Ablation Comes of Age

30 Years of Ablation
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Disclosure

Consulting:
- Biosense Webster
- Boston Scientific
- Endosense
- ACT
- VytronUS

Lecture Honoraria:
- Biotronik
- St Jude Medical
- Biosense Webster
- Boston Scientific
- Medtronic
RF Ablation Came of Age

1988: RF Ablation Electrode Changed

6 Fr  7 Fr
2 mm long  4 mm long
1988: 7 Fr, 4 mm Electrode
- Increased Convective Cooling of the Electrode-Tissue Interface
- Prevented the Early Impedance Rise
Canine Studies
Canine Studies
Catheter Ablation of a Left Posterior Accessory Pathway

Jackman et al, NEJM 1991;324:1605
Left Lateral Accessory Pathway

RAA Pacing

LV Pacing

100 ms
Left Lateral Accessory Pathway

RAA Pacing

LV Pacing

[Diagram with electrocardiogram tracings showing RAA and LV pacing with annotations for A, H, V, AP, and S.]
Left Lateral Accessory Pathway

RAA Pacing

CB

LV Pacing

100 ms
Left Lateral Accessory Pathway

RAA Pacing

LV Pacing

100 ms
Left Lateral Accessory Pathway

RAA Pacing

LV Pacing

100 ms
RAA Pacing

LV Pacing

**Left Lateral Accessory Pathway**

I
II
V1
RAA
4
3
2
1
HB
9
8
7
6
5
4
3
2
1
CS
LV
RV

Late A at Mid-Body of AP
Anteroseptal and Midseptal APs

• Prevent AV Block
  - Keep ablation electrode on *ventricular side of tricuspid or mitral annulus*
Ablation of Anteroseptal AP

RAO

LAO
Anteroseptal AP

I
II
V1
RAA

HB

AS
TA

Bip 3-4
Bip 1-2

100 ms
Anteroseptal AP

I
II
V1
RAA
HB

380
A
A

HB

H
H
A
A

AS
TA

Bip 3-4
Bip 1-2
Uni 2
Uni 1

100 ms
Anteroseptal AP

I
II
V₁
RAA
HB

Bip 3-4
Bip 1-2
Uni 2
Uni 1

AS
TA

380 ms

100 ms
Anteroseptal AP

I
II
V₁
RAA
HB

AS TA
Bip 3-4
Bip 1-2
Uni 2
Uni 1

100 ms
Anteroseptal AP

I
II
V1
RAA

HB
p
m
d

AS
TA

Bip 3-4
Bip 1-2
Uni 2
Uni 1

H
H
H
H
H
H
H
H

100 ms
Anteroseptal AP

RF #1 – Success (No Junctional Extrasystoles)
Ablation of High Midseptal AP

RAO Projection
Targeting a High Midseptal AP

I
II
V

RAA

Bip 3-4
Bip 1-2

MS

TA

Uni 2
Uni 1

CS

p
d

100 ms
Targeting a High Midseptal AP

I
II
V₁
RAA
Bip 3-4
Bip 1-2
MS
TA
Uni 2
Uni 1
CS

Sharp AP
No A

100 ms
Targeting a High Midseptal AP

Waveforms are shown with annotations indicating electrical activity at different sites.

- Bip 3-4
- Bip 1-2
- MS TA
- Uni 2
- Uni 1

Markers indicate successful RF application, with the word "Success" noted.

Sharp AP and No A annotations are highlighted.

Timeline: 100 ms
Accessory Pathway Ablation

Unexpected Locations

- Epicardial Anteroseptal (Non-Coronary Cusp)
- Left Midseptal
- Left Fibrous Trigone
- RAA - Epi RV, LAA - Epi LV
- Right Atriofascicular Pathways
- Epicardial Posteroseptal (CS – LV Connections)
Accessory Pathway Ablation

Unexpected Locations

- Epicardial Anteroseptal (Non-Coronary Cusp)
- Left Midseptal
- Left Fibrous Trigone
- RAA - Epi RV, LAA - Epi LV
- Right Atriofascicular Pathways
- Epicardial Posteroseptal (CS – LV Connections)
  - 20% of all Posteroseptal APs
  - 50% of Posteroseptal APs with Prior Failed Ablation
Great Cardiac Vein

