Role of non-invasive imaging in transcatheter ablation of arrhythmias in CHD

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No conflicts of interests to disclose

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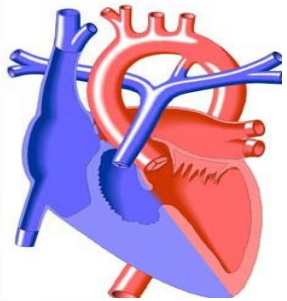
Outline

- Understand the unique issues in patients with CHD
- Understand the cause and impact of arrhythmias in CHD patients
- Understand the evolution of technology in electrophysiology

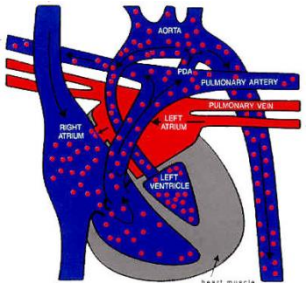
Anatomy in CHD patients

- Variable anatomy:
  - Heterotaxy syndromes (atrial isomerisms)
  - Atrio-ventricular and/or ventriculo-arterial discordance
  - Ventricular anatomy: 2 ventricles, single ventricle

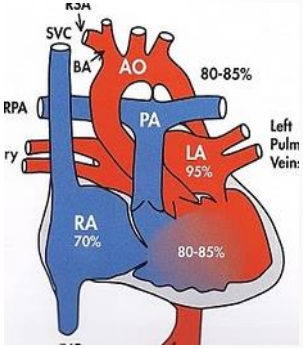
Variants of single ventricle



AV valve atresia:
Tricuspid atresia, single LV
Mitral atresia, single RV



Aortic atresia:
HLHS

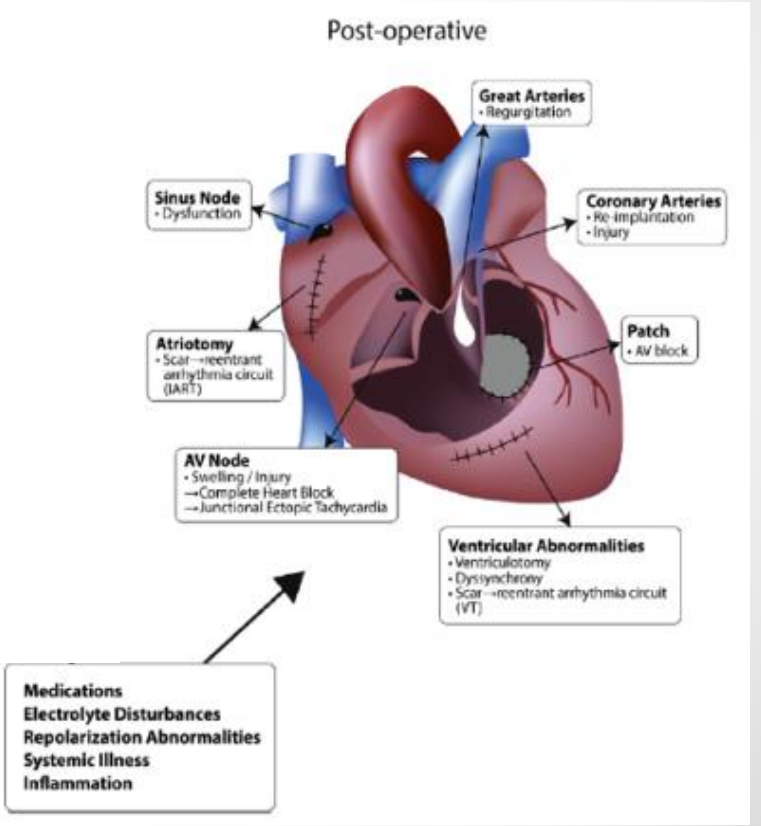


Double inlet left ventricle
Heterotaxy syndrome

  - Abnormal AV node position; twin AV nodes
  - Accessory connections

Arrhythmias in CHD

- Consequence of corrective surgery:
  - SAN/ AVN injury
  - Fibrosis: Surgical incisions and patch material
  - Regions of slow conduction within existing anatomical isthmuses
    - chronic cyanosis
    - pressure +/- volume overload
    - ageing
    - pathological hypertrophy



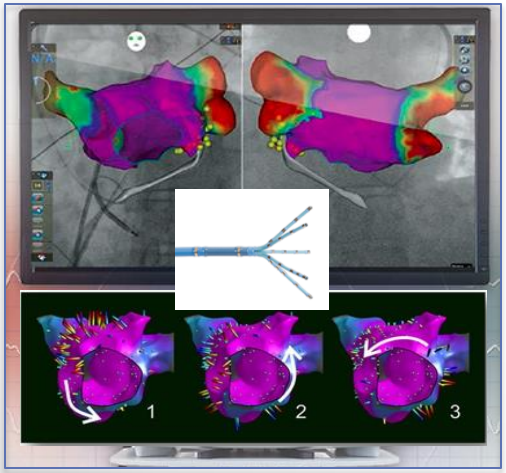
Bouchardy J et al *Circ* 2009
Brouwer C et al *Arrhythm Electrophysiol Rev* 2016
Khairy P et al. *Heart Rhythm* 2014

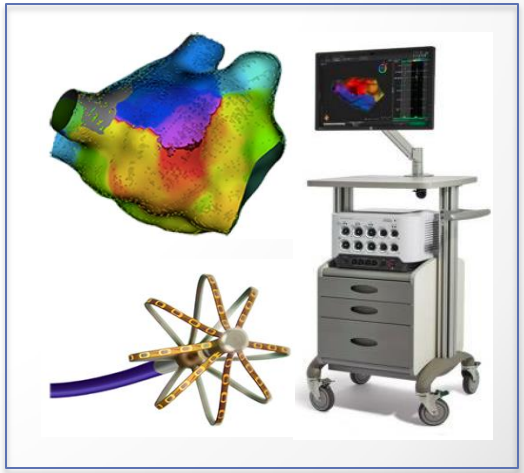
Arrhythmias in (A)CHD

- Many CHD patients eventually develop arrhythmias
- Morbidity & Mortality:
  - 50% increase in mortality
  - 2x risk of stroke/ CHF
  - 3x risk of cardiac interventions
- Catheter ablation has relatively good acute success rates, reaching 60-80% even in single ventricle patients

