HRC 2016

Ablation Lesion Assessment

The creation of effective and permanent lesions

Ian Wright
Imperial College Healthcare

Wed 09:00-09:30
Hall 11

Objective

- Examine the role of existing strategies and emerging technologies designed to improve outcomes by enabling the consistent delivery of permanent lesions through assessment of lesions quality

- Contact force sensing
- The EGM: signal attenuation
- Impedance
- Electrical In-excitability
- Imaging
  - MRI
  - Ultrasound

Introduction

- Well-defined mechanism
- Target region localized and ablated
  – Arrhythmia-free survival approaches 90 to 95%

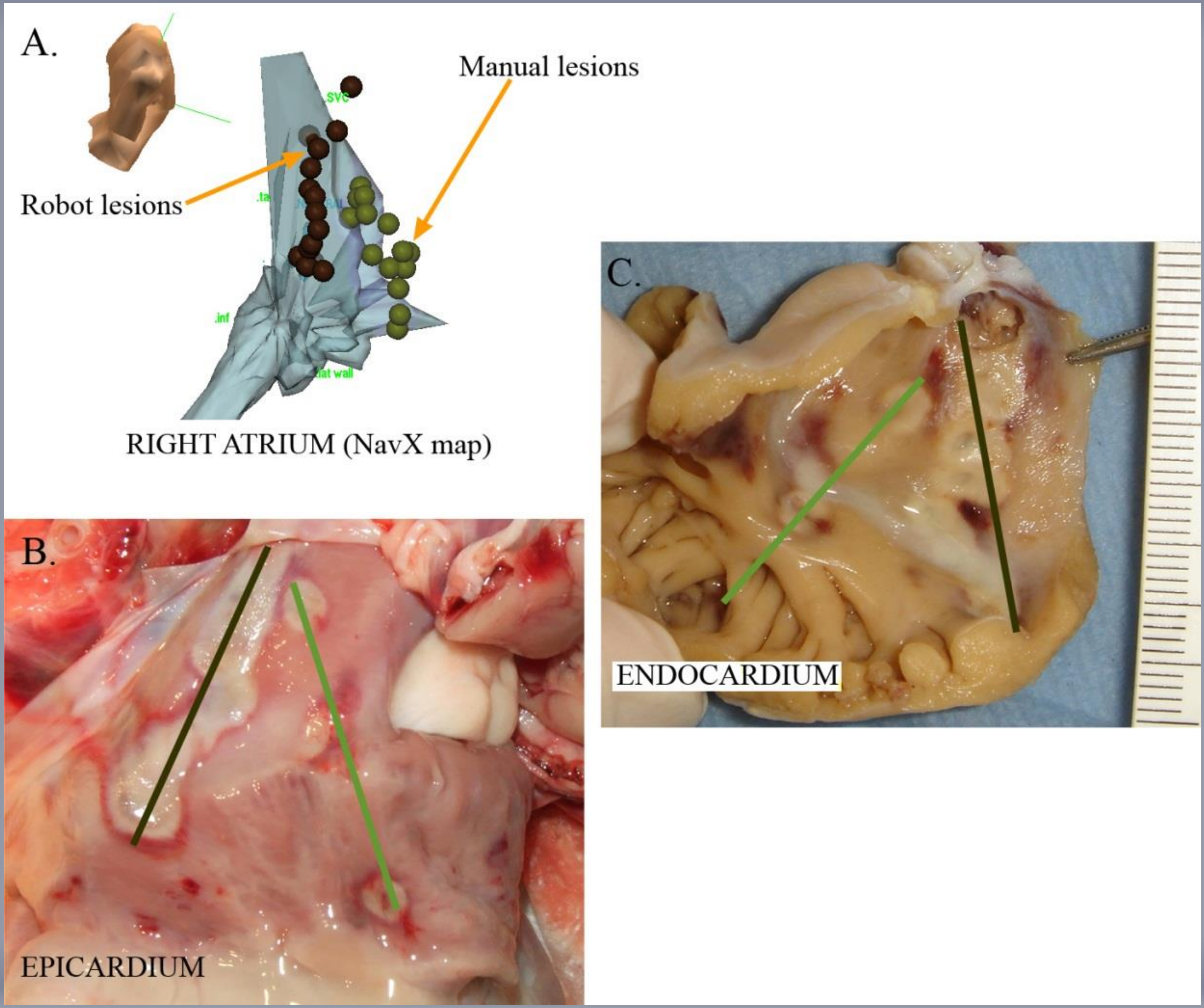
- Complex arrhythmia mechanisms (such as AF)
- More ablation lesions necessary
  – arrhythmia recurrence is 50-70%

- Lower efficacy is likely due to:
  - limitations in mapping
  - incomplete understanding of the mechanisms of the arrhythmia (as is the case in persistent AF)
  - **inability to create transmural and durable lesions without producing collateral injury**
- The creation of effective and permanent lesions remains challenging

RF ablation: biophysics of lesion creation

- RF current is the most widely employed energy source
  - well-understood safety profile
- >50°C irreversible thermal injury and loss of cellular depolarization
- 45-50°C may be reversible loss of cellular excitability
- Tissue temperature is not measurable

Comparison of robotic and manual lesions



Koa-Wing, JCE 2009

Limitations in defining a “better lesion”

- The gold standard:
  - transmural tissue necrosis by histopathology
  - not applicable clinically
- The effectiveness of new technology in human studies
  - Is assessed by acute and long term clinical outcomes (the most clinically relevant goals)
- Need simple ,validated intra-procedural measures

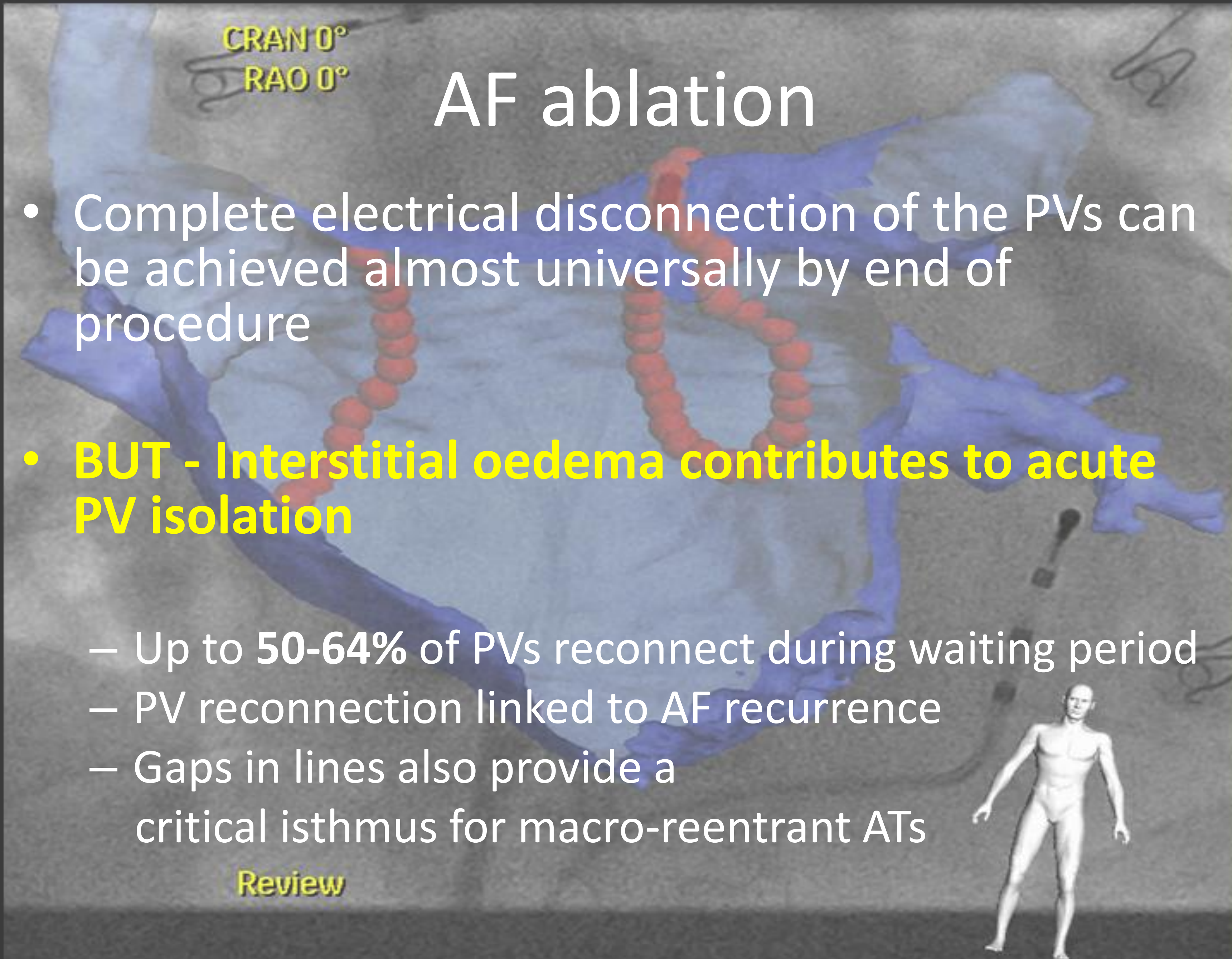
Ablation Lesion Assessment: Goals

- Assess the ablation results after complex RFA and potentially provide an end point
- Continuous real time information about lesions
- Assess incremental progress during procedure
- Provide images of failed ablations (e.g., gaps in ablation lines) and direct repeat procedures