Posterior Coronary Vein

LA-CS Connections

CS Myocardial Coat

CS-LV Connection

Middle Cardiac Vein

CS-Ventricular Connection

Sun, Jackman, et al, Circulation 2002
Coronary Sinus Extension – AP Potential (CSE-AP) Deep in Middle Cardiac Vein

LAO

RAO

2.0 cm
Retrograde AP Conduction (AVRT)

1st Retrograde Potential - Activation of CS Extension
Retrograde AP Conduction (AVRT)

LAO Projection

RAA
HB
CS
RV
MCV

RAO Projection

RAA
HB
CS
CS
CS
CS
RV
MCV

2nd Retrograde Potential - Activation of CS Myocardium

#2 CS Myo

#1 CS Extn
Retrograde AP Conduction (AVRT)

LAO Projection

RAO Projection

3rd Retrograde Potential - Activation of Left Atrium
Ablation of CS-Ventricular Connections

Retrograde Conduction

Ideal Ablation Site

Coronary Sinus Ostium

Earliest LA Activ

LA Activ

Great Cardiac Vein

CS Myo Extn–LV Connection

LA

CSE

Small Cardiac Vein

Middle Cardiac Vein

LV

LV CS Myo Extn–LV Connection
Right Coronary Angiography

LAO

RAO
Accessory AV Pathway Ablation

1702 Pts

904 (53%) Pts
Prior Failed Ablation

Total Accessory Pathways (APs)

1728 APs

Free-Wall APs

1120 (65%) APs

Left Free-Wall

759 APs

Successful Ablation

756 APs (99.6%)

Right Free-Wall

361 APs

Successful Ablation

359 APs (99.4%)

Septal APs

608 (35%) APs

Anteroseptal

117 APs

Successful Ablation

116 APs (99.1%)

Posteroseptal

491 APs

Successful Ablation

476 APs (97.0%)

Nakagawa and Jackman, Circulation 2007
Follow-up: 22 ± 12 months

**Long-Term Outcome**

**Acute Success**

1680/1702 (98.7%)

Recurrence of Preexcitation or AVRT

87 (5.2%)

- Successful Repeat Ablation
  72

Long-term Failure

37/1702 (2.2%)

No Recurrence Preexcitation or AVRT

1593 (94.8%)

Long-term Success

1665/1702 (97.8%)
RF Ablation Came of Age

AVNRT Ablation

- AV Nodal Modification for S/F AVNRT (Fast Pathway Abl)
  - Scheinman, Morady, et al (San Francisco)
  - Morady et al (Michigan)

- Slow Pathway Ablation (All Forms AVNRT)
  - Jackman et al (Oklahoma) 1992
  - Jazayeri et al (Milwaukee) 1992
  - Kay et al (Alabama) 1992
  - Haissaguerre (Bordeaux) 1992
Rightward Inferior Extension is Most Frequently Used Slow Pathway in AVNRT

Inoue and Becker, Circulation 1998;97:188
Retrograde Conduction Over the Rightward Inferior Extension (RIE) of the AV Node
Retrograde Conduction Over the Rightward Inferior Extension (RIE) of the AV Node

RAO Projection

LAO Projection
Retrograde Conduction Over the
Rightward Inferior Extension (RIE) of the AV Node

RAO Projection

LAO Projection

Tendon of Todaro
HB
CS
A_{SF}
Potential
Eustachian Ridge

Tendon of Todaro
Mitral Annulus

Eustachian Ridge

Tricuspid Annulus

 Activation of CS Myocardium

RIE

RIE

Retrograde Conduction Over
the Rightward Inferior Extension (RIE) of the AV Node
Retrograde Conduction Over the 
*Rightward Inferior Extension (RIE)* of the AV Node

RAO Projection

![](image)

LAO Projection

![](image)
Retrograde Conduction Over the Rightward Inferior Extension (RIE) of the AV Node

RAO Projection

LAO Projection
Retrograde Conduction Over the 
Rightward Inferior Extension (RIE) of the AV Node