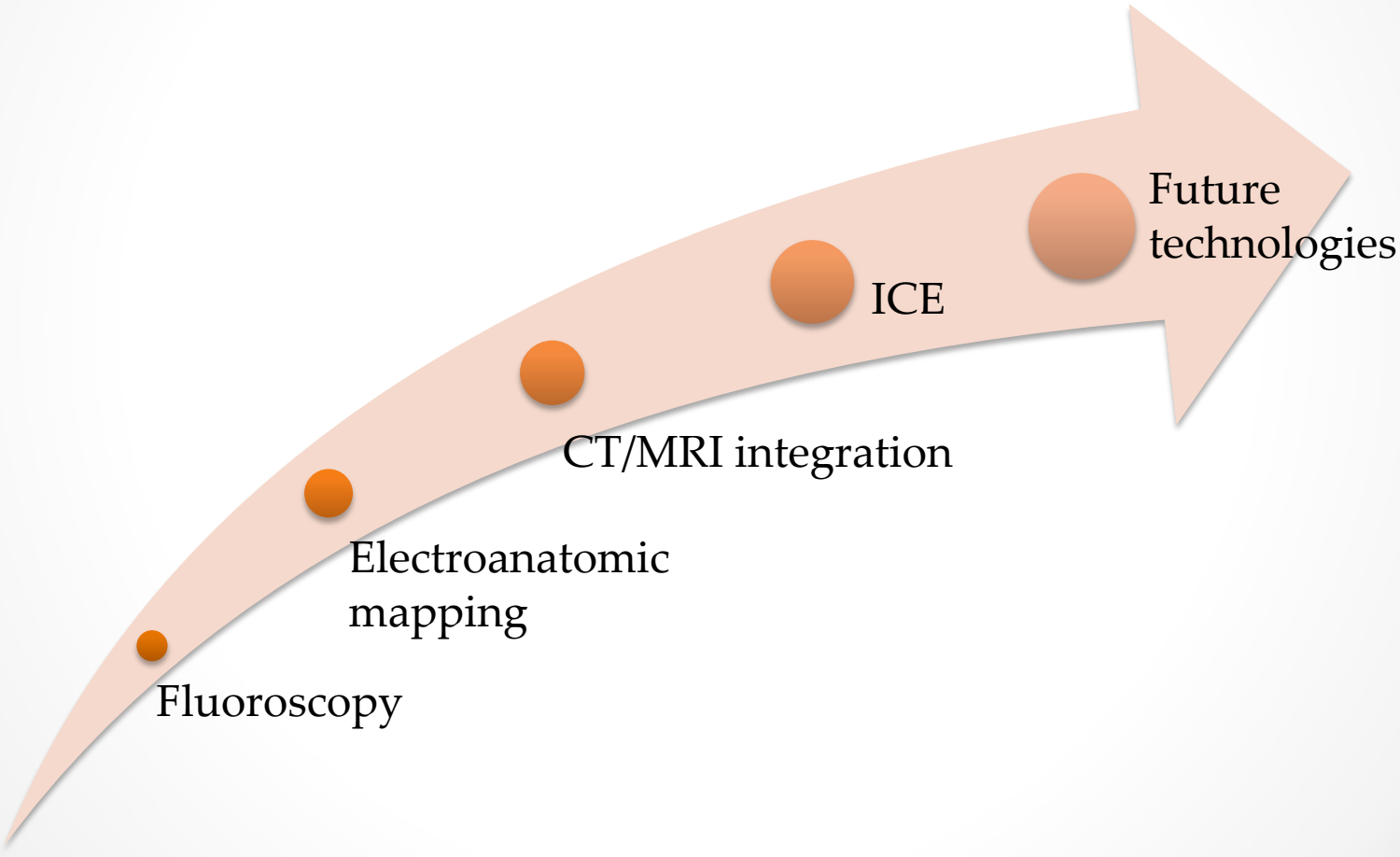
Ablation in (A)CHD

- Plan ablation procedure:
  - Review operative reports
  - Vascular access, access to pulmonary venous atrium
  - Location of AV node
  - Obtain CT/MRI in pts with complex anatomy pre-procedure
  - Activation and voltage mapping
    - use of 3D contact and non-contact mapping systems
    - MRI/ CT image integration
  - Catheters: irrigated tip, contact force, cryoablation





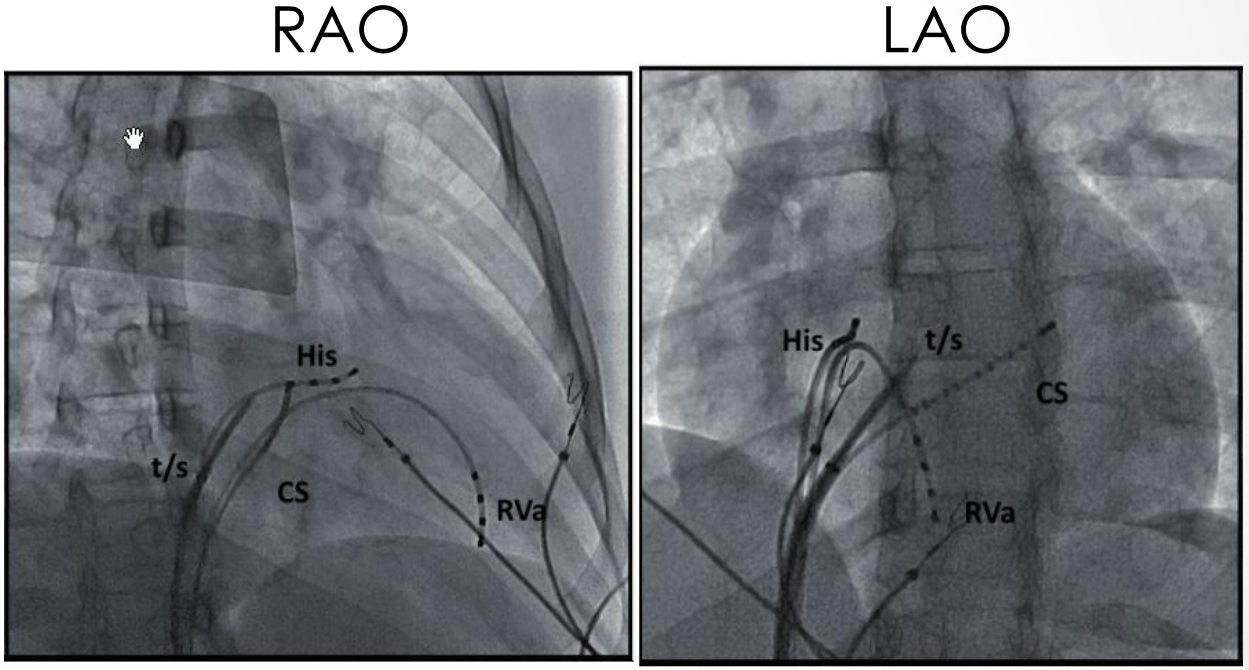
From past to future in EP



Electrophysiology procedures

- Catheters are traditionally placed under fluoroscopy:

His = AVN
CS = coronary sinus
RVa = RV catheter
t/s = transseptal sheath



- Allows electrophysiologists to "view" the heart in 2 orthogonal planes, hence in "3D"

4yo with HLHS (MA/AA)

- S/p Norwood procedure with DKS and BT shunt, s/p bilateral bidirectional Glenn
- WPW syndrome with frequent SVT in newborn period, with occasional recurrence
- Sinus bradycardia limited dose of beta-blocker
- Wt. 15 kg

- LFV thrombosis noted at pre-Fontan cath/EP study
- Access:
  - RIJ, RFV, RFA
  - Transesophageal pacing catheter

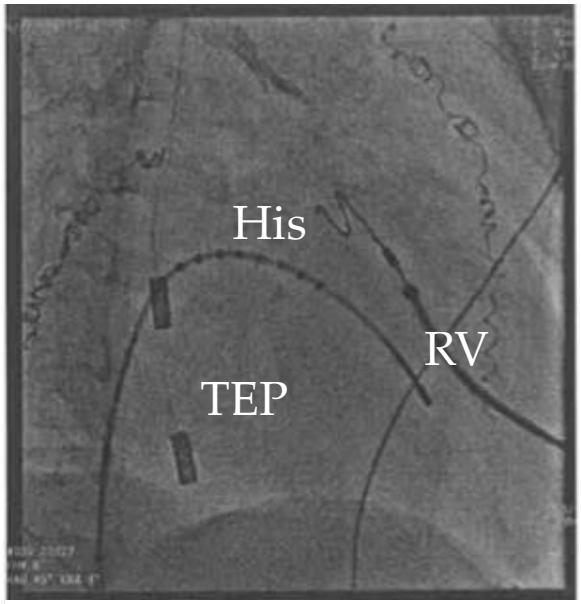
XR

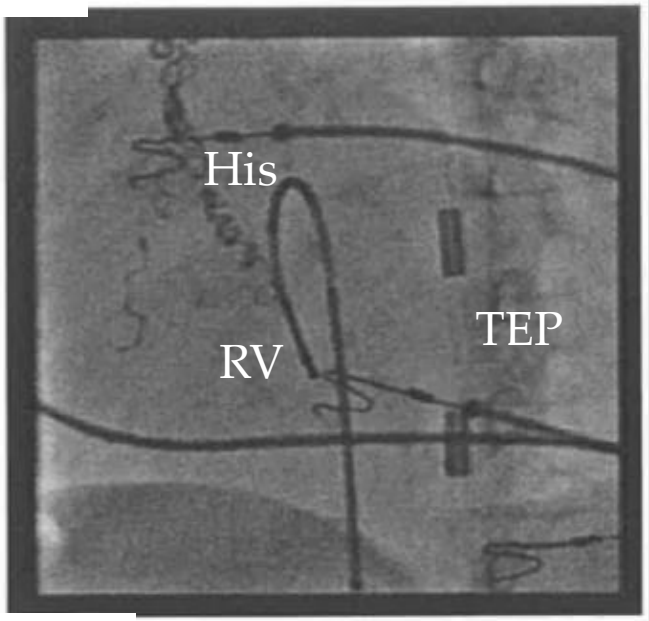
- Bidirecitonal Glenn, so SVC connects to the PAs

With only RFV access:

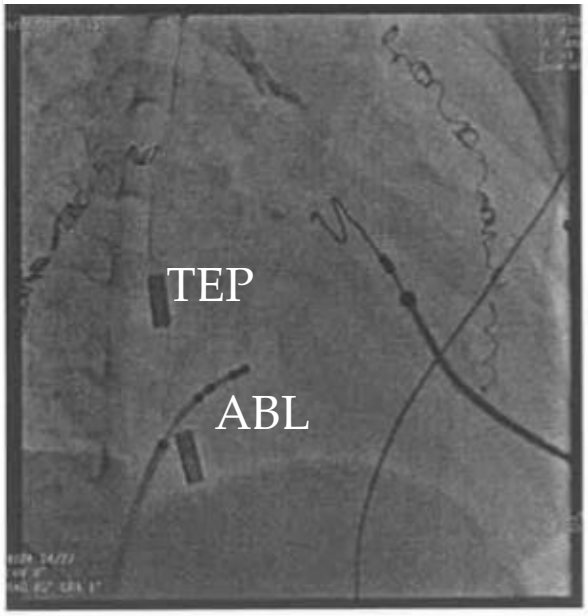
- His-RV catheter to obtain AVN recording and pace/ record RV
- TEP to record and pace LA

