Device Therapy in Heart Failure

Dr Chia Pow-Li
MBBS, MRCP, M.Med(Int Med), FAMS
Director, Coronary Care Unit
Consultant, Dept of Cardiology
Types of Cardiac Devices

• Pacemaker  
  – Single chamber vs dual chamber

• Automated implantable cardioverter-defibrillator  
  – Single chamber vs dual chamber

• Cardiac resynchronization therapy device  
  – 3 leads: RA, RV & CS
Types of Cardiac Devices
Cardiac Device Implantation

A. Electrodes inserted into vein leading to heart
   - Electrodes in heart
   - Double lead pacemaker
   - Right atrium and ventricle

B. Electrode stimulation of heart muscle

C. Single lead pacemaker
   - Electrode in right ventricle
Heart Failure Syndrome

At risk for heart failure

**Stage A**
At high risk for HF but without structural heart disease or symptoms of HF
- eg: Patients with:
  - Hypertension
  - Atherosclerotic disease
  - Diabetes
  - Obesity
  - Metabolic syndrome
  - Using cardiotoxins
  - With Frx CM

**Stage B**
Structural heart disease but without signs or symptoms of HF
- eg: Patients with:
  - Previous MI
  - LV remodeling including LVH and low EF
  - Asymptomatic valvular disease

**Stage C**
Structural heart disease with prior or current symptoms of HF
- eg: Patients with:
  - Known structural heart disease
  - Shortness of breath and fatigue, reduced exercise tolerance

**Stage D**
Refractory HF requiring specialized interventions
- eg: Patients who have marked symptoms at rest despite maximal medical therapy (eg, those who are recurrently hospitalized or cannot be safely discharged from the hospital without specialized interventions)

Therapy

**Goals**
- Treat hypertension
- Encourage smoking cessation
- Treat lipid disorders
- Encourage regular exercise
- Discourage alcohol intake, illicit drug use
- Control metabolic syndrome

**Drugs**
- ACEI or ARB in appropriate patients
- β-Blockers in appropriate patients
- Devices in selected patients: Implantable defibrillators

Heart failure

**Goals**
- All measures under stage A
- Dietary salt restriction
- Drugs for routine use
- Diuretics for fluid retention
- ACEI
- β-Blockers
- Drugs in selected patients: Aldosterone antagonist, ARBs, Digitalis, Hydralazine/nitrates
- Devices in selected patients: Biventricular pacing, Implantable defibrillators
Heart Failure & Sudden Cardiac Death

• Patients with LV dilation and reduced LVEF frequently manifest ventricular tachyarrhythmias, both nonsustained ventricular tachycardia (VT) and sustained VT.
• The cardiac mortality of patients with all types of ventricular tachyarrhythmias is high.
• The high mortality results from progressive HF, as well as from sudden death.
Heart Failure & Sudden Cardiac Death

• Bradycardia are common in patients with advanced HF (Luu et al. Circulation 1989;80:1675–1680)

• The absolute frequency of sudden death is highest in patients with Stage D HF.
  – Prevention of sudden death in this population could potentially shift the mode of death from sudden to that of progressive HF without decreasing total mortality, as competing risks of death emerge.

• On the other hand, prevention of sudden death in mild HF may allow many years of meaningful survival.

• This makes it imperative for physicians to not only assess an individual patient’s risk for sudden death but also assess overall prognosis and functional capacity before consideration of device implantation.
Heart Failure & Sudden Cardiac Death

• Secondary prevention refers to the prevention of SCD in those patients who have survived a prior cardiac arrest or sustained VT.
• Primary prevention refers to the prevention of SCD in individuals without a history of cardiac arrest or sustained VT.
IMPLANTABLE CARDIOVERTER DEFIBRILLATOR
Implantable cardioverter-defibrillator

• Terminates VT/VF in 2 ways
  – Anti-tachycardiac Pacing
  – Cardioversion
## Major Implantable Cardioverter-Defibrillator Trials for Prevention of Sudden Cardiac Death

