Cardiac Resynchronization Therapy

Michelle Khoo, MD
10.7.08
Sudden Death (SD) in Subset Populations

HuiKuri HV
NEJM 2001
Sudden Death (SD) in Subset Populations

Uncommon causes
- Primary electrical and genetic ion-channel abnormalities, valvular or congenital heart disease, other causes
  - <5%

Cardiomyopathy
- Genetic factors, hypertension
  - ~10–15%
- Genetic factors, infection, others

Risk factors for coronary atherosclerosis: older age, male sex, hyperlipidemia, smoking, hypertension, diabetes
- ~80%

Triggers of cardiac arrest:
- transient ischemia, hemodynamic fluctuations, neurocardiovascular influences, environmental factors

Sudden Death

Typical sequence of electrical events:
- Sinus rhythm
- Ventricular tachycardia
- Ventricular fibrillation
- Asystole

HuiKuri HV
NEJM 2001
SD in Competitive Athletes

- SD during exercise in healthy young adults – 1:200,000 to 250,000 per year
- 20 – 25 sports-related SDs annually in U.S. (Libethson RR NEJM 1996)

**≤ 35 years old**
- Idiopathic LVH: 18%
- Coronary Anomalies: 14%
- Coronary HD: 10%
- Ruptured Aorta: 7%
- Unexplained: 3%
- HCM: 48%

**> 35 years old**
- Coronary HD: 80%
- Valvular HD: 5%
- MVP: 5%
- HCM: 5%
- Unexplained: 5%

Zipes DP *Circulation* 1998
Maron BJ *JACC* 1989
Excitation-Contraction Coupling

Bers, D Nature 2002
Electrical & AP Remodeling

Macroscopic

Cellular

Action potential prolongation

Torsades de pointes

Ventricular fibrillation

O’Rourke B, Circ Res 1999
Heart Failure and Electrophysiology

- Diagnosis
- Arrhythmias in Cardiomyopathy and Heart Failure
  - Atrial arrhythmias
  - Supraventricular tachycardias
  - Ventricular tachycardias
  - Sudden death prevention and long-term device management
- Slow/Modify Disease Progression
  - Cardiac Resynchronization Therapy
- Monitoring of Cardiomyopathy and Heart Failure
Heart Failure and Electrophysiology

- Many new heart failure patients present with rhythm abnormalities
- Atrial flutters, atrial tachycardias, supraventricular tachycardias and frequent PVCs
  - Amenable to catheter ablation therapy which could be “cure” if heart failure is due to tachycardia-induced cardiomyopathy
- Significant conduction system disease frequently accompanies heart failure
Goals of Heart Failure Therapy

- Relieve HF symptoms
  - make patients feel better
  - Improve overall clinical status
  - Stabilize acute episodes of decompensation
- Decrease morbidity and mortality
  - Slow and/or reverse disease progression
  - Identify and treat reversible causes of LV dysfunction

Electrophysiology – close partner in care of patient from time of diagnosis/presentation
Holter monitor recording of a patient who did not have a defibrillator – he died at 6:11 am
A life-saving shock – normal rhythm restored
1980 Large devices - Abdominal site

- First human implants
- Thoracotomy, multiple incisions
- Primary implanter = cardiac surgeon
- General anesthesia
- Long hospital stays
- Complications from major surgery
- Perioperative mortality up to 9%
- High-energy shock only
- Device longevity ≈ 1.5 years
- Fewer than 1,000 implants/year
Today: Much Smaller devices - Pectoral site

- Transvenous, single incision
- Local anesthesia; conscious sedation
- Short hospital stays and few complications
- Perioperative mortality < 1%
- Many programmable therapy options
- Battery longevity up to 9 years
- More than 120,000 world-wide implants/year

1Morgan Stanley Dean Witter. Investors Guide to ICDs.

83% size reduction since 1989
Evolution of ICD Therapy and Adoption: 1980 to Present

- **First Human Implant**
- **FDA Approval of ICDs**
- **Transvenous Leads**
- **Biphasic Waveform**
- **Smaller Devices**
- **Dual-Chamber ICDs**
- **Size Reduction**
- **AVID**
- **CASH**
- **CIDS**
- **AT Therapies**
- **MUSTT**
- **MADIT**
- **Steroid-eluting Leads**
- **Increased Diagnostic and Memory**
- **SCD –HeFT**
- **COMPANION**
- **MADIT-II**
- **SCD-HeFT**

Number of Worldwide ICD Implants Per Year

- 1980
- 1985
- 1988
- 1989
- 1993
- 1996
- 1997/8
- 2000
- 2003
- 2004-5
Heart Failure & Cardiac Resynchronization Therapy

- Altered and improved regional loading
- Reduction of mitral regurgitation
- Reduction in sympathetic activity
- Increase in parasympathetic activity

- QRS > 120 ms
- NYHA Class III-IV
- LVEF ≤ 35%
- Sinus rhythm
- Atrial fibrillation

ACC/AHA Practice Guidelines Update 2008
CRT Class I indication
Level of evidence: A
Class IIa indication
Inter-Ventricular Delay