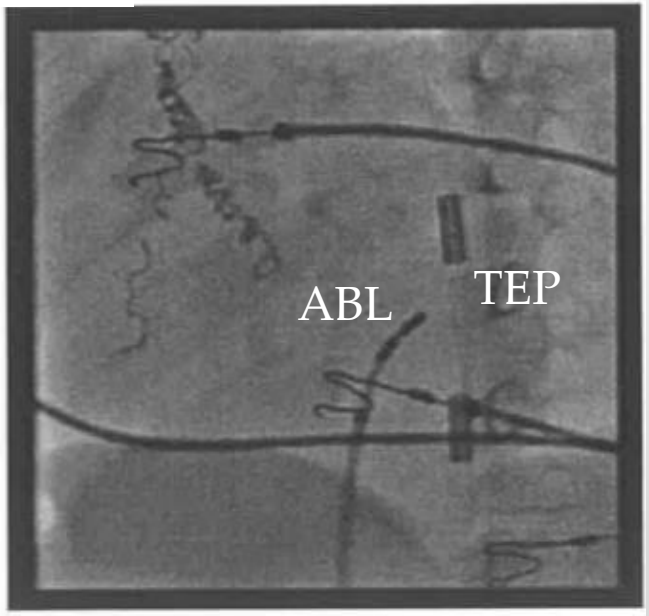
RAO and LAO of HIS position





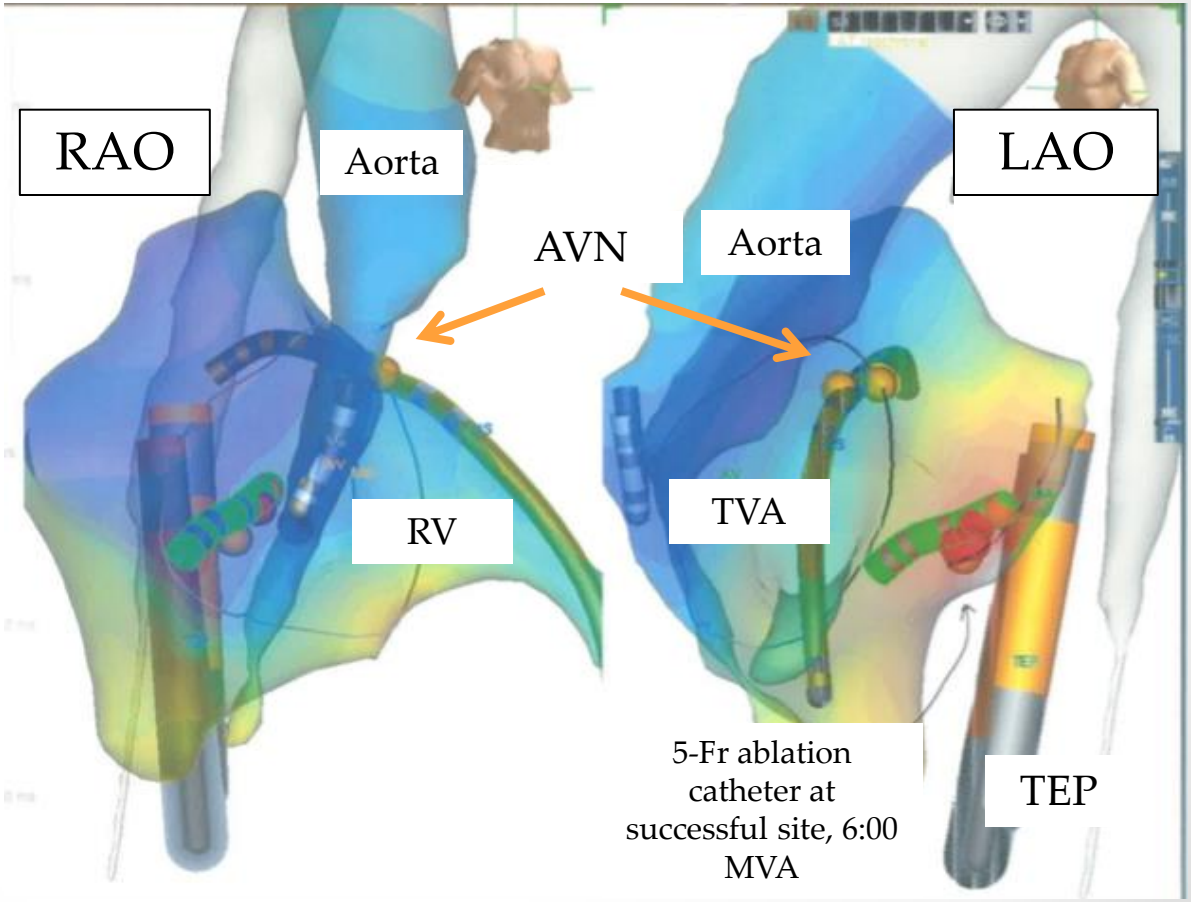
RAO and LAO of ablation site



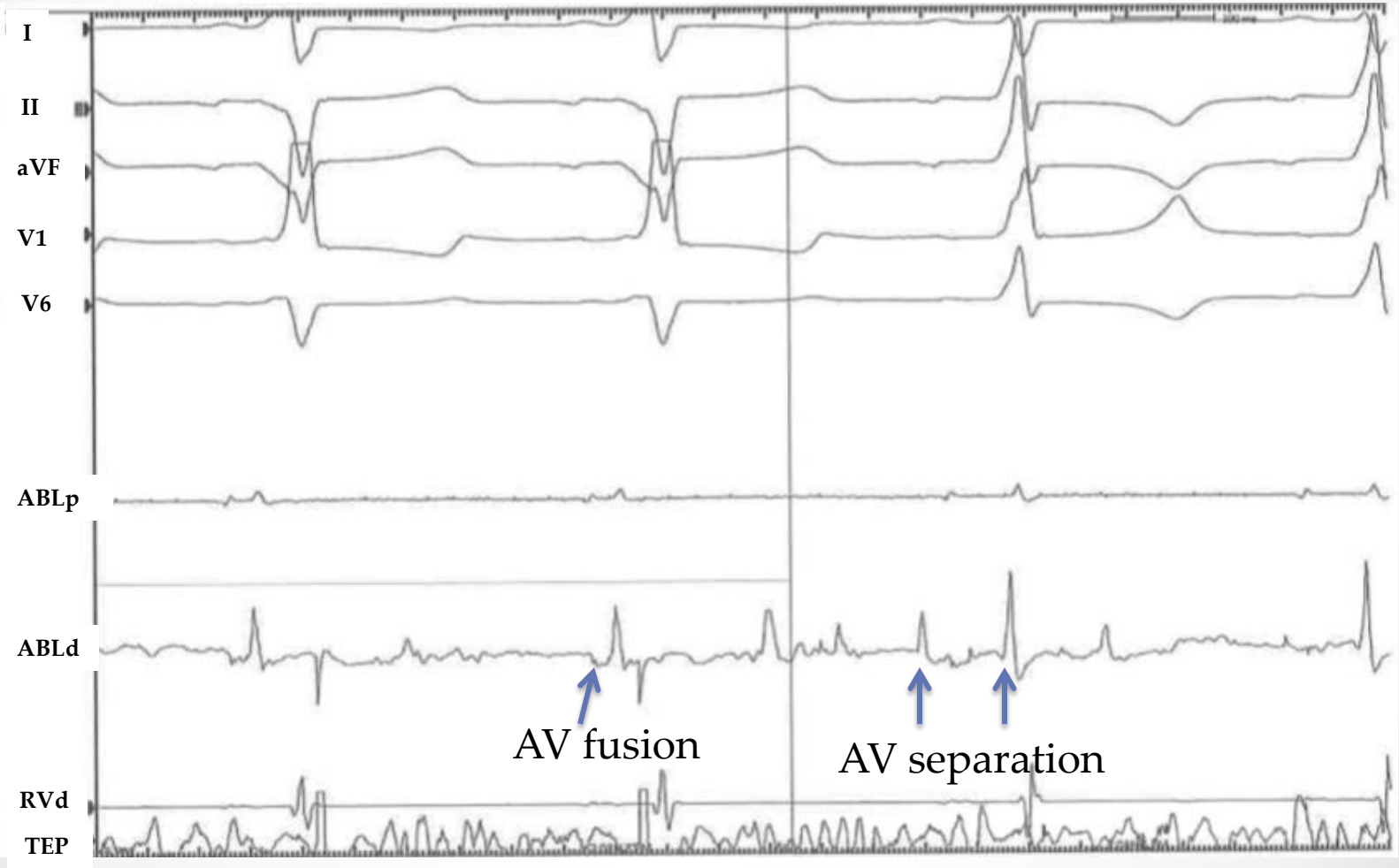


Using electroanatomic mapping

- Mark location of AVN and TV
- Fluoro time: <3 mins
- Successful ablation with the 1st lesion

