4: VSD patch-to-tricuspid annulus

• His-Purkinje system (HBP) related macro-reentry:

• Focal VT

Moore JP et al. Circ Arrhythm Electrophysiol. 2013
van Zyl et al. Heart Rhythm 2016
Yang et al. J Cardiovasc Electrophysiol. 2019
Catheter Ablation of ventricular arrhythmias

**Procedural success** (no inducible VT): 75-90%
Modification: 5-16%
**Recurrence**: 15-21%

Isthmus reentrant VT: **isthmus conduction block** is associated no recurrence
**ICD is still recommended**. Successful catheter ablation decreases ICD shocks
Patients with advanced degrees of ventricular dysfunction can develop polymorphic VT or abrupt ventricular fibrillation

Surgical ablation of ventricular arrhythmias

Recurrence: 26 % (concomitant ablation during PVR, TVP, Maze for atrial arrhythmia)


*Moore JP et al. Circ Arrhythm Electrophysiol. 2013*

*van Zyl et al. Heart Rhythm 2016*

*Yang et al. J Cardiovasc Electrophysiol. 2019*
If ICD Therapy necessary in Repaired TOF after PVR?

- 12 r-TOF patients with VT and received ICD (11 also received PVR and optional surgical ablation).
- Even after PVR:
  - Appropriate shock: 50%, 7.7% /year
  - Inappropriate shock: 42%, 9.2% per year

ICD implantation is mandatory in all rTOF with VT patients to prevent SCD. B-blocker is helpful for those with coexisting LQT gene changes.

- ICD patients had higher frequency of long QT genes mutation/SNP (11/13 vs. 54/121, p=0.008), particularly hERG and SCN5A genes.
- The VT in those with long QT genes mutation/SNP manifested earlier.

Chiu et al. Int J Cardiol 2017
ICD therapy for SD prevention in TOF

Secondary prevention
• Justified by the incidence of appropriate (TOF: 9.8% per year\(^1\)) and inappropriate shocks after ICD

Primary prevention
• Risk stratification for each lesion required
• The WHO rule of thumb suggests that it is reasonable for countries with a per capita GDP >US$26,700 to allocate healthcare resources for primary prevention ICDs for patients with a risk profile similar to SCD-HeFT (3.5% per year).

1 Khairy et al. Current Opinion in Cardiol 2011
## Timing for ICD in TOF: primary prevention

<table>
<thead>
<tr>
<th>Variable</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior palliative shunt</td>
<td>2</td>
</tr>
<tr>
<td>Inducible sustained VT</td>
<td>2</td>
</tr>
<tr>
<td>QRS &gt;180 ms</td>
<td>1</td>
</tr>
<tr>
<td>Ventriculotomy incision</td>
<td>2</td>
</tr>
<tr>
<td>Nonsustained VT</td>
<td>2</td>
</tr>
<tr>
<td>LV EDP &gt;12mmHg</td>
<td>3</td>
</tr>
</tbody>
</table>

### Total point 0-12

<table>
<thead>
<tr>
<th>Risk score</th>
<th>Risk</th>
<th>Rate of appropriate shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>Low</td>
<td>0</td>
</tr>
<tr>
<td>3-5</td>
<td>Intermediate</td>
<td>3.8%</td>
</tr>
<tr>
<td>6-12</td>
<td>High</td>
<td>17.5%</td>
</tr>
</tbody>
</table>

Khairy et al.  
Current Opinion in Cardiol 2011
### Published guidelines for surgical PVR in the asymptomatic TOF patient

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RVEDVi</td>
<td>≥ moderate</td>
<td>&gt; 160 ml/m²</td>
<td>&gt; 170 ml/m²</td>
<td>&gt;150 mL/m² or Z-score &gt;4 or RV/LVEDV volume ratio &gt;2</td>
</tr>
<tr>
<td>RVESDi</td>
<td></td>
<td></td>
<td>&gt; 80 ml/m²</td>
<td></td>
</tr>
<tr>
<td>RV dysfunction</td>
<td>≥ moderate</td>
<td>progressive</td>
<td>≥ moderate</td>
<td>RVEF &lt; 47%</td>
</tr>
<tr>
<td>RVOT obstruction</td>
<td>≥50 mm Hg or RVP/LVP ≥0.7</td>
<td>≥80 mm Hg</td>
<td>RVP/LVP ≥2/3</td>
<td>RVP/LVP ≥2/3</td>
</tr>
<tr>
<td>PR</td>
<td>severe</td>
<td>severe</td>
<td>free</td>
<td>≥Moderate (PRF ≥ 25%)</td>
</tr>
<tr>
<td>TR</td>
<td>≥ moderate</td>
<td>≥ moderate</td>
<td>important</td>
<td>≥ moderate</td>
</tr>
<tr>
<td>QRS duration</td>
<td>&gt; 180 ms</td>
<td></td>
<td>&gt; 140 ms</td>
<td></td>
</tr>
<tr>
<td>Arrhythmias</td>
<td>AT or VT</td>
<td>AT or VT</td>
<td>AT or VT</td>
<td>sustained AT or VT</td>
</tr>
<tr>
<td></td>
<td>CPX: decrease</td>
<td>significant</td>
<td>LV EF &lt;55%, large RVOT aneurysm, severe branch PA stenosis (&lt;30% flow to affected lung), significant residual left-to-right shunt, severe AR or aortic dilation</td>
<td></td>
</tr>
</tbody>
</table>
Symptomatic (CHF, CPX) → Early PVR