AF ablation

- Complete electrical disconnection of the PVs can be achieved almost universally by end of procedure

- **BUT - Interstitial oedema contributes to acute PV isolation**
  - Up to **50-64%** of PVs reconnect during waiting period
  - PV reconnection linked to AF recurrence
  - Gaps in lines also provide a critical isthmus for macro-reentrant ATs



References

JAFIB

Featured Review

Journal of Atrial Fibrillation

www. jafib.com

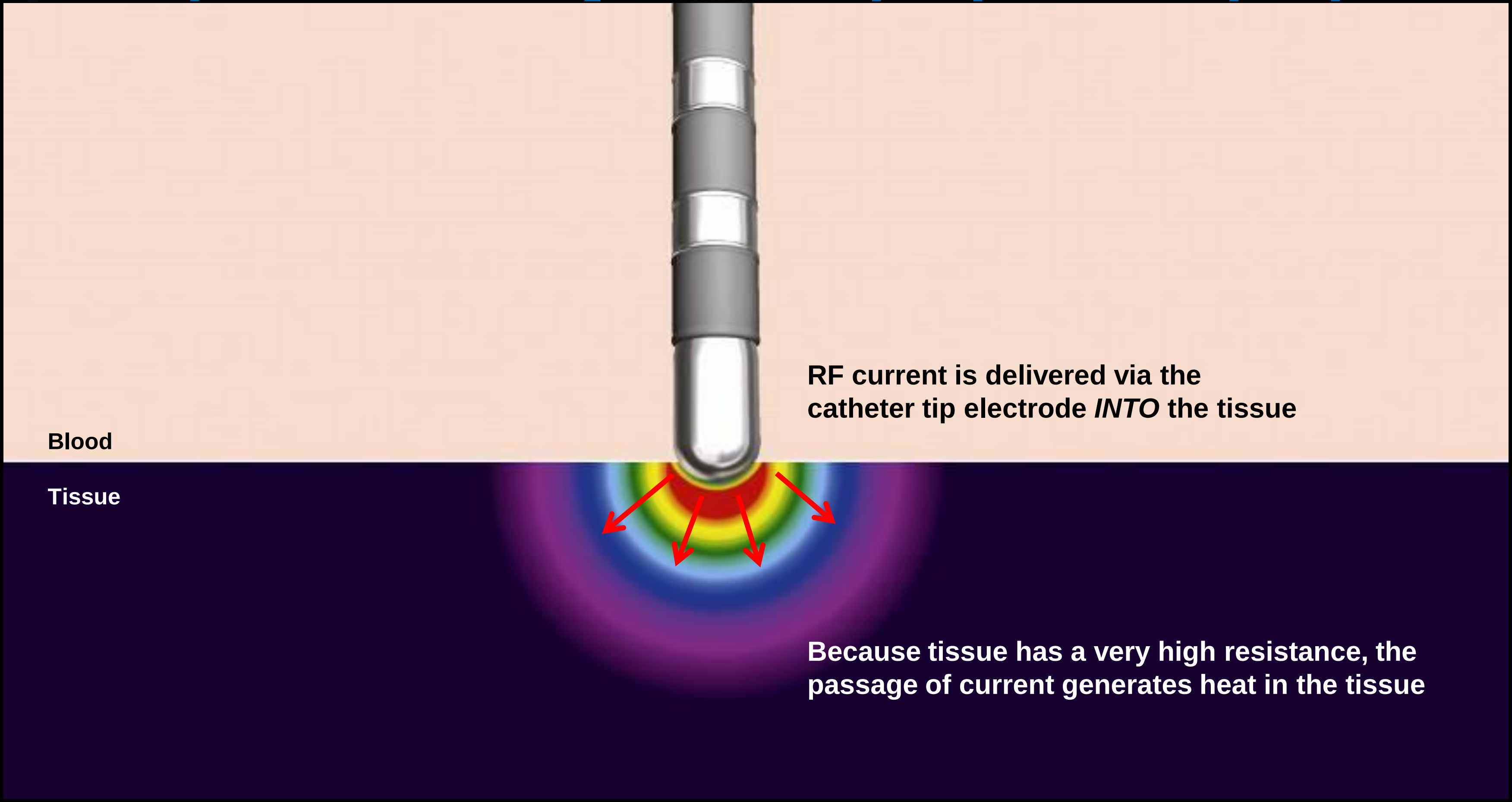
Better Lesion Creation And Assessment During Catheter Ablation

Saurabh Kumar, MBBS, PhD, Chirag R. Barbhaiya, MD, Samuel Balindger, MD, Roy M. John MD, PhD, Laurence M. Epstein, MD, Bruce A. Koplan, MD, Usha B. Tedrow, MD, William G. Stevenson, MD, Gregory F. Michaud, MD

Cardiovascular Division, Brigham and Women's Hospital, 75 Francis St, Boston, MA, 02115.

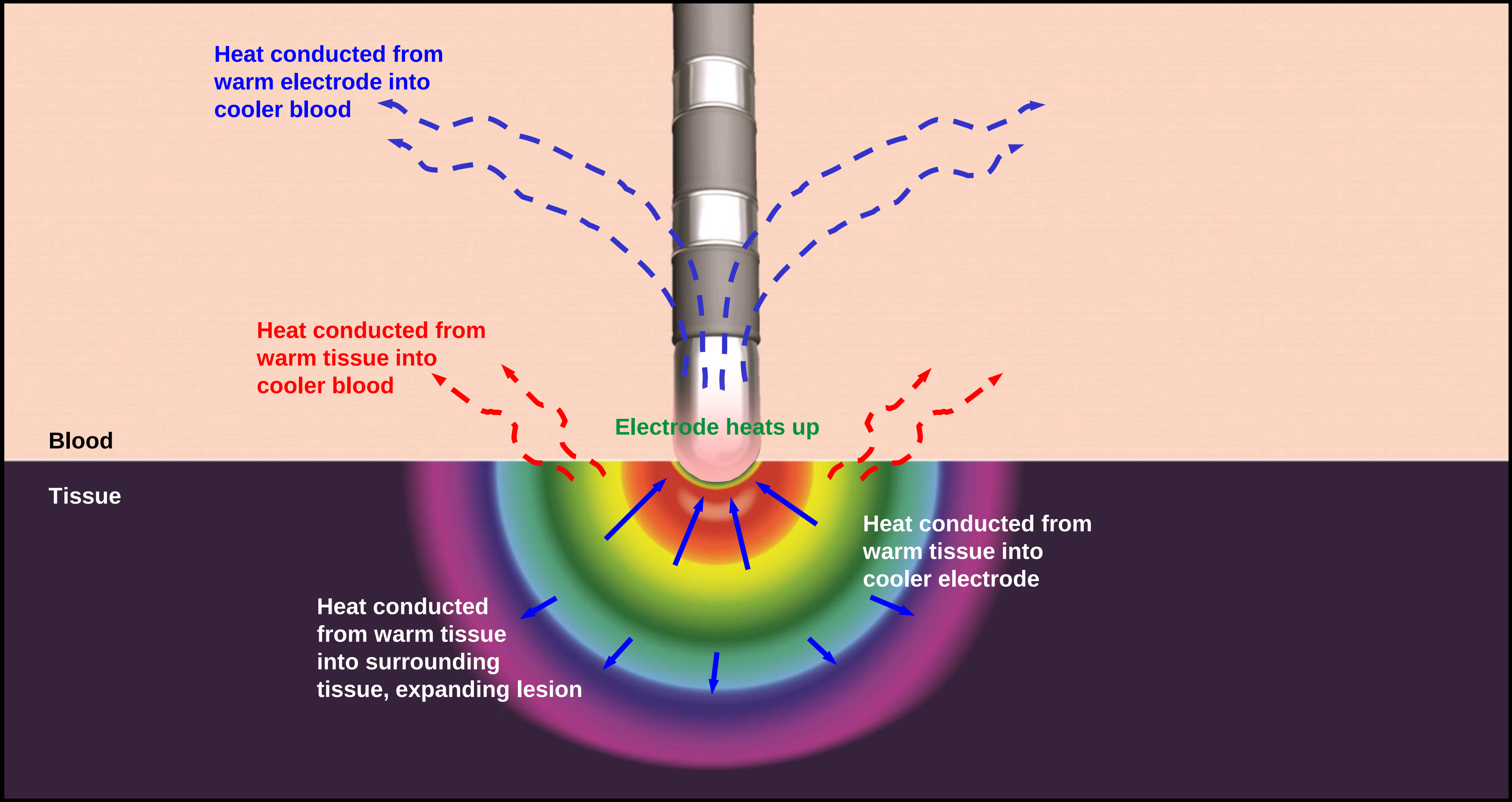
Abstract

Permanent destruction of abnormal cardiac tissue responsible for cardiac arrhythmogenesis whilst avoiding collateral tissue injury forms the cornerstone of catheter ablation therapy. As the acceptance and performance of catheter ablation increases worldwide, limitations in current technology are becoming increasingly apparent in the treatment of complex arrhythmias such as atrial fibrillation. This review will discuss the role of new technologies aimed to improve lesion formation with the ultimate goal of improving arrhythmia-free survival of patients undergoing catheter ablation of atrial arrhythmias.