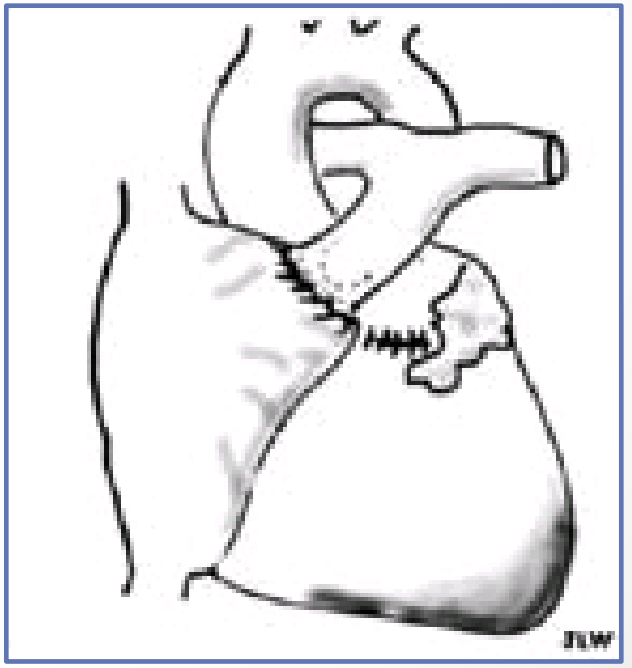


Loss of AC in RF#1



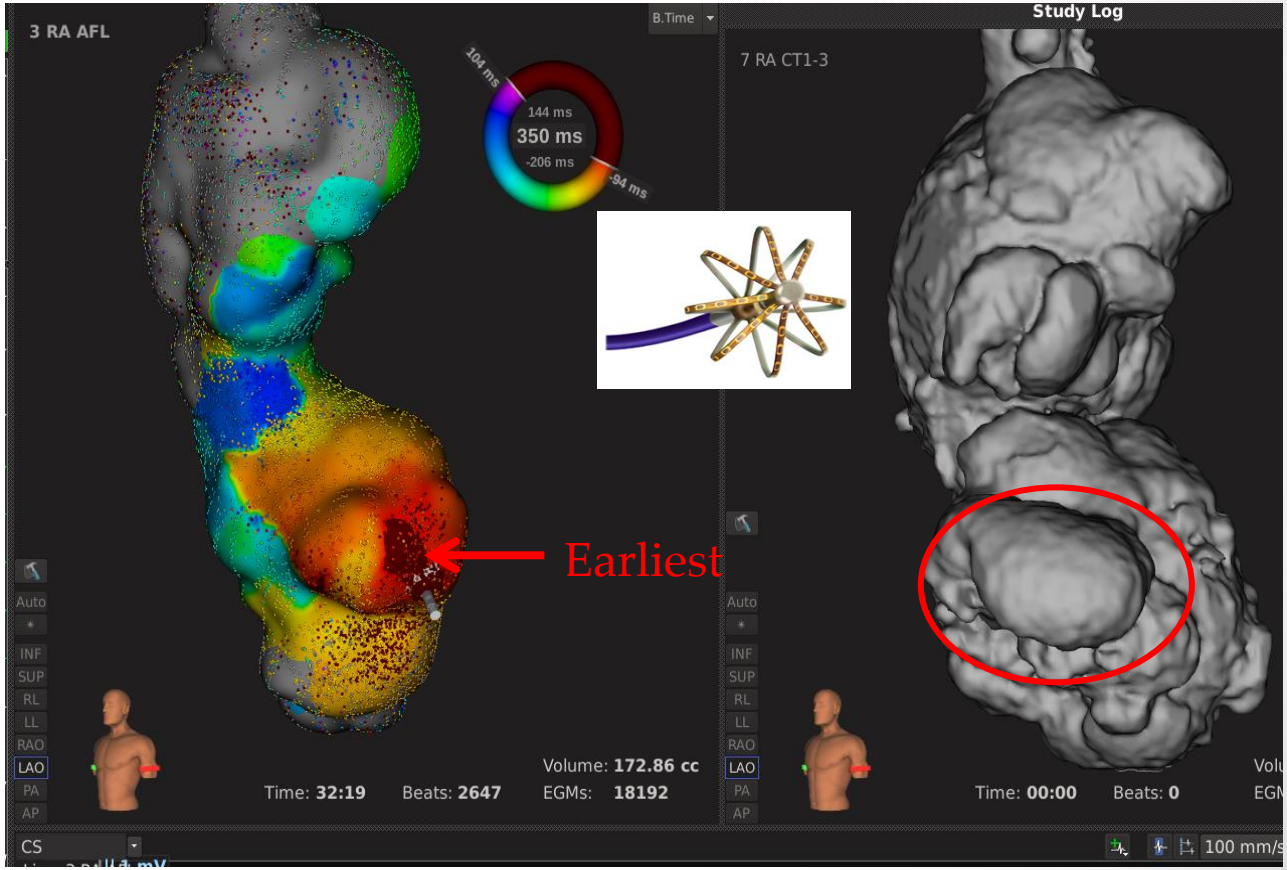
36yo with single ventricle

- Double inlet RV, hypoplastic LV, VSD, VA discordance, s/p atriopulmonary Fontan
- Recurrent atrial tachycardia despite medications
- Preserved hemodynamics



