Durable PV Isolation - Is it the Holy Grail of AF Ablation?

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Disclosures

- Medtronic Cryocath – Consultant
- CardioFocus – Honararia
• What is the current success rate of PVI?

• What can we do to improve our success rate using our current technology?
AF: Catheter Ablation

PVI
Why Does AF Ablation Fail?

PV Reconnections

Non-PV Triggers
- posterior LA, SVC, IVC, CS, Fossa ovalis, Ligament of Marshall, behind Eustachian ridge, adjacent to AV valve annuli
Long-term Outcome after PVI: Late Recurrence


Weerasooriya R et al. JACC 57:160, 2011
Long-term Outcome after PVI: Late Recurrence


No AADs

On AADs

Parox AF

Persist AF

Atrial arrhythmia-free survival

Months

Number at risk

177  166  141  114  79  43  23  3

P=NS
Why does AF ablation fail?

But how can this explain late recurrences?
Why does AF ablation fail?

What if initially, only the left PVs are active?
Why does AF ablation fail?

…but over time, the right PVs become active?
Why does AF ablation fail?

…but over time, the right PVs become active?
How often does PV reconnection occur?

Ablation Procedure
• Map the PVs

Re-Map Procedure
• All patients regardless of intervening symptoms
• Wait at least ~3 months
• Re-Map the PVs
How often does PV reconnection occur?

Ablation Procedure
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Re-Map Procedure
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- Wait at least ~3 months
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Ablation Procedure
- Pts with first ever procedure

Clinically–Indicated 2nd Procedure
- Re- Map the PVs
- Likely underestimate of true measure of durable PVI
# PV Reconnections (Based on “Redos”)

<table>
<thead>
<tr>
<th>Study</th>
<th>#</th>
<th>No. (%) of Redo Procedures</th>
<th>Durable PV Isolation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>% of PVs</td>
</tr>
<tr>
<td>Weerasooriya, JACC, 2011</td>
<td>100</td>
<td>51 (51%)</td>
<td>0</td>
</tr>
<tr>
<td>Ouyang et al, Circ, 2010</td>
<td>161</td>
<td>66 (41%)</td>
<td>31%</td>
</tr>
<tr>
<td>Medi et al, JCE, 2010</td>
<td>100</td>
<td>22 (22%)</td>
<td>19%</td>
</tr>
<tr>
<td>Sy et al, H.Rhythm, 2010</td>
<td>99</td>
<td>22 (22%)</td>
<td>19%</td>
</tr>
<tr>
<td>Tzou et al, Circ-Array, 2010</td>
<td>123</td>
<td>15 (12%)</td>
<td>4%</td>
</tr>
<tr>
<td>Sawhney et al, AJC, 2009</td>
<td>71</td>
<td>31 (44%)</td>
<td>0%</td>
</tr>
<tr>
<td>Bhargava, H.Rhythm, 2009</td>
<td>728</td>
<td>121 (17%)</td>
<td>≤13%</td>
</tr>
<tr>
<td>Gaita et al, Circ-Array, 2008</td>
<td>204</td>
<td>99 (49%)</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1586</td>
<td>427 (27%)</td>
<td>24%</td>
</tr>
</tbody>
</table>
Correlation of PVI & Clinical Success

Patients free of AF Recurrence (%)

PV Arrhythmogenicity
- Low
- High

PV Arrhythmogenicity Based on:
- Frequency of AF episodes
- Symptomaticity of episodes
- Aggressiveness of follow-up
- Duration of follow-up

Probability of achieving durable PV Isolation (on a per vein basis)

Model assumes: i) 4 PVs / pt, and ii) PVs are isolated individually
What if durable PV Isolation was actually achieved?

• Lee G et al, *Eur Heart J*, 2010

• AF after lung transplantation
  – Compare early & late AF
  – Retrospective analysis after:
    • Double Lung Transplantation (n=200)
    • Single Lung Transplantation (n=127)
    • Thoracic Surgery (n=201)
What if durable PV Isolation was actually achieved?