<table>
<thead>
<tr>
<th>Trial</th>
<th>Year</th>
<th>Patients (n)</th>
<th>LVEF</th>
<th>Additional Study Features</th>
<th>Hazard Ratio*</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADIT I</td>
<td>1996</td>
<td>196</td>
<td>≤ 35%</td>
<td>NSVT and EP+</td>
<td>0.46</td>
<td>(0.26-0.82)</td>
<td>p=0.009</td>
</tr>
<tr>
<td>MADIT II</td>
<td>2002</td>
<td>1232</td>
<td>≤ 30%</td>
<td>Prior MI</td>
<td>0.69</td>
<td>(0.51-0.93)</td>
<td>p=0.016</td>
</tr>
<tr>
<td>CABG-Patch</td>
<td>1997</td>
<td>900</td>
<td>≤ 36%</td>
<td>+SAECG and CABG</td>
<td>1.07</td>
<td>(0.81-1.42)</td>
<td>p=0.63</td>
</tr>
<tr>
<td>DEFINITE</td>
<td>2004</td>
<td>485</td>
<td>≤ 35%</td>
<td>NICM, PVCs or NSVT</td>
<td>0.65</td>
<td>(0.40-1.06)</td>
<td>p=0.08</td>
</tr>
<tr>
<td>DINAMIT</td>
<td>2004</td>
<td>674</td>
<td>≤ 35%</td>
<td>6-40 days post-MI and Impaired HRV</td>
<td>1.08</td>
<td>(0.76-1.55)</td>
<td>p=0.66</td>
</tr>
<tr>
<td>SCD-HeFT</td>
<td>2006</td>
<td>1676</td>
<td>≤ 35%</td>
<td>Prior MI of NICM</td>
<td>0.77</td>
<td>(0.62-0.96)</td>
<td>p=0.007</td>
</tr>
<tr>
<td>AVID</td>
<td>1997</td>
<td>1016</td>
<td></td>
<td>Prior cardiac arrest</td>
<td>0.62</td>
<td>(0.43-0.82)</td>
<td>NS</td>
</tr>
<tr>
<td>CASH†</td>
<td>2000</td>
<td>191</td>
<td></td>
<td>Prior cardiac arrest</td>
<td>0.766</td>
<td>‡</td>
<td>1-sided p=0.081</td>
</tr>
<tr>
<td>CIDS</td>
<td>2000</td>
<td>659</td>
<td></td>
<td>Prior cardiac arrest, syncope</td>
<td>0.82</td>
<td>(0.60-1.1)</td>
<td>NS</td>
</tr>
</tbody>
</table>

* Hazard ratios for death from any cause in the ICD group compared with the non-ICD group. Includes only ICD and amiodarone patients from CASH.
‡CI Upper Bound 1.112 CI indicates Confidence Interval, NS = Not statistically significant, NSVT = nonsustained ventricular tachycardia, SAECG = signal-averaged electrocardiogram.

Secondary Prevention

ICD therapy is indicated in patients who are survivors of cardiac arrest due to ventricular fibrillation or hemodynamically unstable sustained VT after evaluation to define the cause of the event and to exclude any completely reversible causes.

ICD therapy is indicated in patients with structural heart disease and spontaneous sustained VT, whether hemodynamically stable or unstable.

ICD therapy is indicated in patients with syncope of undetermined origin with clinically relevant, hemodynamically significant sustained VT or VF induced at electrophysiological study.
ICD therapy is indicated in patients with LVEF less than or equal to 35% due to prior MI who are at least 40 days post-MI and are in NYHA functional Class II or III.

ICD therapy is indicated in patients with nonischemic DCM who have an LVEF less than or equal to 35% and who are in NYHA functional Class II or III.

ICD therapy is indicated in patients with LV dysfunction due to prior MI who are at least 40 days post-MI, have an LVEF less than or equal to 30%, and are in NYHA functional Class I.

ICD therapy is indicated in patients with nonsustained VT due to prior MI, LVEF less than or equal to 40%, and inducible VF or sustained VT at electrophysiological study.

All primary SCD prevention ICD recommendations apply only to patients who are receiving optimal medical therapy and have reasonable expectation of survival with good functional capacity for more than 1 year.
ICD implantation is reasonable for patients with unexplained syncope, significant LV dysfunction, and nonischemic DCM.

ICD implantation is reasonable for patients with sustained VT and normal or near-normal ventricular function.