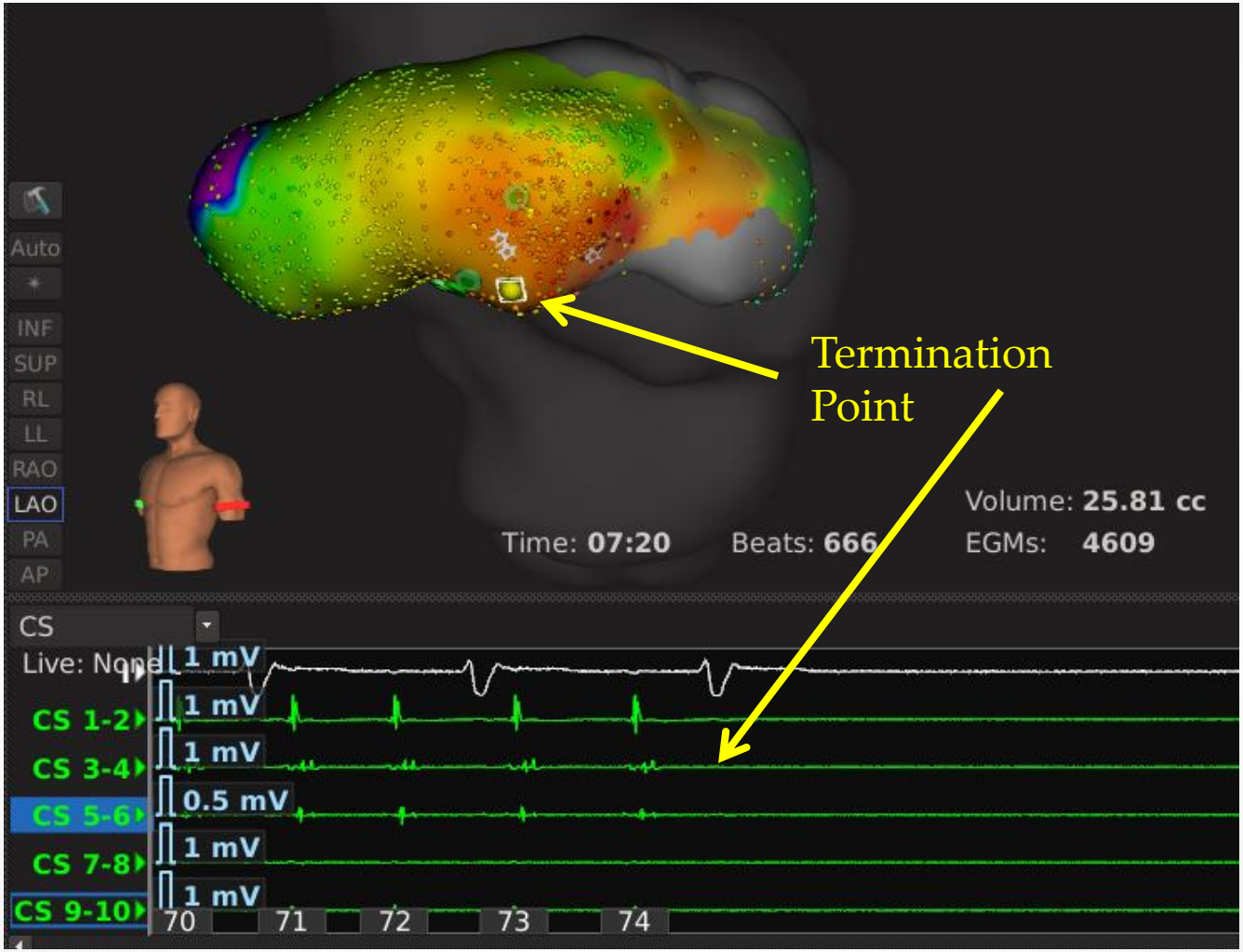
Pre-procedure CT

- Initial mapping with Orion basket missed the pouch
- After CT fusion, the missing pouch was mapped
- Earliest activation was in the pouch