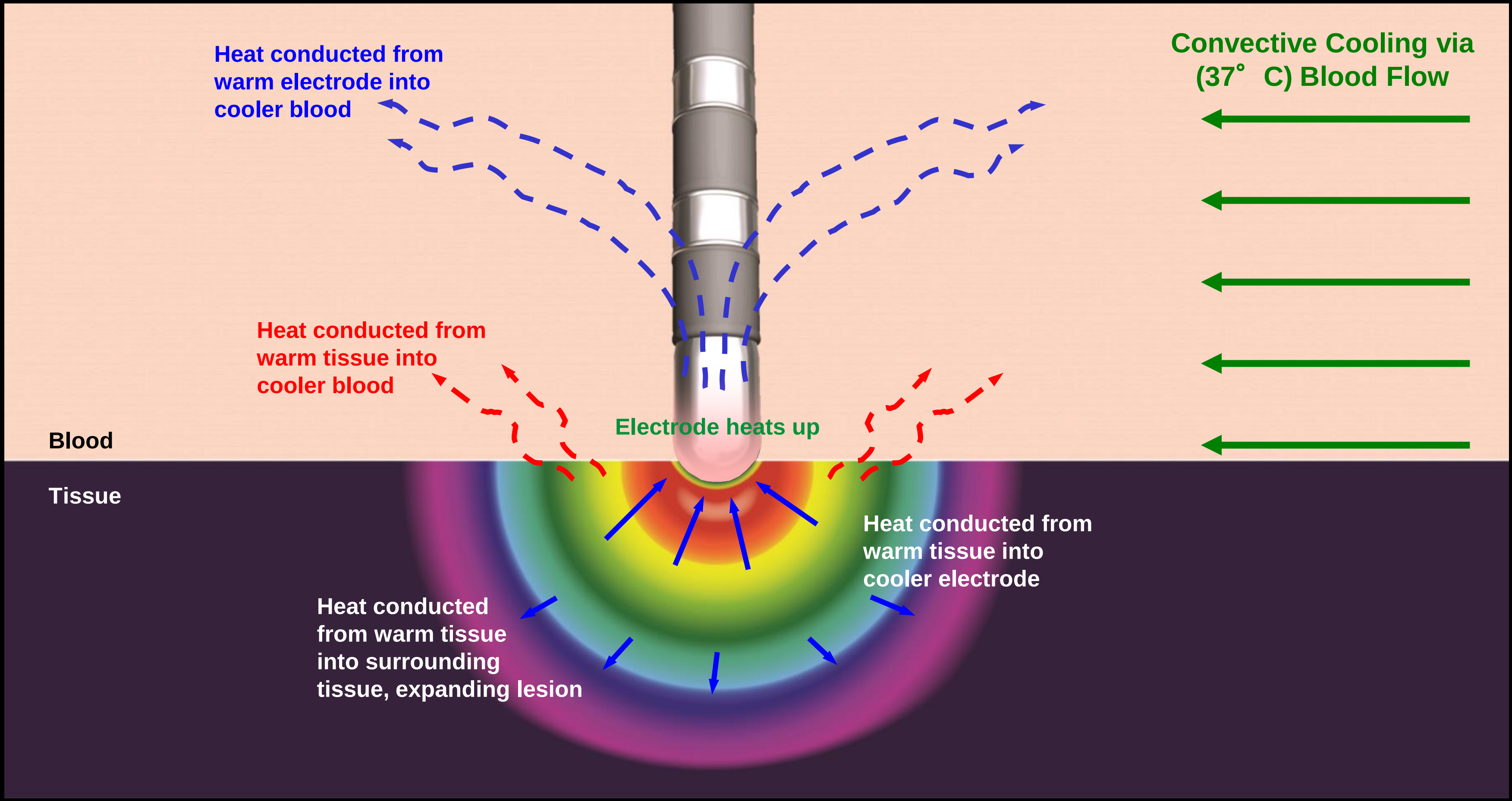
Haines, DE et. al. : Pacing Clinical Electrophysiol 1989 12:962-976
Haines D. The Biophysics of Radiofrequency Catheter Ablation in the Heart. *PACE Vol 16, Part II, March 1993; 586-591*

Competing factors at work: thermal conduction



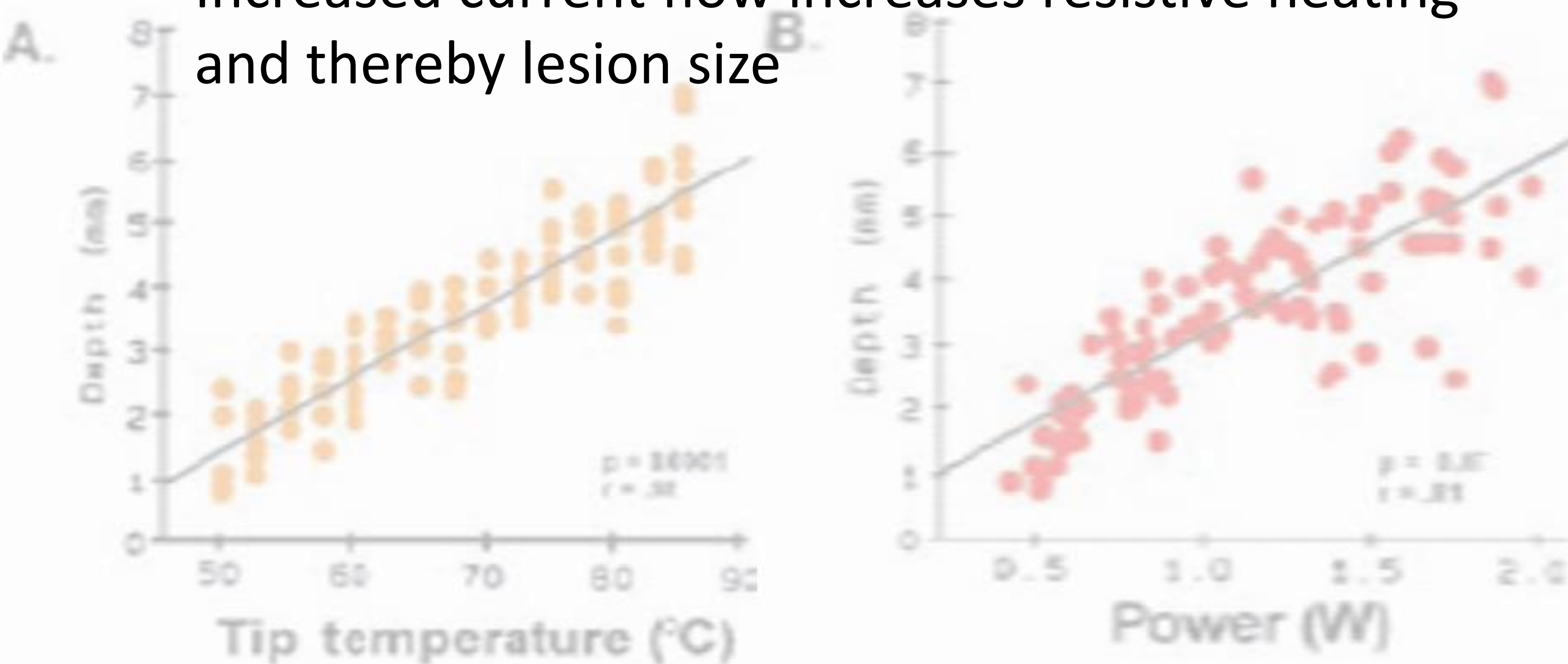
Haines, DE et. al. : Pacing Clinical Electrophysiol 1989 12:962-976
Haines D. The Biophysics of Radiofrequency Catheter Ablation in the Heart. *PACE Vol 16, Part II, March 1993; 586-591*
Strickberger SA, Hummel J, Gallagher M, et al." Effect of accessory pathway location on the efficiency of heating during RF catheter ablation. AM Heart J 129:54-58. 1995.