ICD therapy may be considered in patients with nonischemic heart disease who have an LVEF of less than or equal to 35% and who are in NYHA functional Class I.
Contraindications

ICD therapy is not indicated for patients who do not have a reasonable expectation of survival with an acceptable functional status for at least 1 year, even if they meet ICD implantation criteria specified in the Class I, IIa, and IIb recommendations above.

ICD therapy is not indicated for patients with incessant VT or VF.

ICD therapy is not indicated in patients with significant psychiatric illnesses that may be aggravated by device implantation or that may preclude systematic follow-up.

ICD therapy is not indicated for NYHA Class IV patients with drug-refractory congestive heart failure who are not candidates for cardiac transplantation or cardiac resynchronization therapy defibrillators (CRT-D).
Contraindications

ICD therapy is not indicated for syncope of undetermined cause in a patient without inducible ventricular tachyarrhythmias and without structural heart disease.

ICD therapy is not indicated when VF or VT is amenable to surgical or catheter ablation (e.g., atrial arrhythmias associated with the Wolff-Parkinson-White syndrome, RV or LV outflow tract VT, idiopathic VT, or fascicular VT in the absence of structural heart disease).

ICD therapy is not indicated for patients with ventricular tachyarrhythmias due to a completely reversible disorder in the absence of structural heart disease (e.g., electrolyte imbalance, drugs, or trauma).
Post-Implant CXR
CARDIAC RESYNCHRONIZATION THERAPY
Ventricular Dysynchrony and Cardiac Resynchronization

• Ventricular Dysynchrony\(^1\)
  – **Electrical:** Inter- or Intraventricular conduction delays typically manifested as left bundle branch block
  – **Structural:** disruption of myocardial collagen matrix impairing electrical conduction and mechanical efficiency
  – **Mechanical:** Regional wall motion abnormalities with increased workload and stress—compromising ventricular mechanics

• Cardiac Resynchronization
  – Therapeutic intent of atrial synchronized biventricular pacing
    • Modification of interventricular, intraventricular, and atrial-ventricular activation sequences in patients with ventricular dysynchrony
    • Complement to optimal medical medical therapy

\(^1\) Tavazzi L. Eur Heart J 2000;21:1211-1214
Clinical Consequences of Ventricular Dysynchrony

- Abnormal interventricular septal wall motion
- Reduced dP/dt
- Reduced pulse pressure
- Reduced EF and CO
- Reduced diastolic filling time
- Prolonged MR duration

Prevalence of Inter- or Intraventricular Conduction Delay

General HF Population\(^1,2\)

- IVCD 15%

Moderate to Severe HF Population\(^3,4,5\)

- IVCD >30%

Increased Mortality Rate with LBBB

- Increased 1-year mortality with presence of complete LBBB (QRS > 140 ms)
- Risk remains significant even after adjusting for age, underlying cardiac disease, indicators of HF severity, and HF medications

* HR = Hazard Ratio

Summary of Proposed Mechanisms

Cardiac Resynchronization

Intraventricular Synchrony

↑ dP/dt, ↑ EF, ↑ CO (↑ Pulse Pressure)

↓ LVESV

Atrioventricular Synchrony

↓ MR

↓ LA Pressure

↑ LV Diastolic Filling

Reverse Remodeling

↓ LVEDV

Interventricular Synchrony

↑ RV Stroke Volume

# Mortality/Morbidity From Published Randomized, Controlled Trials

## Risk reduction with CRT

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MIRACLE(^1) (n=453)</td>
<td>6 Mo</td>
<td>NR</td>
<td>39%*</td>
<td>27%</td>
<td>NR</td>
<td>50%*</td>
</tr>
<tr>
<td>MIRACLE ICD(^2) (n=369)</td>
<td>6 Mo</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Contak CD(^3) (n=490)</td>
<td>3-6 Mo</td>
<td>NR</td>
<td>NR</td>
<td>30%</td>
<td>NR</td>
<td>18%</td>
</tr>
<tr>
<td>Meta-analysis(^4) (n=1634)</td>
<td>3-6 Mo</td>
<td>NR</td>
<td>NR</td>
<td>23%</td>
<td>51%*</td>
<td>29%*</td>
</tr>
</tbody>
</table>


*P < 0.05

 NR = Not reported in publication

Individual trials were not powered for mortality or hospitalization
Benefits Sustained Through 2 Years

MIRACLE Study Program

Mean distance walked in 6 minutes (m)