Courtesy of HF Tse/ SY Kwok, QMH

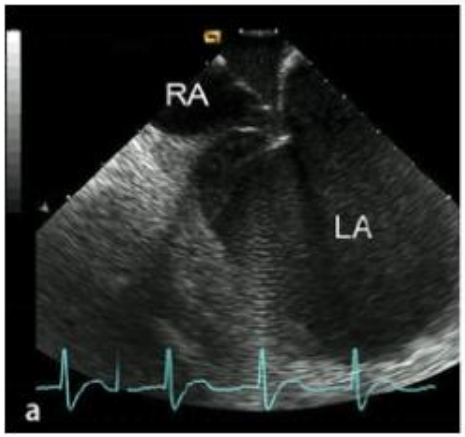
Termination of AT



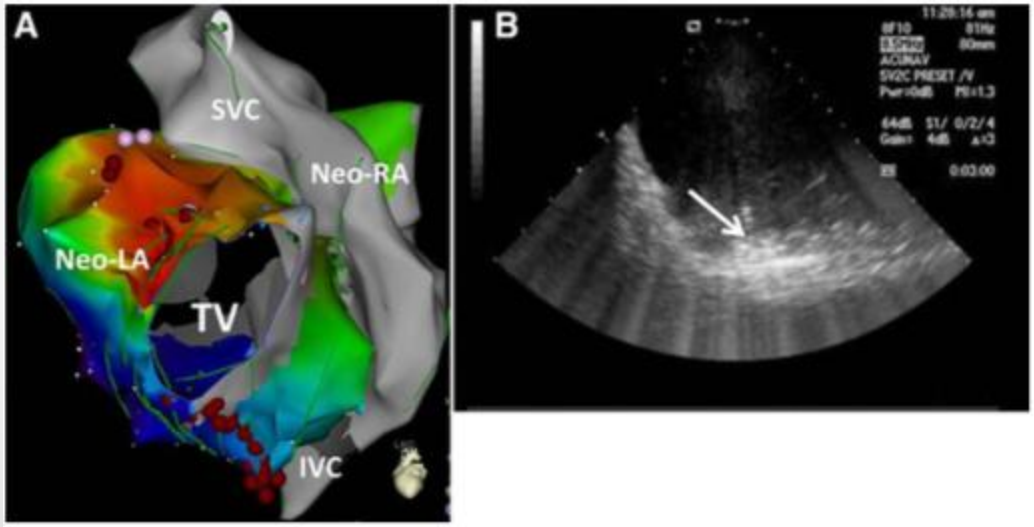
- Courtesy of HF Tse/ SY Kwok, QMH

Intracardiac ECHO (ICE)

- To aid transseptal puncture:
  - ↓ use of XR, ↑ safety
  - BUT – may not be feasible in smaller children



- To improve catheter contact in big chambers



Mustard patient

A. Anatomic shell based on echo images with neo-LA details
B. Direct visualization of ablation catheter tip during RF verifying tissue contact

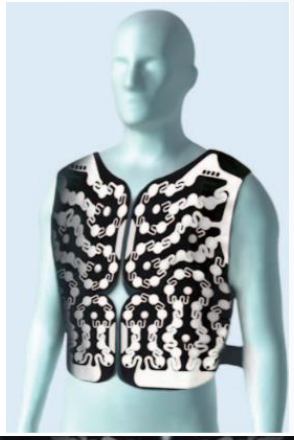
Sherwin EA et al *CircAE* 2013

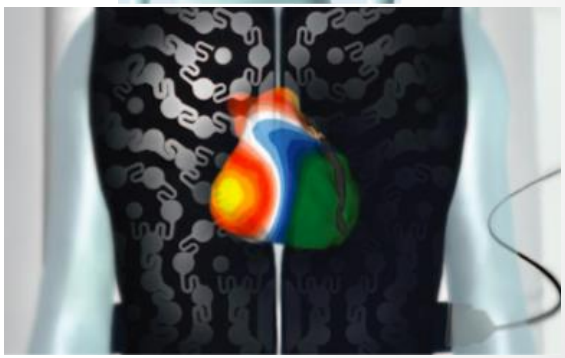
Future advances

- ECVue
- Personalized virtual-heart technology
- Real-time MRI guided mapping
- Optogenetics

ECVue – in AF

- CardioInsight vest contains 252 electrodes
- Perform cardiac CT or MRI
- Combine them to map spatiotemporal electrical patterns during AF
  - high resolution
  - patient specific
  - 3D biatrial geometry
- AFACART study:
  - 118 persistent AF pts in 8 European centers
  - ECVue driver-only ablation -> 64% AF termination
  - With additional ablation -> 72% total AF termination rate
  - At 1-year FU, 78% pts off AADs and 88% free from AF recurrence





Konrad T et al. *Herzschr Elektrophys* 2014
Knecht S et al. *Europace* 2017

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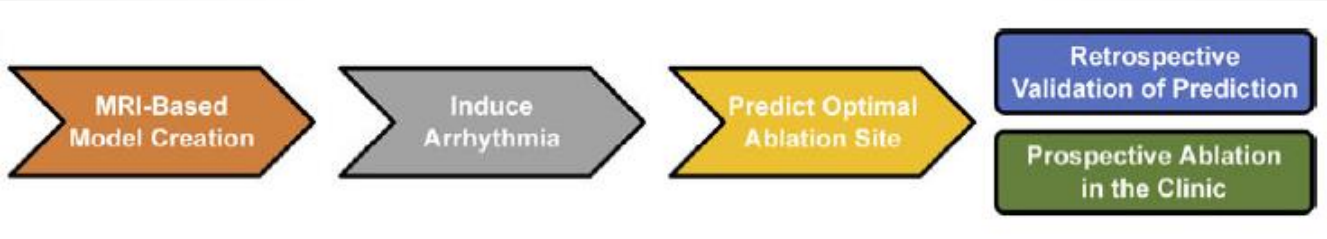
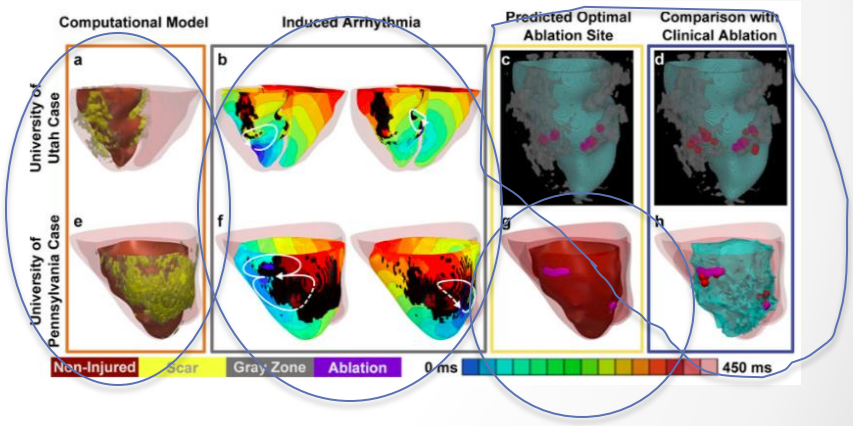
Virtual heart technology



- Use LGE-MRI images to create an individualized geometric virtual model of ventricles
- Perform virtual multi-site ventricular pacing to induce VT
- Use VAAT to predict minimum-sized "optimal" ablation lesions. Repeat VT stimulation protocol
- Incorporate into EAM