Competing factors at work: convective cooling



– Lesion size is proportional to the electrode-tissue interface temperature

– Increased current flow increases resistive heating and thereby lesion size



– Lesion size is also directly proportional to the radius of the heat source

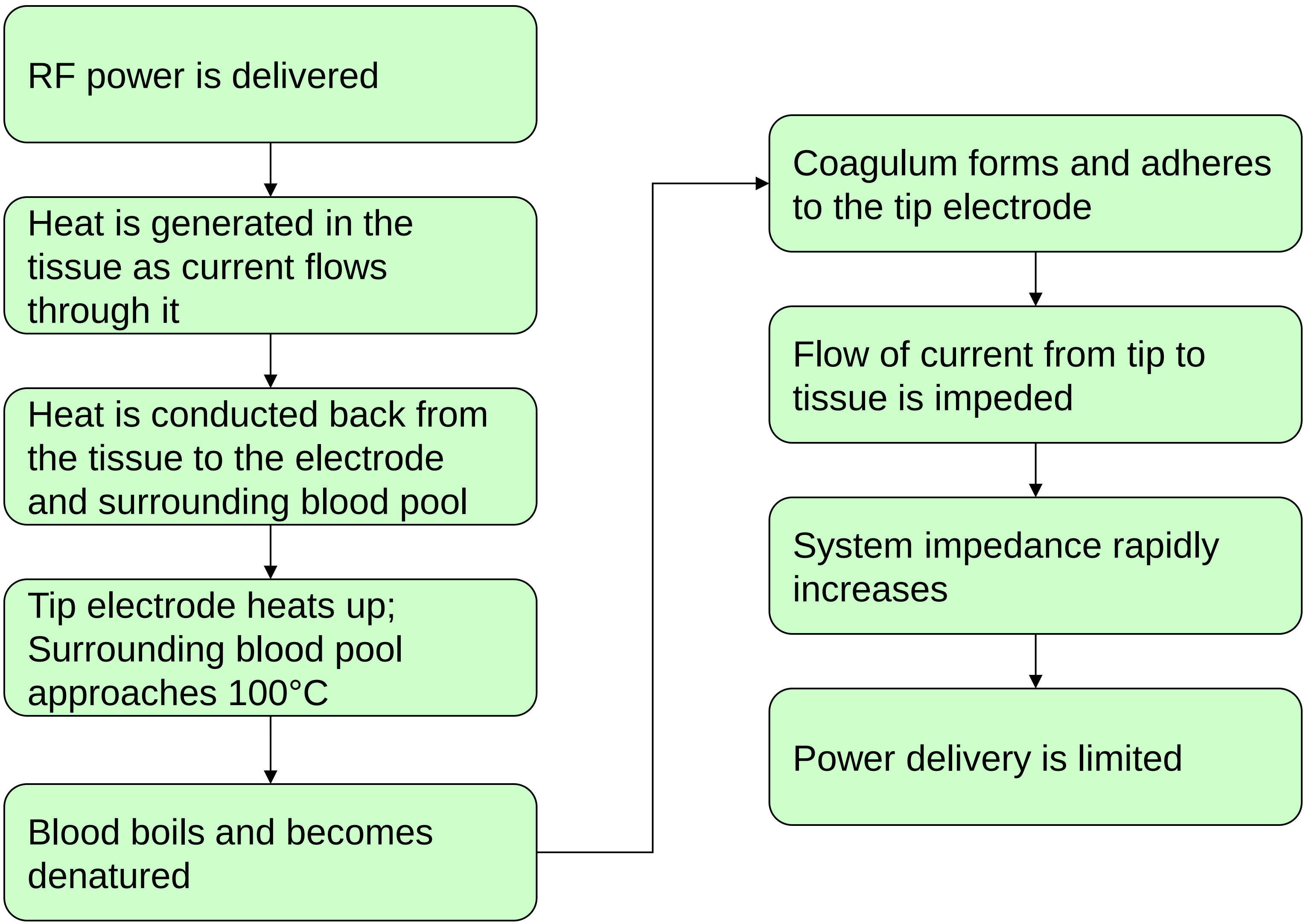
Safety

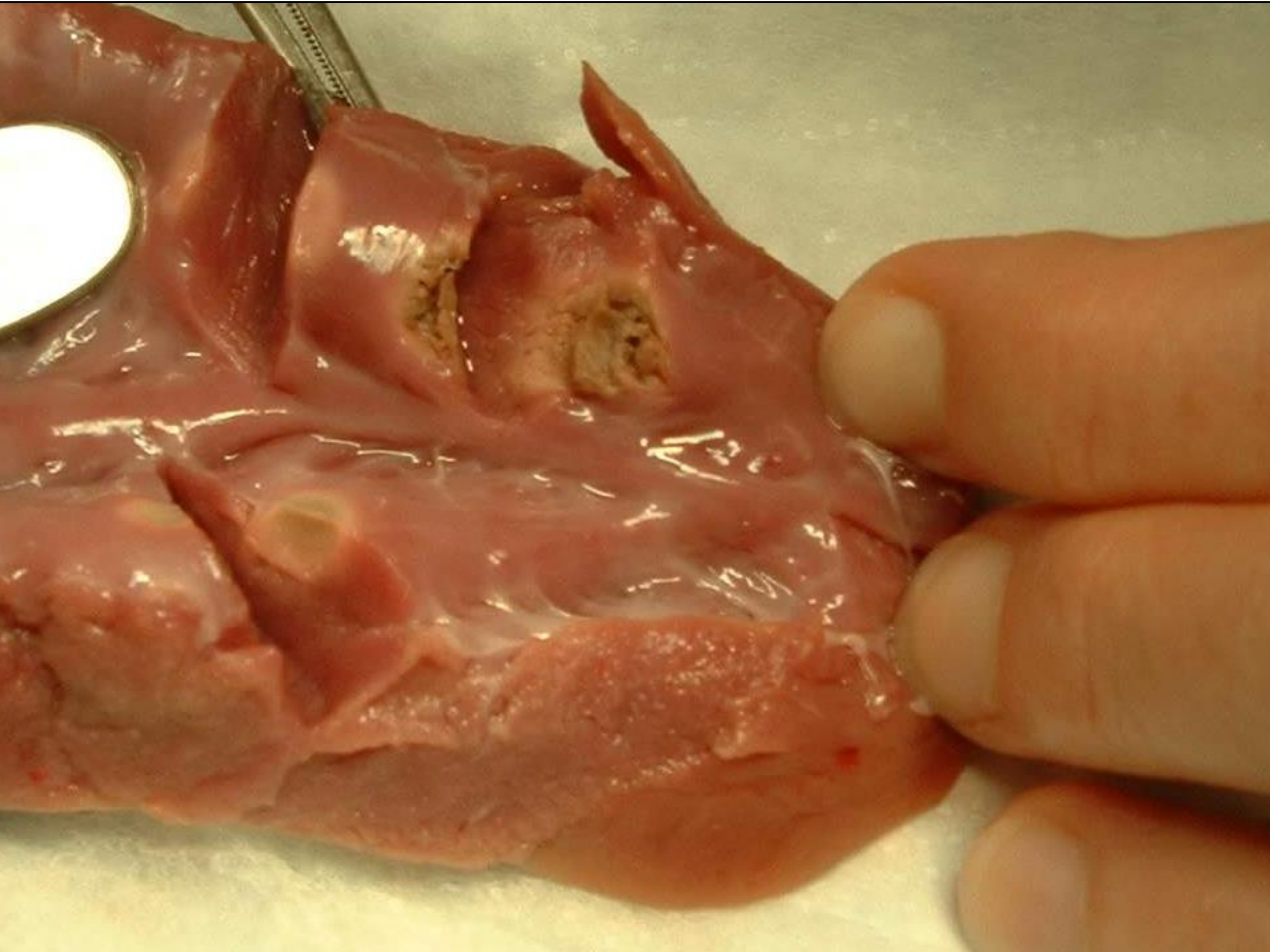
- Larger RF ablation lesions can increase the success of ablation

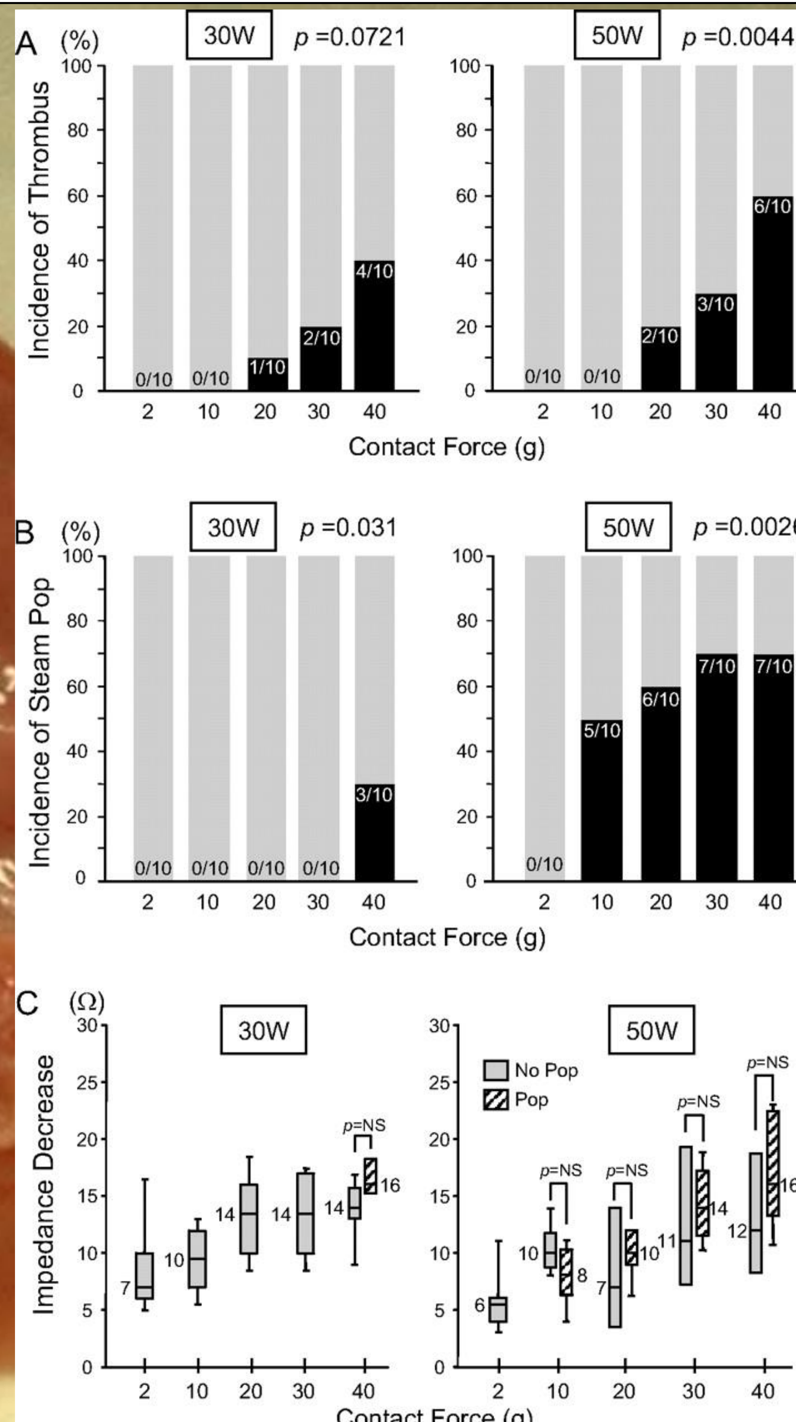
- BUT increase the risk of collateral tissue injury:

  – cardiac perforation and tamponade
  – oesophageal injury during PVI
  – phrenic nerve injury
  – acute coronary artery vasospasm
  – long term effects on the coronary lumen

Consequences of overheating tissue

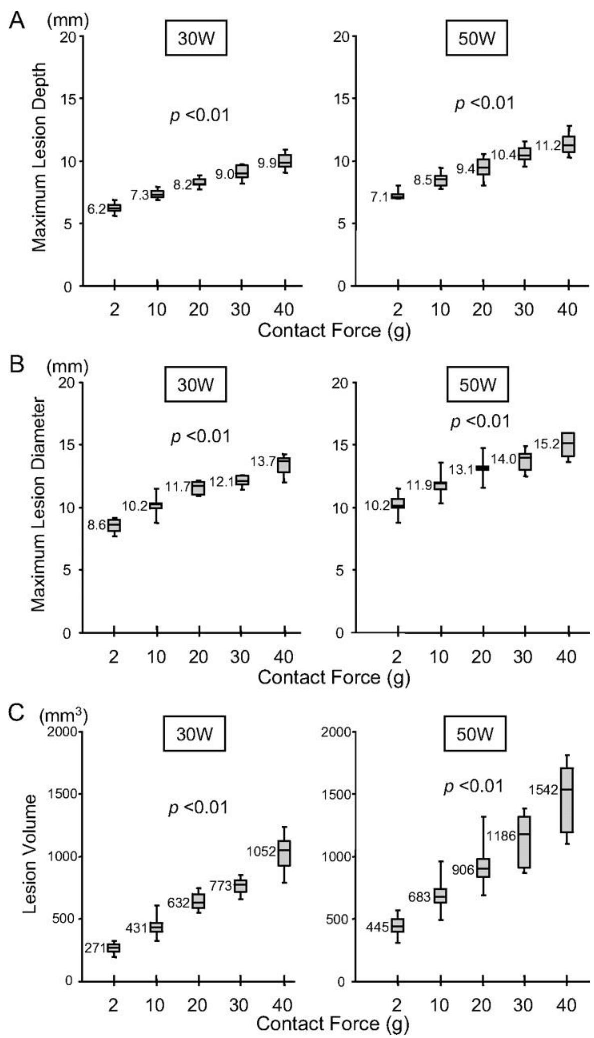






Yokoyama, K. et al. Circ Arrhythmia Eectrophysiol 2008;1:354-362

Graphs showing RF lesion size as a function of CONTACT FORCE



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Circulation: Arrhythmia and Electrophysiology

American Heart Association
Learn and Live

Impedance: baseline

- Greater contact = larger interface area = higher impedance
- Less contact = lower resistivity of blood = lower impedance
- Many factors such as body surface characteristics (e.g. chest), indifferent electrode position, and hemodynamic conditions, make the correlation between impedance and CF imperfect
- Impedance also varies at different sites in the heart
- Baseline impedance not a reliable indicator of RF lesion creation

Impedance: fall during RF

- Tissue heating results in reduced myocardial resistivity and a fall in tissue impedance

- Magnitude of impedance fall early after onset of ablation strongly correlates with:

  – lesion depth (R2 = 0.6845)
  – diameter (R2=0.66 45)
  – volume (R=0.7242)

(animal studies)

- Contact force influences the rate and duration of impedance decrease

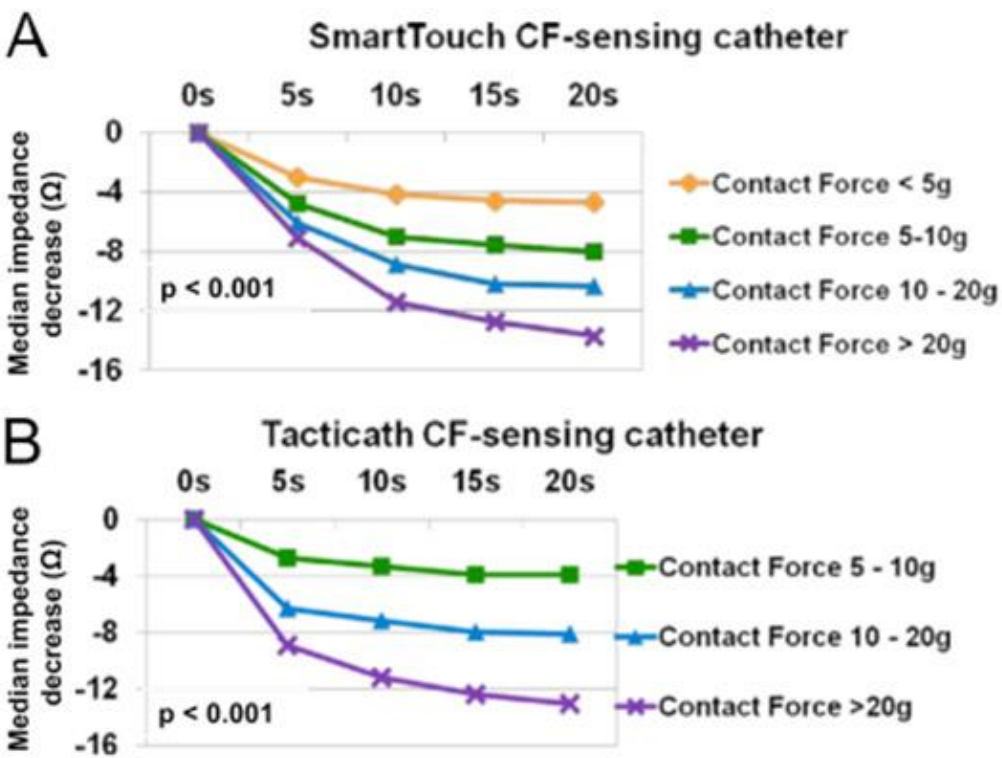
- Poor contact results in earlier plateau (≤13 seconds)

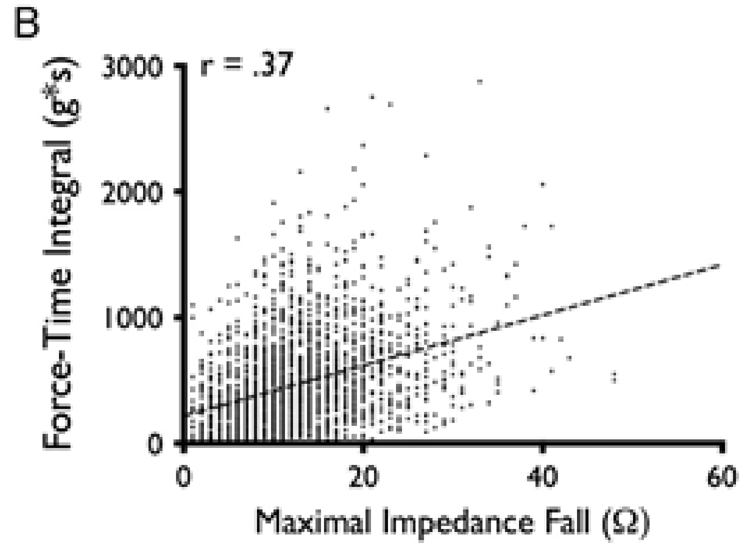
- Good contact results in continuous fall in impedance reaching a later plateau (eg 40 seconds)

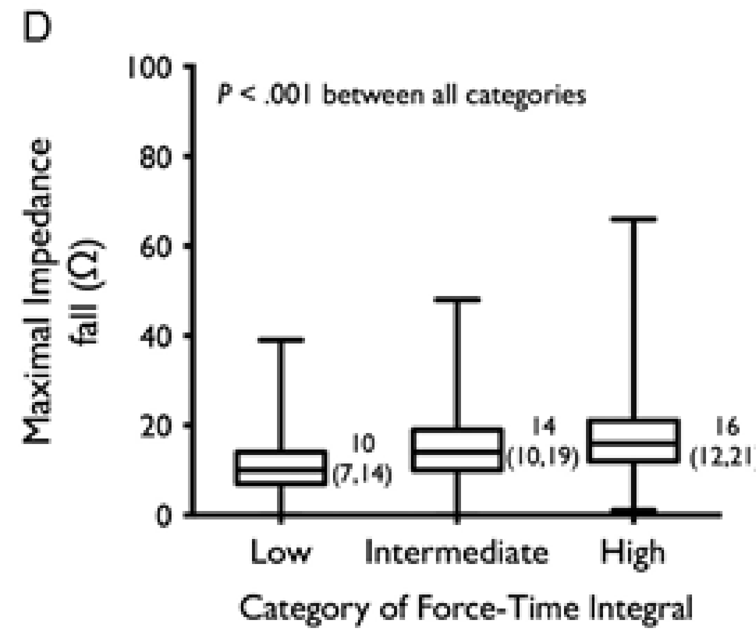
Correlation with CF (humans)