Mean NYHA Functional Class

Mean QoL Score Improvement

Source: Abraham, WT et al. AHA 2003
CARE-HF Design

• All patients were on state-of-the-art drug therapy and randomized into two groups
  – CRT device (no defibrillation)
  – No device

• Primary endpoints
  – All-cause mortality
  – Unplanned hospitalization for a major cardiovascular event

• Multicenter, prospective, non-blinded study (n=813)
CARE-HF Results

The graph shows the percentage of patients free of death from any cause or unplanned hospitalization for a major cardiovascular event over time for Cardiac Resynchronization and Medical Therapy. The blue line represents Cardiac Resynchronization and the red line represents Medical Therapy.

- **Cardiac Resynchronization**:
  - No. at Risk: 409
  - Days: 0, 500, 1000, 1500
  - Percentages: 100, 75, 50, 25

- **Medical Therapy**:
  - No. at Risk: 404
  - Days: 0, 500, 1000, 1500
  - Percentages: 100, 75, 50, 25

The graph indicates a statistically significant difference between the two treatment options, with Cardiac Resynchronization showing a higher percentage of patients free of events over time compared to Medical Therapy. The p-value is less than 0.001, indicating a strong statistical significance.

<table>
<thead>
<tr>
<th>No. at Risk</th>
<th>Days</th>
<th>Medical Therapy</th>
<th>Cardiac Resynchronization</th>
</tr>
</thead>
<tbody>
<tr>
<td>409</td>
<td>1500</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>404</td>
<td>1500</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>323</td>
<td>1000</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>273</td>
<td>500</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>166</td>
<td>0</td>
<td>14</td>
<td>2</td>
</tr>
</tbody>
</table>

The study conveys that Cardiac Resynchronization therapy is more effective in preventing major cardiovascular events compared to Medical Therapy.
CARE-HF Findings

• CRT conferred a significant morbidity and mortality benefit on NYHA Class III and IV patients with a wide QRS and low LVEF, even without the rescue defibrillation

• First study to show benefits of CRT apart from defibrillation

• “For every nine devices implanted, one death and three hospitalizations for a major CV cause could be avoided”
Cardiac Resynchronization Therapy* in Patients With Severe Systolic Heart Failure

For patients who have LVEF ≤ 35%, a QRS duration ≥ 0.12 seconds, and sinus rhythm, CRT with or without an ICD is indicated for the treatment of NYHA functional Class III or ambulatory Class IV heart failure symptoms on optimal recommended medical therapy.

For patients who have LVEF ≤ 35%, a QRS duration ≥ 0.12 seconds, and AF, CRT with or without an ICD is reasonable for the treatment of NYHA functional Class III or ambulatory Class IV heart failure symptoms on optimal recommended medical therapy.

For patients with LVEF ≤ 35% with NYHA functional Class III or ambulatory Class IV symptoms who are receiving optimal recommended medical therapy and who have frequent dependence on ventricular pacing, CRT is reasonable.
Cardiac Resynchronization Therapy* in Patients With Severe Systolic Heart Failure

For patients with LVEF ≤ 35% with NYHA functional Class I or II symptoms who are receiving optimal recommended medical therapy and who are undergoing implantation of a permanent pacemaker and/or ICD with anticipated frequent ventricular pacing, CRT may be considered.

CRT is not indicated for asymptomatic patients with reduced LVEF in the absence of other indications for pacing.

CRT is not indicated for patients whose functional status and life expectancy are limited predominantly by chronic noncardiac conditions.
Implantation of CRT
Implantation of CRT

Varying Patient Anatomy \(^1,2,3\)

1. Potkin et al. Am J Cardiol 1987;60:1418-1421
Cardiac Venous Anatomy

- CS Os
- Middle Posterior
- Great Postero-lateral
- Antero-lateral
- Lateral
- Anterior

RAO(40) AP LAO(40)
Implantation of CRT
CXR of patient with CRT
Monitoring of Fluid Status

- Cardiac devices are able to track and monitor fluid status in patients using intrathoracic impedance measurements
- Allow clinicians to detect early pulmonary congestion before symptoms appear
- Allows for timely intervention, reducing hospitalization rates.
Questions??

Sorry, we're trying to save money... hence the wind-up pacemaker.