RAO Projection

LAO Projection

RA Activation

Tendon of Todaro

HB

RA Activation

Tendon of Todaro

Mitral Annulus

Activation of CS Myocardium

Eustachian Ridge

CS

A_SP Potential

Tendon of Todaro

Heterogeneity Band

Tricuspid Annulus

IVC

Activation of CS Myocardium

Eustachian Ridge

Tendon of Todaro

Heterogeneity Band

Tricuspid Annulus

IVC
Fast/Slow AVNRT Using Rightward Inferior Extn for Retro Conduction
Fast/Slow AVNRT Using Rightward Inferior Extn for Retro Conduction

#1 - Inferior Triangle of Koch
Fast/Slow AVNRT Using Rightward Inferior Extn for Retro Conduction

#2 - Floor CS Ostium
Fast/Slow AVNRT Using Rightward Inferior Extn for Retro Conduction

1. II
2. V1
3. RAA
4. HBp
5. HBd

Inf ToK

CS Roof
- prox
- distal

CS Floor
- prox
- distal

Roof CS

Floor CS Os

#3 - Roof CS Ostium

A 45 H

A SP

A

H

100 ms
Fast/Slow AVNRT Using Rightward Inferior Extn for Retro Conduction

- **LA #4**
- **Floor CS Os**
- **Roof CS**
- **CS Roof prox**
- **CS Floor prox**
- **CS Floor distal**
- **CS Roof distal**
- **Inf ToK prox**
- **Inf ToK distal**
- **RAA**
- **HB_p**
- **HB_d**
- **V_1**
- **II**

#4 - Left Atrium

100 ms
Leftward Inferior Extension is 2\textsuperscript{nd} Most Frequently Used Slow Pathway in AVNRT

Inoue and Becker, Circulation 1998;97:188
Retrograde Conduction Over the “Leftward Inferior Extension” Slow Pathway

RAO Projection

LIE

Eustachian Ridge

Tendon of Todaro

HB

CS

TA

LAO Projection

Mitral Annulus

Tendon of Todaro

HB

Eustachian Ridge

Tricuspid Annulus

IVC

CS
Retrograde Conduction Over the “Leftward Inferior Extension” Slow Pathway

RAO Projection

LAO Projection

Tendon of Todaro
HB
CS
Eustachian Ridge
TA

LIE

Tendon of Todaro
Mitral Annulus

Eustachian Ridge

IVC
Tricuspid Annulus
CS

HB

LIE

Retrograde Conduction Over the “Leftward Inferior Extension” Slow Pathway
Retrograde Conduction Over the “Leftward Inferior Extension” Slow Pathway

RAO Projection

LAO Projection
Retrograde Conduction Over the “Leftward Inferior Extension” Slow Pathway

Early Retrograde Activation At Roof of Proximal CS (3-4 cm from CS Os)
Retrograde Conduction Over the “Inferolateral Left Atrial” Slow Pathway

RAO Projection

LAO Projection
Retrograde Conduction Over the “Anterior Superior” Slow Pathway
Retrograde Conduction Over the “Anterior Superior” Slow Pathway

RAO Projection
AV Nodal Reentrant Tachycardia

- ≥ 9 Forms of AVNRT

<table>
<thead>
<tr>
<th>Type</th>
<th>Forms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow/Fast AVNRT</td>
<td>≥ 3</td>
</tr>
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</tr>
<tr>
<td>Fast/Slow AVNRT</td>
<td>≥ 3</td>
</tr>
</tbody>
</table>
AV Nodal Reentrant Tachycardia

- Differentiation Between Forms

1. Identify Retrograde Pathway
   - Site of Earliest Retro Atrial Activation

2. Identify Anterograde Pathway
   - Resetting Response
   - Ablation Site of Antegrade Slow Pathway
RF Ablation of Slow Pathway (1st 10 Years)

Patients
593

- Elimination of AVNRT
  606 (99.3%)
- Ablation Failure
  1 (0.2%)
- AV Block
  3 (0.5%)
Thank You
Left Posterior Accessory Pathway

RAO

LAO

MA

HB

MA

CS
Recurrence of Atrial Fibrillation

AP Ablation 11/88 - 5/93

500 Pts

Atrial Fib Prior to Ablation

100 Pts

Follow-up (5/95): 2.0-6.5 yrs (mean 3.5 ± 1.0) yrs

No Structural Heart Disease

1/88 (1.1%)

Structural Heart Disease

6/12 (50%)
Left Posterior Accessory AV Pathway

Section Through the Mitral Annulus

A

B

C

Trichrome Stain

Courtesy Anton Becker
Canine Studies
Canine Studies
Schematic Section Through Heart Wall

- Atrium
- CS
- Mitral Valve Leaflet
- Accessory Pathway
- Ventricle
Hypothesis

Atrium

Large Current

Mitral Valve Leaflet

Small Current

Ventricle

Accessory Pathway
Hypothesis

Atrium

Large Current

Small Current

Accessory Pathway

Dilution of Current by Ventricle – Fails to Activate Ventricle

Mitral Valve Leaflet

Ventricle
Fig 4.