**Early post-op AF:**
- Double Lung 29%
- Single Lung 28%
- Thoracic Surg 14% (p<0.001)

**Late AF (mean f/u 5.4±2.9 yrs)**
- Double Lung 0.5%
- Single Lung 12.6%
- Thoracic Surg 11.4% (p<0.001)
PV REMAPPING STUDY

- 52 pts returned for PV remapping at 105 ± 44 days
- Durable electrical isolation was present in 162/189 (85.7%) PVs
- 32/52 (61.5%) pts w/ all PVs isolated
- Freedom from AF at 12 months was 71% off AADs

S.Dukkipati / P.Neuzil / A.d’ Avila / V.Reddy, Circ Arrhy, 2010
S.Dukkipati / P.Neuzil / J.Kautzner / V.Reddy Heart Rhythm 2012
Disparity between Durable PVI & Efficacy with Visually-Guided Laser

- Non-PV triggers
- Ostial level of isolation
Maximizing chance of durable PVI
Methodological Changes we Instituted

• Catheter Stability:
  – GA / JET Ventilation (*Natale, Schwartzman, Marchlinski*)
  – Deflectable sheath to maximize tissue contact (*Hindricks*)

• “Good Lesions”:
  – ICE Imaging of tissue contact (*Marchlinski, Natale, Mangrum*)
  – Attention to impedance drop during ablation

• Circumferential tissue necrosis:
  – PV isolation as ipsilateral vein pairs
  – No Visual Gaps: Full encircling ablation despite PVI prior to encircling
  – Contiguous lesions (*Visually-Guided Laser, EFFICAS 1 & 2*)

• Minimize chance of dormant conduction:
  – Longitudinal redundancy of the lesion set
  – After PVI, additional ablation at sites of pace-capture (*Michaud, Hindricks*)
  – Use Adenosine to identify dormant conduction (*Arentz, Nattel*)

• Use Isuprel to identify non-PV Triggers (*Marchlinski, Natale*)
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Steerable vs Fixed-Curve Sheath

# Steerable vs Fixed-Curve Sheath

## Procedural Data for the Group of Patients Treated with Steerable Sheath Catheter Navigation (Cases) and for the Group of Patients Treated with a Nonsteerable Sheath (controls)

<table>
<thead>
<tr>
<th></th>
<th>Cases (n = 83)</th>
<th>Controls (n = 83)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure time [minutes]†</td>
<td>149 ± 32</td>
<td>143 ± 29</td>
<td>0.256</td>
</tr>
<tr>
<td>Fluoroscopy time [minutes]‡‡</td>
<td>21 (17;25)</td>
<td>22 (16;29)</td>
<td>0.652</td>
</tr>
<tr>
<td>Irradiation dose [cGy/cm²]‡‡</td>
<td>6,200 (3,425;7,775)</td>
<td>7,100 (3,950;10,600)</td>
<td>0.128</td>
</tr>
<tr>
<td>RF burning time [minutes]†</td>
<td>42 ± 13</td>
<td>40 ± 12</td>
<td>0.447</td>
</tr>
<tr>
<td>Number of RF pulses‡‡</td>
<td>30 (24;37)</td>
<td>34 (25;43)</td>
<td>0.127</td>
</tr>
<tr>
<td>Mean procedural RF power [W]†</td>
<td>33 ± 9</td>
<td>41 ± 4</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Radiofrequency energy [J]‡‡</td>
<td>97,498 (71,649;115,680)</td>
<td>111,864 (98,065;131,700)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Complete pulmonary vein isolation, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left-sided veins, n (%)</td>
<td>58 (70)</td>
<td>12 (14)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Right-sided veins, n (%)</td>
<td>64 (77)</td>
<td>18 (22)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Left- and right-sided veins, n (%)</td>
<td>43 (52)</td>
<td>8 (10)</td>
<td>&lt;0.0005</td>
</tr>
</tbody>
</table>

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Impedance Changes during RFA
EFFICAS 1: The Importance of Not Making a Bad Lesion

Ablation Procedure
• PV Isolation: irrigated force-sensing RF catheter
• Operator: blinded to force

Re-Map Procedure
• All patients regardless of intervening symptoms
• Wait at least ~3 months
• Re-Map the PVs

![Graph showing minimum force comparison between GAP and NO GAP (p = 0.009)]
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What to do with a Visual Gap?

Baseline (pre-ablation) Voltage Map

Entrance Block Transiently Achieved with this Lesion (green)

Baseline PV EGMs

Entrance Delay During CPVA

Entrance Block

LA Far-field

How can we explain electrical isolation despite a visual gap?

