Creating Order out of Chaos: New Research into Treatment of Atrial Fibrillation

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What is Atrial Fibrillation?

Chaotic Electrical Activity
Who cares?:

- most common arrhythmia (6.7 million cases US/EU)
- 1.5-1.9 fold increased risk of death
- up to 24% increased risk of stroke

Framingham Heart study
Current Treatment is Inadequate

% Cure

Medication | Ablation
The majority of AF patients are *not* candidates for Ablation.
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How can we do better?

What is responsible for perpetuation of AF?

How can we reduce the heart’s tendency to fibrillate?
What causes AF?

• Why do medications work for a while and then stop working?
• Why is ablation effective for early AF but not for more advanced AF?
• Why do medications sometimes work after an unsuccessful ablation (but not before)?
What causes AF?

• Why is AF common shortly after a **successful** ablation?
• Why is AF so common after cardiac surgery?
• Why is the ability to induce AF at the end of an ablation **NOT** a marker of failure?
What is AF (exactly)?

AF is comprised of multiple spiral waves of excitation.
AF is a type of “Reentry”
Reentry = continuous propagation

Electricity can’t backup

Therefore, continuous propagation requires a circuit
Because reentry requires a circuit...

...circuit interruption results in termination
Circuits can be simple or extremely complex.

Regardless of the circuit... reentry terminates if you interrupt the circuit.
But, how do you interrupt a moving circuit (with a stationary ablation)…?

...let the circuit come to you.
AF stops when rotors collide with a boundary, therefore:

• With shorter boundary, collision is less likely
• With larger area, collision is less likely
• Specifically:
• as the boundary length to tissue area ratio decreases

AF duration increases
In a series of simulations we varied tissue shape, keeping area fixed.

The probability of termination varied as a function of boundary-length/area ratio.
Hypothesis:

We can’t change the shape of the atria, but we can add boundaries (ablation) & increase the likelihood of termination
# of Ablation Lines

Duration of Atrial Fibrillation

# of Ablation Lines
Regional Variation of Ablation Efficacy

Due to regional variation in tissue properties rotor density is not uniform...
Regional Variation of Ablation Efficacy

the center can accommodate shorter circuits producing higher rotor density
Regional Variation of Ablation Efficacy

...lines inside the region of high rotor density had a higher probability of terminating atrial fibrillation
Regional Variation of Ablation Efficacy

Surround: 15%

Central: 95%
Ablation at sites with high rotor density is much more effective:

“How do we identify areas with high rotor density in patients?”

“…when we can’t see electricity?”
We’ve developed a method for determining rotor density based upon electrograms.
• Why do medications work for a while and then stop working?

Beyond Length and Area

Wave-Length
AF progresses because the atria dilate and wavelength decreases.

As tissue area increases and wave-length decreases, the chance of collision decreases.
• Why do medications work for a while and then stop working?

(Length/Area) x wave-length
• Why do medications work for a while and then stop working?

Medication increases wave-length but only so much...

Once \( (L/A) \times WL \) is too small, collision becomes so unlikely that AF persists
Why is ablation so ineffective for advanced AF?

\[(\text{Length/area}) \times \text{wave-length}\]
Current ablation strategy is “one size fits all”...

...but as \((L/A) \times WL\) decreases

\textit{length must increase}

this tells us how to deliver

patient-specific therapy
Atrial surface area and AF wave-length determine appropriate lesion length.

not all area is created equal
Length/Area and Wave-length

• Why is AF common shortly after a successful ablation?
• Why is AF so common after cardiac surgery?
• Why is the ability to induce AF at the end of an ablation NOT a marker of failure?
Inflammation shortens wave-length
Ablation causes inflammation
Even if the L/A following ablation is adequate...
...because of acute WL shortening
AF may remain inducible
How do you know if you’re done?

Hypothesis:
If we can predict the amount that WL will increase (as inflammation heals) then we can ablate until the WL of induced AF is long enough...
Review:

• AF requires circuits to perpetuate
• If circuits are interrupted reentry stops
• Moving circuits stop when they hit a boundary
• Therefore AF gets worse if:
  • atrial area increases (boundary length/area)
  • and/or circuit size decreases (wave-length)
Review:

• We can improve the likelihood of terminating AF by:
  • increasing boundaries (ablation)
  • and/or increasing wave-length (meds)
Clinical Studies

Retrospective analysis of (L/A) x WL vs. outcome

Sub-study: AF WL pre-, <6 weeks post, late
Clinical Studies

Prospective Clinical Trial

Patient-specific, map-guided ablation:

• Length determined by CT (area) and EKG (wave-length)
• Location determined by frequency mapping
• Final ablation length determination – AF inducibility
  
  Wave-length of induced AF