Modest linear relationship

Fall of 10 ohms at 10 secs = > 20g







Impedance: fall during RF

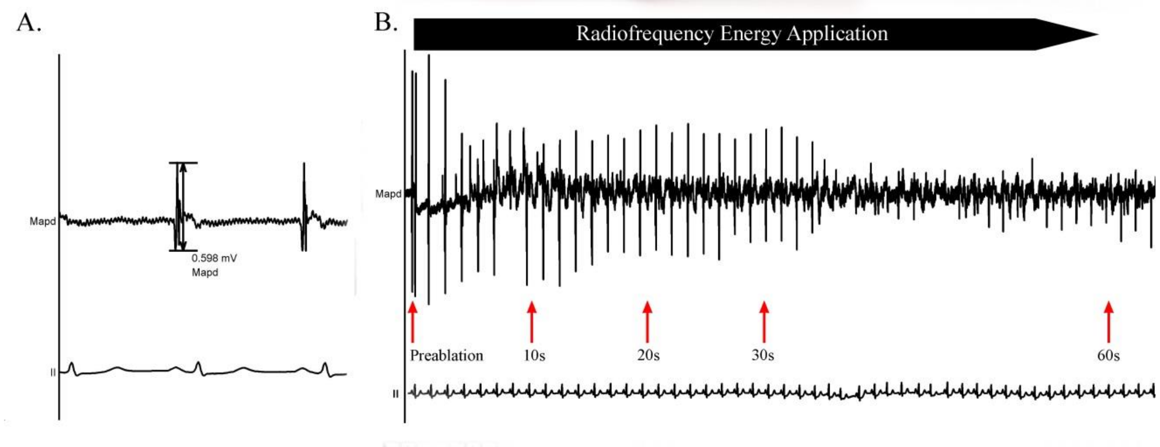
- Controversial whether impedance drop gives reliable information about lesion formation

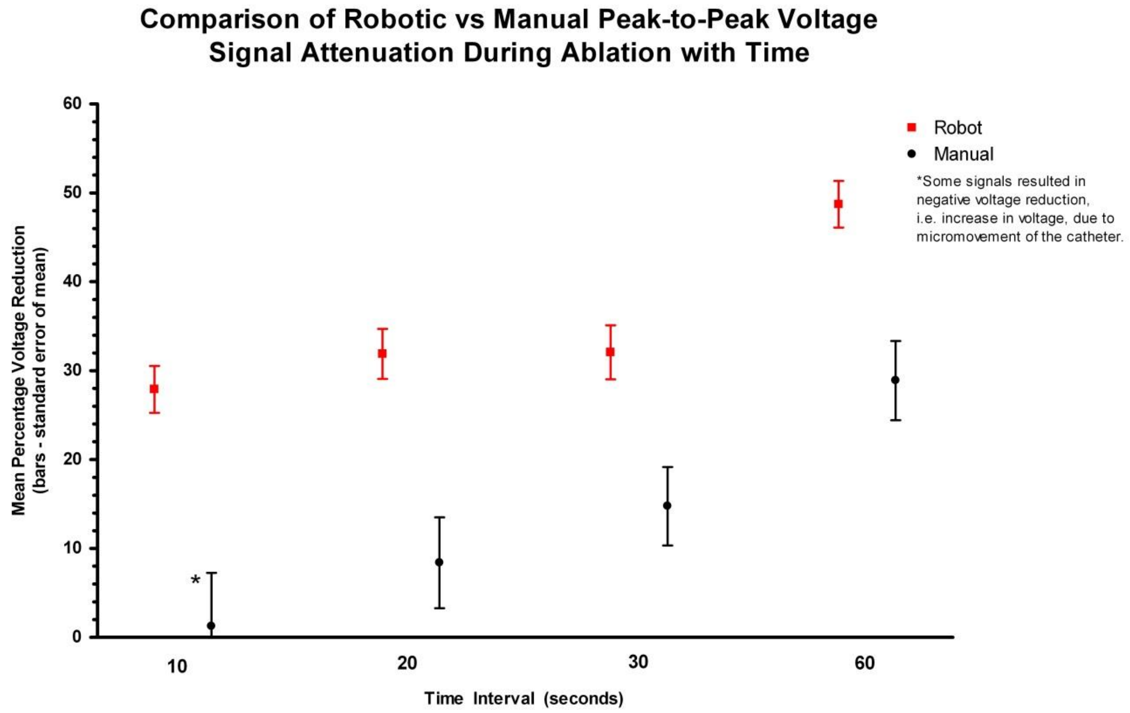
- There is no fixed value of impedance drop that reliably predicts transmural lesion formation

The electrogram (EGM)

- EGM changes have been described as a surrogate for lesion transmurality:
  - A reduction in EGM amplitude of >80% is thought to indicate a transmural lesion
- Changes in unipolar and bipolar EGM morphology post versus pre- ablation may also detect lesion transmurality

Comparison of robotic and manual signal attenuation





Koa-Wing, JCE 2009

Unipolar EGM: morphology

- Elimination of the negative deflection on the unipolar EGM identified a transmural lesion with 100% sensitivity and specificity (animal study)
- Continuing RF application until the creation of a completely positive unipolar signal was associated with improved AF-free survival compared to 30 seconds of RF at each site during PVI in one non-randomized study.

Electrical In-excitability

- The change in pacing threshold with ablation is greater than the decrease in EGM amplitude
- In the atrium, loss of bipolar capture predicts formation of a uniform transmural lesion
- Superior to EGM for detection of gaps
- In the ventricle, change in pacing threshold correlates with, and is a better marker of lesion size than change in EGM

Electrical In-excitability: AF ablation

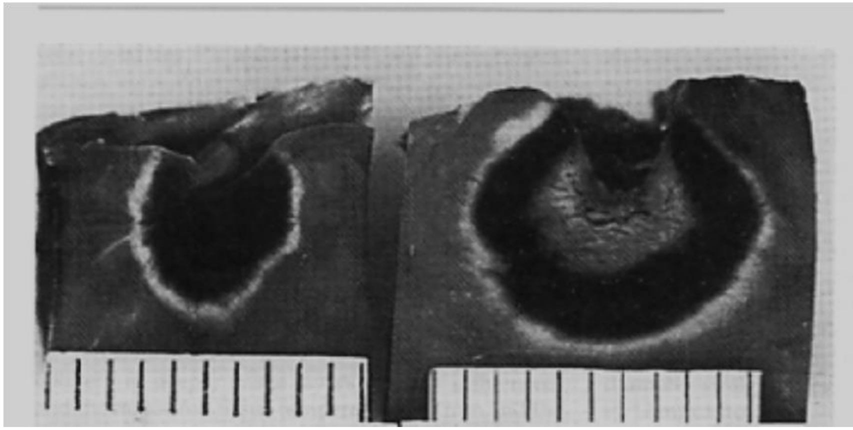
- In human studies, RF ablation with the endpoint of electrical in-excitability along a circumferential PVI line has been shown to enhance single procedure success

- It may also reduce acute PV reconnection rates and dormant conduction

Imaging

- Effects of heating by RF:
  - Cell membranes burst
  - Cells dehydrate
  - Denaturation of proteins
  - Coagulative necrosis

MRI
Endoscopic
Ultrasound



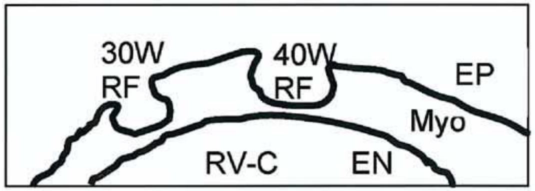
MRI

- Capable of:
  - delineating areas of permanent tissue damage
  - identifying gaps in atrial ablation lesion lines in animal studies

- Real-time MRI, and MRI thermography, are promising methods for intra-procedural assessment of lesion completeness

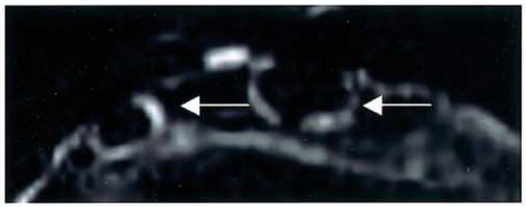
MRI

- Dynamic contrast enhanced (DCE) MRI
  - may be used to differentiate between 3 distinct tissue types in acute post RF ablation studies:
    - lesion core, edema, and normal myocardium.
- Gadolinium
- Delayed enhancement (DE-MRI)
- T2 weighted MRI

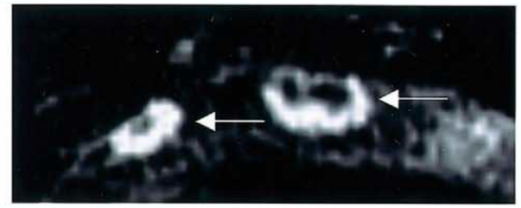


A Schematic of Anatomic Orientation in MR Images

B Phase 1: Contrast Void (1min)



C Phase 2: Peripheral Enhancement I (15min)