How can this happen?
- No tissue?
- Preferential conduction?
- Edema?
How can we explain electrical isolation despite a visual gap?

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PV Voltage Map Following Spontaneous Reconnection (Gap Open)

Entrance Conduction Resumes During Waiting Period

LA Far-field

M.Miller / A.d’Avila / S.Dukkipati / V.Reddy, Europace (accepted)
How can we explain electrical isolation despite a visual gap?

How can this happen?
- No tissue?
- Preferential conduction?
- Edema?

Single Lesion (yellow) on Superior Aspect of Gap, Re-isolates Vein

Entrance Block

PV Potential

LA Far-field

How can we explain electrical isolation despite a visual gap?

How can this happen?
- No tissue?
- Preferential conduction?
- Edema?

Visual Gap Present: Entrance Block, Exit Block, No Pace Capture and No Dormant Conduction

Adenosine: Complete AV Block → No Dormant Conduction

How can we explain electrical isolation despite a visual gap?

How can this happen?
- No tissue?
- Preferential conduction?
- Edema?
28 Patients / 56 PV pairs

42 PV pairs (75%) Isolated with a ViG
- 21 RPVs
- 21 LPVs

14 PV Pairs Isolated without a ViG

1) Waiting Period
2) Testing for Exit Block
   - 96% of tested PV pairs with Exit Block
3) Testing for Pace Capture
   - 70% of Tested PV Pairs with Pace Capture

Adenosine

Dormant Conduction
- 12 PV pairs (29%)
  - 67% ViG Dependent
  - 33% Prior Ablation

No Dormant Conduction
- 30 PV pairs (71%)

Example of an Unablated ViG

A 1st Procedure: RIPV Isolated (ViG present, left un-ablated)

1st Procedure: Baseline RIPV

B 2nd Procedure: RIPV Reconnected (Re-isolated with ablation along prior ViG)

2nd Procedure: RIPV Re-isolated

The Problem of Visual Gaps
The Problem of Visual Gaps
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EFFICAS 2: Make Continuous Lesions!

Ablation Procedure
• PV Isolation: irrigated force-sensing RF catheter
• Operator: can see force

Re-Map Procedure
• All patients regardless of intervening symptoms
• Wait at least ~3 months
• Re-Map the PVs

Non-adjacent lesions

Adjacent lesions

• Jump index: Cumulative sum of the distance between non adjacent lesion until all sections are ablated once
EFFICAS 2: Make Continuous Lesions!

EFFICAS 1:

Success Ratio in EFFICAS 1 as a function of jump index

- <6: n=20
- 6-10: n=13
- >=10: n=19

EFFICAS 2:

Success Ratio in EFFICAS 2 as a function of jump index

- <6: n=27
- 6-10: n=13
- >=10: n=7

EFF1: 26 patients
EFF2: 24 patients
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Does Pace-Capture Facilitate Ablation?

Anatomical Encircling
- Irrigated RF Catheter
- PV potentials hidden
- Ipsilateral PVs as pairs

Render Non-Capturable
- Pace-Capture on lines
- More RF till non-capture

Un-blind Operator
- Assess whether isolation
- More RF if not isolated

- 30 PAF patients (2 centers)
- After anatomical encircling, PVI occurred in 19/60 (32%)
- After PC, PVI in 57/60 (95%)
- More RF: PVI in 60/60 (100%)
- Even after PVI, additional sites of pace-capture in 30/60 (50%)

D.Steven / V.Reddy / G.Michaud, Heart Rhythm, 2009
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Adenososine-Mediated Acute PV Reconnection: It may be too late!

• 109 PAF pts → PVI
• Adenosine challenge:
  – Group 1:
    • 70 patients
    • No PV reconnections
  – Group 2:
    • 39 patients
    • PV reconnections
    • Additional RF to isolate
• One year follow-up

Miyazaki S, et al. *JCE* 2012;23:256-60
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Employing Techniques to Maximize Lesion Contiguity and Transmurality During PV Isolation: Impact on the Durability of PV Isolation (in Redo Procedures)

81 Consecutive Pts
42 PAF

14 Redo after Single Recurrence
96 ± 58 days

93% of PV Pairs
86% of the Pts