Asymptomatic → Careful individual decision-making

- Cut-off values and guidelines
- Informed discussion about uncertainties and potential risks

Echo: RV function (TAPSE/RVSP(>0.4), LV function
MRI: RVEDVi (<160-180), RVESVi (<80-95),
  RVEF (>40-47%), LVEF (>45-55%)
EKG: no arrhythmias, QRSD (<160-180 ms)
Age: < 28 (30) yrs?!
Subcutaneous ICD in ACHD

- Good for those without venous access and right to left shunt
- Reliable detection and conversion of induced ventricular arrhythmia
- Reasonable clinical rhythm discrimination
- Interdevice interactions can be avoided
- Drawbacks:
  - No antibradycardia pacing
  - Inability to pace-terminate monomorphic VT
  - No opportunity for resynchronization therapy
1. The prevalence in current decade is 1.7-6.1/1000. Grown up pediatric illness, a new field!!

2. Tachyarrhythmias will increase with aging. Pharmacological control is often discouraging. Catheter ablation and hemodynamic optimization should be considered first.

3. For ventricular tachyarrhythmias (associated with SD), drugs are adjunct therapy to ICD and catheter ablation.

4. Class I antiarrhythmic agents are not recommended due to potentially fatal proarrhythmic effects from residual hemodynamic/anatomical.

5. Sometimes, drugs are needed for the coexisting diseases, such as acquired LQTS.

6. Genomic diagnosis, functional changes by AI, Integrated electro/anatomical/genomic assessment as acquired LQTS.
### Congress Information

<table>
<thead>
<tr>
<th>Congress</th>
<th>The 8th Asia-Pacific Congress of Pediatric Cardiology and Cardiac Surgery (APPCS2020)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>April 2-5 (Thursday – Sunday), 2020</td>
</tr>
<tr>
<td>Location</td>
<td>Taipei, Taiwan</td>
</tr>
<tr>
<td>Venue</td>
<td>Taipei International Convention Center (TICC)</td>
</tr>
<tr>
<td>Organizer</td>
<td>Taiwan Society of Pediatric Cardiology</td>
</tr>
<tr>
<td></td>
<td>Cardiac Children’s Foundation Taiwan</td>
</tr>
<tr>
<td>Program</td>
<td>Plenary Lecture, Live Demo, Parallel Session (Keynote &amp; Invited Talk), Oral Presentation, Poster Presentation, Tutorial Course, Opening &amp; Closing Ceremony</td>
</tr>
<tr>
<td>Spotlight Program</td>
<td><strong>Tutorial Course</strong></td>
</tr>
<tr>
<td></td>
<td>1. Catheter Closure of VSD from A to Z</td>
</tr>
<tr>
<td></td>
<td>2. Electrophysiology and Ablation for Tachyarrhythmias from A to Z</td>
</tr>
<tr>
<td></td>
<td>3. CPX and Sport Medicine</td>
</tr>
<tr>
<td>Social Event</td>
<td>Welcome Reception, Faculty Dinner, Gala Dinner, Congress Tour</td>
</tr>
<tr>
<td>Exhibition</td>
<td>20 units of booth</td>
</tr>
<tr>
<td>Anticipated Attendees</td>
<td>800 (Overseas 550 &amp; Domestic 250)</td>
</tr>
<tr>
<td>Congress Website</td>
<td><a href="http://www.appcs2020.org">www.appcs2020.org</a></td>
</tr>
</tbody>
</table>
Thank you 고맙습니다

National Taiwan University Children’s Hospital, PCV team in Cath Lab, Taipei, Taiwan