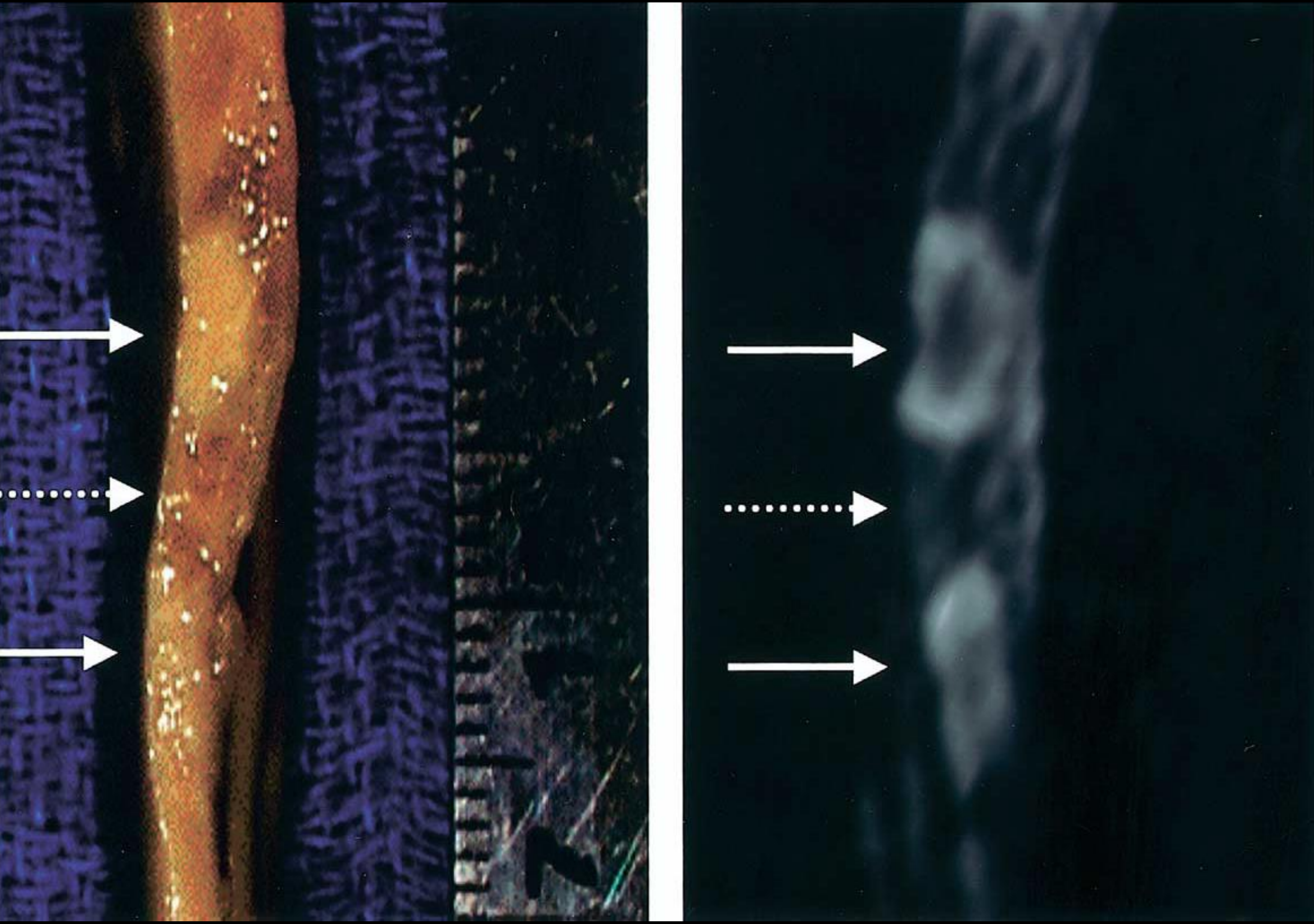
D Phase 2: Peripheral Enhancement II (45min)

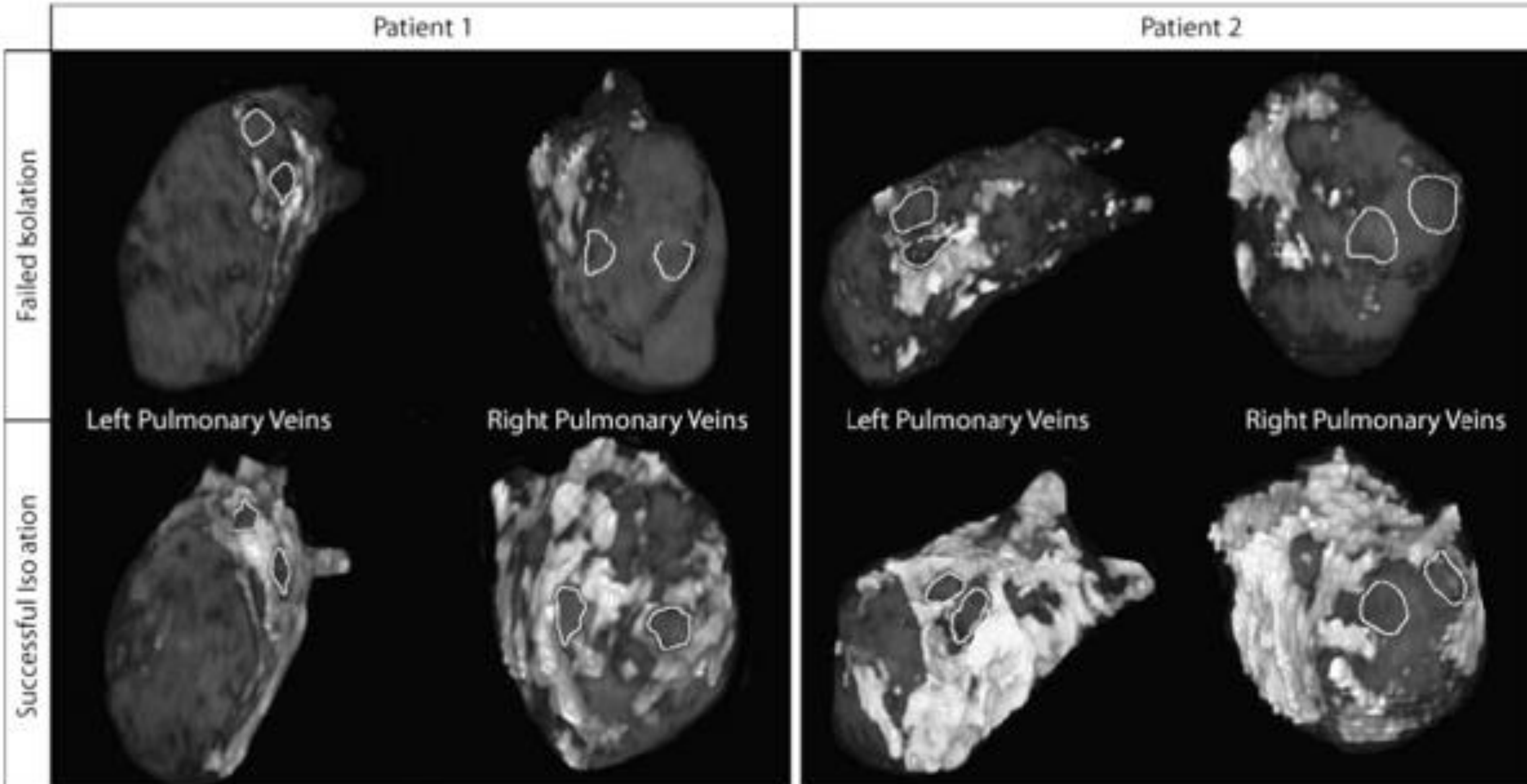
E Phase 3: 'Very' Delayed Enhancement (85min)

F Phase 4: Loss of Enhancement (600min)

G Pathological Specimen

Dickfield et al JACC 2006





TJ Badger et al Circulation. 2008;118:S_832

Endoscopic Catheter Visualization

- A novel endoscopic catheter (Voyage IRIS) is capable of direct endocardial visualization (animal model)

- Visualize and quantify differences in tissue characteristics
  - normal myocardium, border zone, and dense scar

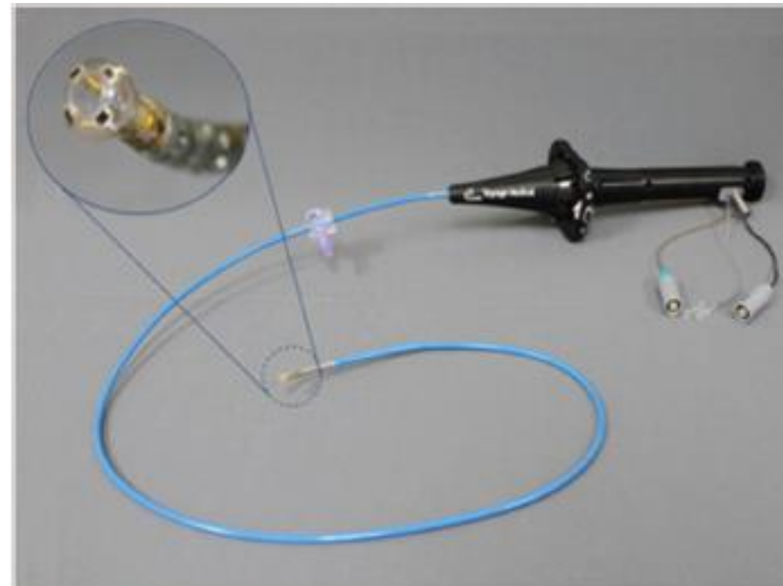
- Integration of direct visualization with current mapping techniques may enable visually guided ablation of heterogeneous scar capable of supporting VT