LV is activated 60 ms after RV

Auricchio A Circ 2004
Intra-ventricular Dyssynchrony

Dilative Cardiomyopathy; QRS 90 ms

Dilative Cardiomyopathy; QRS 179 ms

Lateral & posterolateral regions last activated

Aurrichio A Circ 2004
Connexin 43 Redistribution

Spragg D  Cardiovas Res 2005
Cumulative Enrollment in Cardiac Resynchronization Randomized Trials

Results Presented:
- PATH CHF
- MUSTIC SR
- MUSTIC AF
- MIRACLE
- MIRACLE ICD
- CONTAK CD
- PATH CHF II
- COMPANION
- MIRACLE ICD II
- CARE HF

Cumulative Patients

Years:
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
CRT Randomized Trials

- **PATH-CHF (41)**
  - Improved 6MWT, NYHA Class, QOL
  - Less hospitalizations

- **MUSTIC-SR (58)**
  - Improved 6MWT, NYHA Class, Peak VO2, LV volumes, MR
  - Less hospitalizations

- **MIRACLE (453)**
  - Improved 6MWT, NYHA Class, QOL, LVEF, LVEDD, MR

- **CONTAK-CD (490)**
  - Improved 6MWT, NYHA Class, QOL, LVEF, LV volumes

- **MIRACLE-ICD (555)**
  - Improved NYHA Class, QOL

- **PATH-CHF II (86)**
  - Improved 6MWT, QOL, Peak VO2

- **COMPANION (1520)**
  - Reduced all-cause mortality
  - Less hospitalizations

- **CARE-HF (814)**
  - Reduced mortality/morbidity
  - Improved NYHA Class, QOL, LVEF, LVESV
Role of Echocardiography in CRT

Can quantify favorable effects of resynchronization

ACUTE EFFECTS
Immediate
- Reduction in mitral regurgitation
- Acute hemodynamic effects

LATE EFFECTS
3 – 6 months
- Decrease in LV size
- Increase in LV function
- Improvements in LV synchrony

REVERSE REMODELING
Summary

• Large number of patients studied in RCTs
• Concordant proof that CRT improves quality of life, functional status, and exercise capacity
  – Improvements persist through $\geq 1$ year
• CRT reduces mortality and the risk of hospitalization due to worsening HF
• CRT + ICD reduces all-cause mortality
• CRT improves cardiac function and structure
Achieving Cardiac Resynchronization

Transvenous approach for left ventricular lead via coronary sinus
Back-up epicardial approach
Coronary Sinus anatomy
ECHO pre- and post-CRT-D (next day)
June 2005
Post CRT-D Implantation
ASVP 100 ms
Sim LV/RV

September 2005
Post CRT-optimization
ASVP 140 ms
LV 30 ms
Optimizing Delivery of CRT

- Maximize BiV-pacing (> 93 – 95%)
- Echo-guided CRT-optimization *in all* to maximize potential benefit
  - Optimize AV-delay for best stroke volume
  - LV or RV preactivation
- Minimize atrial pacing
  - Use DDD pacing mode where possible
  - Minimize basal pacing rate
- Sinus rhythm is best
- Tachycardia not desirable
- Consider AV nodal ablation in non-responder with atrial fibrillation if inadequate biV-pacing
Anti-Tachycardia Pacing
ICD discharge
The Power of Defibrillation

- A corrective shock of 35 – 36J is applied within a tenth of a second
- That is the same voltage as 500-533 AA batteries
How often do we check ICDs?

- At time of surgery, the next day, then every 3 months
- Effectiveness of ICD tested during surgery, and 3 months after surgery
- If previous cardiac arrest/VT/VF, we recommend annual ICD testing
Success story – VF episode 2.29.08
“I want to die like my father, peacefully in his sleep, not screaming and terrified, like his passengers....”
## Benefits of Remote Monitoring

<table>
<thead>
<tr>
<th>Early identification of ...</th>
<th>Clinical action taken ...</th>
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<tbody>
<tr>
<td>Atrial Fibrillation</td>
<td>- Warfarin/medications</td>
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<tr>
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<td>- Cardioversion</td>
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<td></td>
<td>- Ablation</td>
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<tr>
<td>Ventricular Tachycardia</td>
<td>- Device reprogramming</td>
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<tr>
<td></td>
<td>- Ablation/medications</td>
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<tr>
<td>Heart Failure Progression</td>
<td>- Office visit</td>
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<td></td>
<td>- Medications/diet</td>
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<tr>
<td>Loss of CRT Therapy</td>
<td>- Adjust medications</td>
</tr>
<tr>
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<td>- Device programming</td>
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OptiVol fluid index is an accumulation of the difference between the daily and reference impedance.
Electrophysiology in Cardiomyopathy & Heart Failure

• Complex patient population at advanced stages of disease process
• Multitude of clinical scenarios
• Complex, expensive and individualized care
• Current approach mainly to reduce morbidity and mortality
• Future
  – Identify early at risk populations
  – Specific targeting of sub-populations based on specific markers of response (still defining)
  – LV remodeling is key
  – Improved technology
Thank You
Spragg D * Circ 2003