G. Ventricular Insertion (Septal)  

Mid-Body of AP

- Left Atrium
- Mitral Annulus (Fibrosis)
- Mitral Valve
- LV

Atrial Insertion (Lateral)
Long-Term Outcome

Follow-up: 22 ± 12 mo

Acute Success
1680/1702 (98.7%) pts

Recurrence of Preexcitation or AVRT
87/1680 (5.2%) pts

Successful Repeat Ablation
72/87 pts

Long-term Success
1665/1702 (97.8%) pts
A.

**Fig 3.**

- **RAO Projection**
  - Anterior Parasept TA
  - RAA
  - HB
  - RV

- **LAO Projection**
  - Anterior Parasept TA
  - 8-10 mm
  - RAA
  - HB
  - RV

- **Electrocardiogram (ECG) Traces**
  - Onset of Delta
  - Far-field AP
  - Local Vent Activ
  - Far-field Ventricular Activation

- **Markers**
  - Bip1-2
  - Bip3-4
  - Uni1
  - Uni2
  - RV
  - RA
  - HB
  - S
Fig 3.
Fig 3.

D.

I  II  III  V₁  RAA  HBₚ  HB₍  AOₚ  AO₍  RV

S₁  S₁ = 580

A  A = 580

AP  AP = 580

V₁ - V₂ = 510

S₂
Fig 3.
Fig 3.

During RF 1

Far-field AP

Loss of Far-field AP

Loss of AP

Loss of AP
Fig 4.

A. $V_1$

B.

100 msec
Fig 5.
Fig 5.
Fig 6A.

CS - Ventricular Connection

Great Cardiac Vein

Posterior Coronary Vein

CS Myocardial Coat

Branches of RCA

Middle Cardiac Vein

LA-CS Connections

IVC
Delay in Reversing Direction of Activation

Earliest LA Activ

Great Cardiac Vein

Small Cardiac Vein

Middle Cardiac Vein

CS Myocard Extension

Posterior Coronary Vein

LV

LA

1st Potential

2nd Potential

3rd Potential

Fig 6B.
Fig 6C.

Retrograde AP Conduction (AVRT)

LA (3)

CS Myo (2)

CS Extn (1)

LA (3)

RV

CS

MCV

HB

RAA

LAO

RAO

MCV

CS8

CS5

CS1

RV

HB

HB4

HB1

I

II

V1

RAA

H

RB

A

Fig 6C.
Fig 6D.
Fig 6E.
Fig 7.
Fig 7.

C.

[Diagram showing electrocardiogram tracings with annotations]

Tiny Prox Accessory HB
Fig 3.

A. Concurrent Ventricular Wavefront

RV-PS Pacing

B. Countercurrent Ventricular Wavefront

RV-OT Pacing

Late A at Mid-Body of AP
Accessory AV Pathway Ablation

1702 Patients

904 (53%) pts with prior failed catheter and/or surgical ablation

Total Accessory Pathways (APs)

1728 APs

Left Free-Wall
- 759 APs
  - Successful Ablation
    - 756 APs (99.6%)

Posteroseptal
- 491 APs
  - Successful Ablation
    - 476 APs (97.0%)

Right Free-Wall
- 361 APs
  - Successful Ablation
    - 359 APs (99.4%)

Anteroseptal
- 117 APs
  - Successful Ablation
    - 116 APs (99.1%)
Conventional Electrode Catheter

Orthogonal Electrode Catheter

Accessory Pathway

Jackman, In Cardiac Preexcitation Syndromes, 1986
Hypothesis

Accessory Pathway

Large Current

Small Current

Dilution of Current by Ventricle – Fails to Activate Ventricle

Mitral Valve Leaflet

Ventricle

CS
Thank You