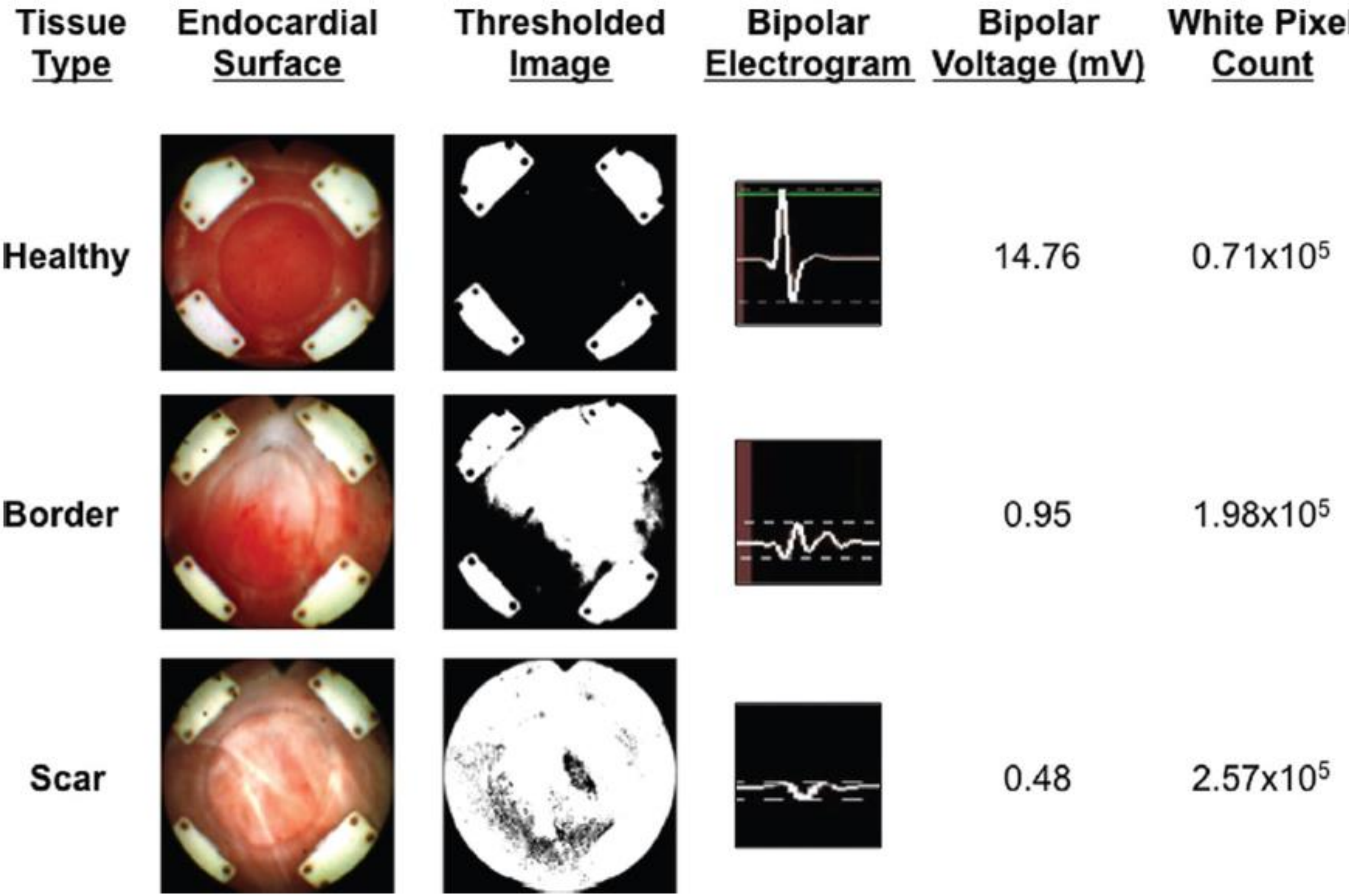
Betensky et al *Circulation*. 2012;126:2065-2072.)

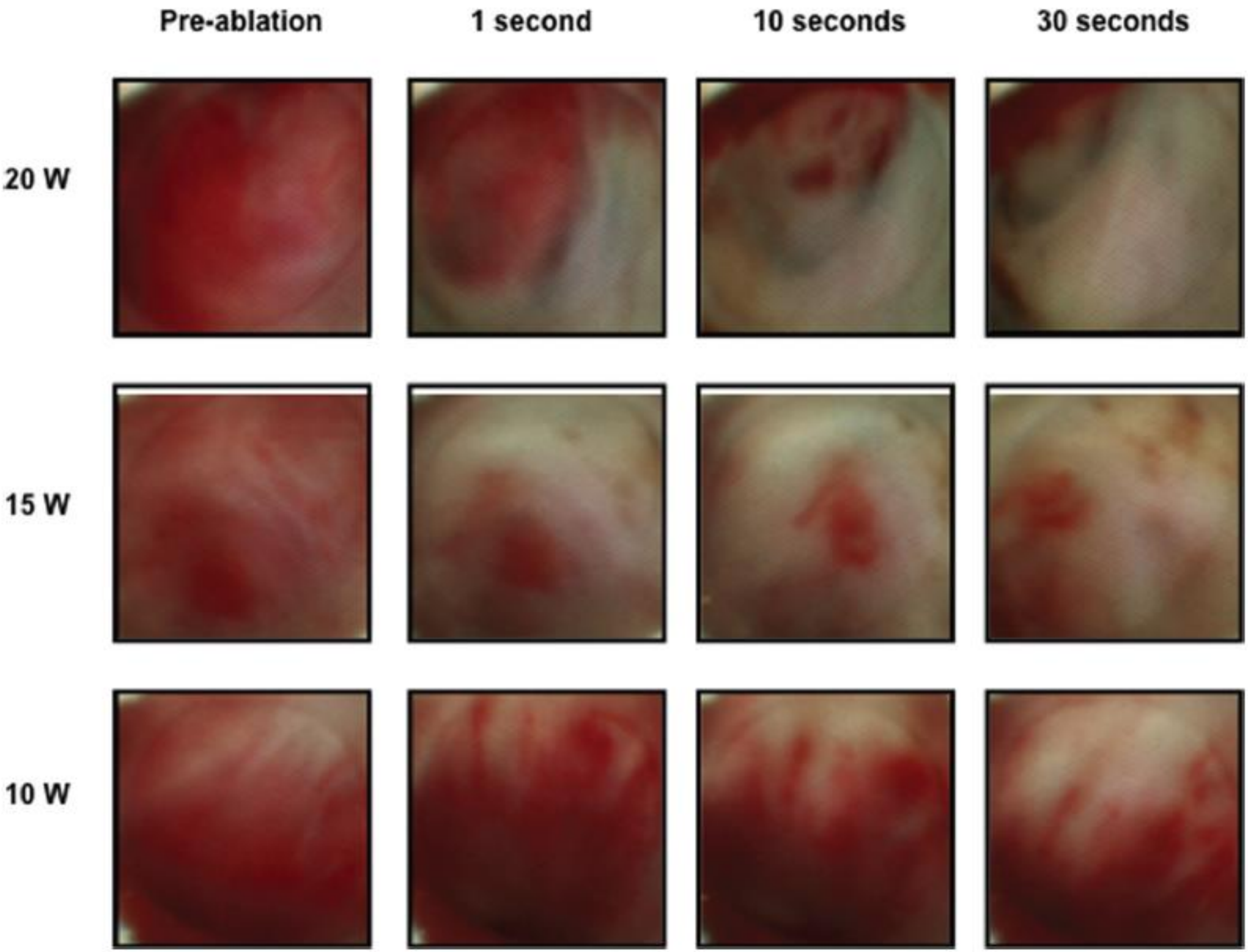
The IRIS catheter is designed for visualization of anatomic structures within the heart, cardiac mapping, and delivery of RF energy

Allow direct visualization of:

- tissue characteristics (for example dense scar versus border zone in infarcted ventricles)
- monitor catheter location and stability, lesion development and lesion contiguity




Tissue Type
Endocardial Surface
Thresholded Image
Bipolar Electrogram
Bipolar Voltage (mV)
White Pixel Count
Healthy
14.76
0.71x10^5
Border
0.95
1.98x10^5
Scar
0.48
2.57x10^5

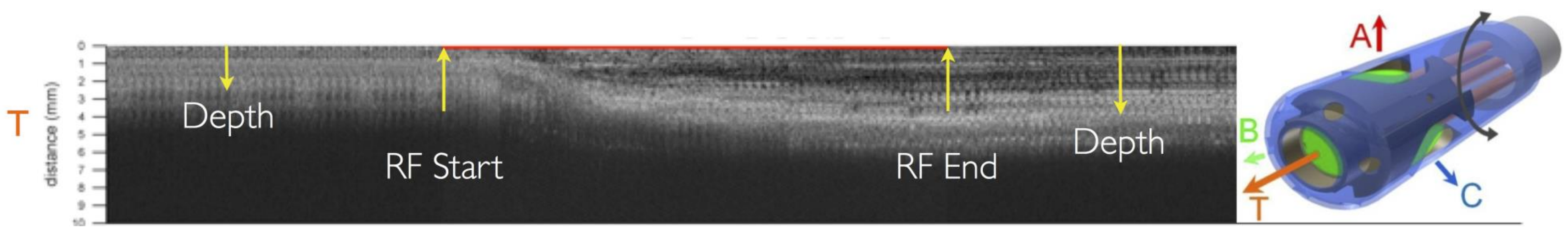

Pre-ablation
1 second
10 seconds
30 seconds
20 W
15 W
10 W

- In an animal model, visually-guided RF ablation in the ventricle resulted in more reliable lesion creation as assessed on histopathology compared with standard open irrigated catheter guided by “traditional” markers of contact

ULTRASOUND
Acoustic radiation force impulse (ARFI) imaging

- Utrasound-based technique
  - quantification of tissue stiffness based on mechanical displacement of tissue in response to ultrasonic impulses
  - monitors tissue response using conventional ultrasound
  - can be utilized with intra-cardiac echo
  - can visualise the relative elasticity difference between ablated and unablated myocardium
  - accurately assess focal RFA lesion morphology in vitro

RF ablation catheter with 4 ultrasound (US) transducers embedded in the ablation tip.



Conclusions

- Progress has been made

- Further work is needed on intra-procedural methods of identifying lesion completeness that reliably predict arrhythmia-free survival in long term follow up