Prakosa A et al, *Nat Biomed Eng* 2018

Future advances

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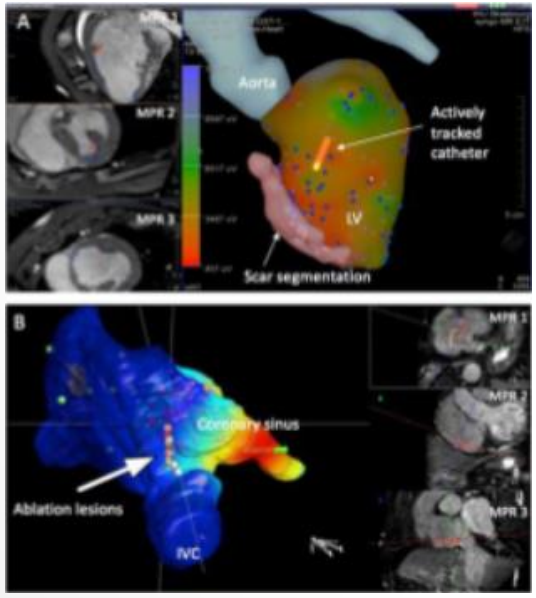
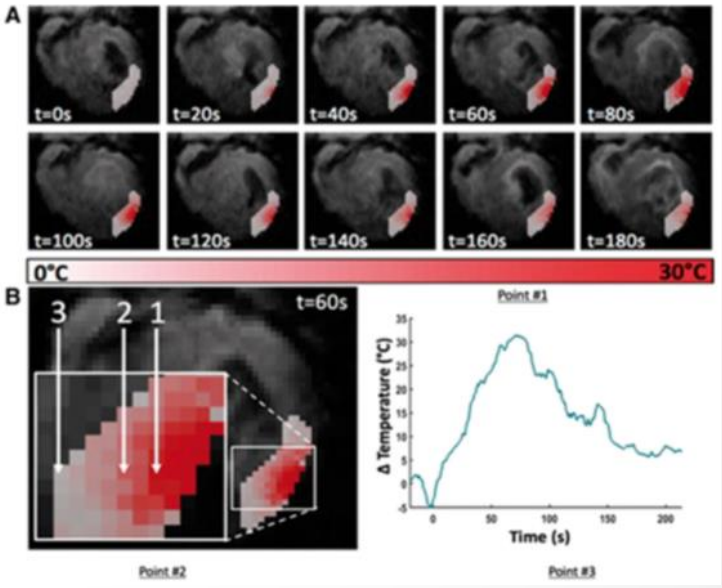
Real-time MRI guided EP

Pros
Real-time 3D substrate assessment
Accurate intra-procedural guidance in combination with EAM system
Evaluation of ablation effectiveness: - Acute tissue edema with T2 imaging - Assess lesion necrosis with LGE - MR thermometry

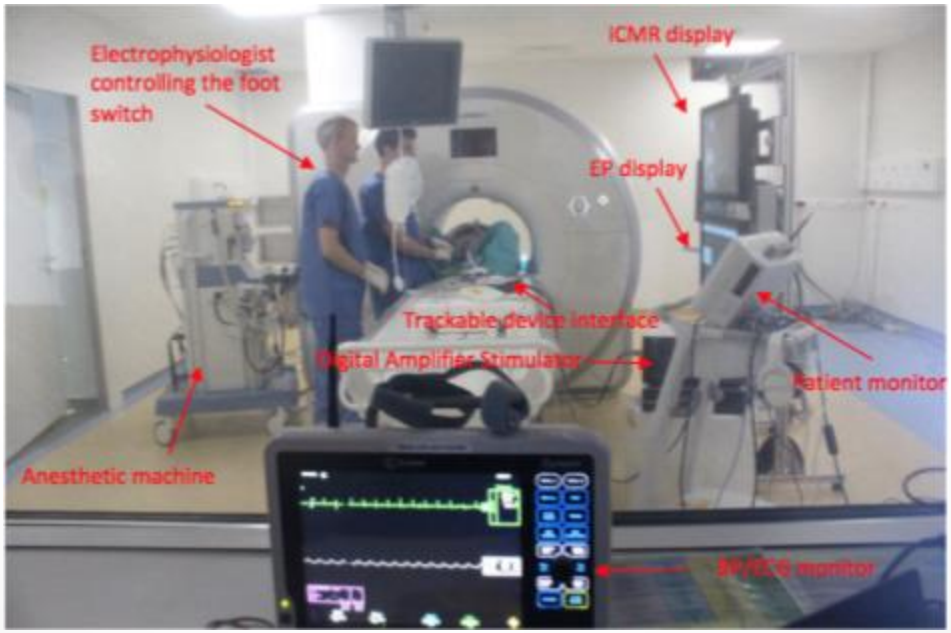




Mukherjee RK et al. *Curr Cardiovasc Imaging Rep* 2019

Real-time MRI guided EP

Cons
Large lab space
Availability and range of MR-compatible devices
MR scan creates electromagnetic fields that can interfere with intracardiac EGMs, so need filtering system, computer processing



Future advances

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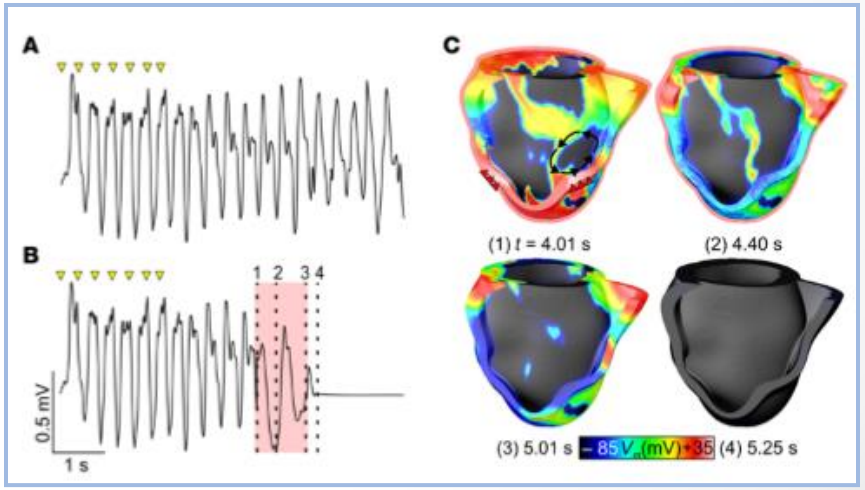
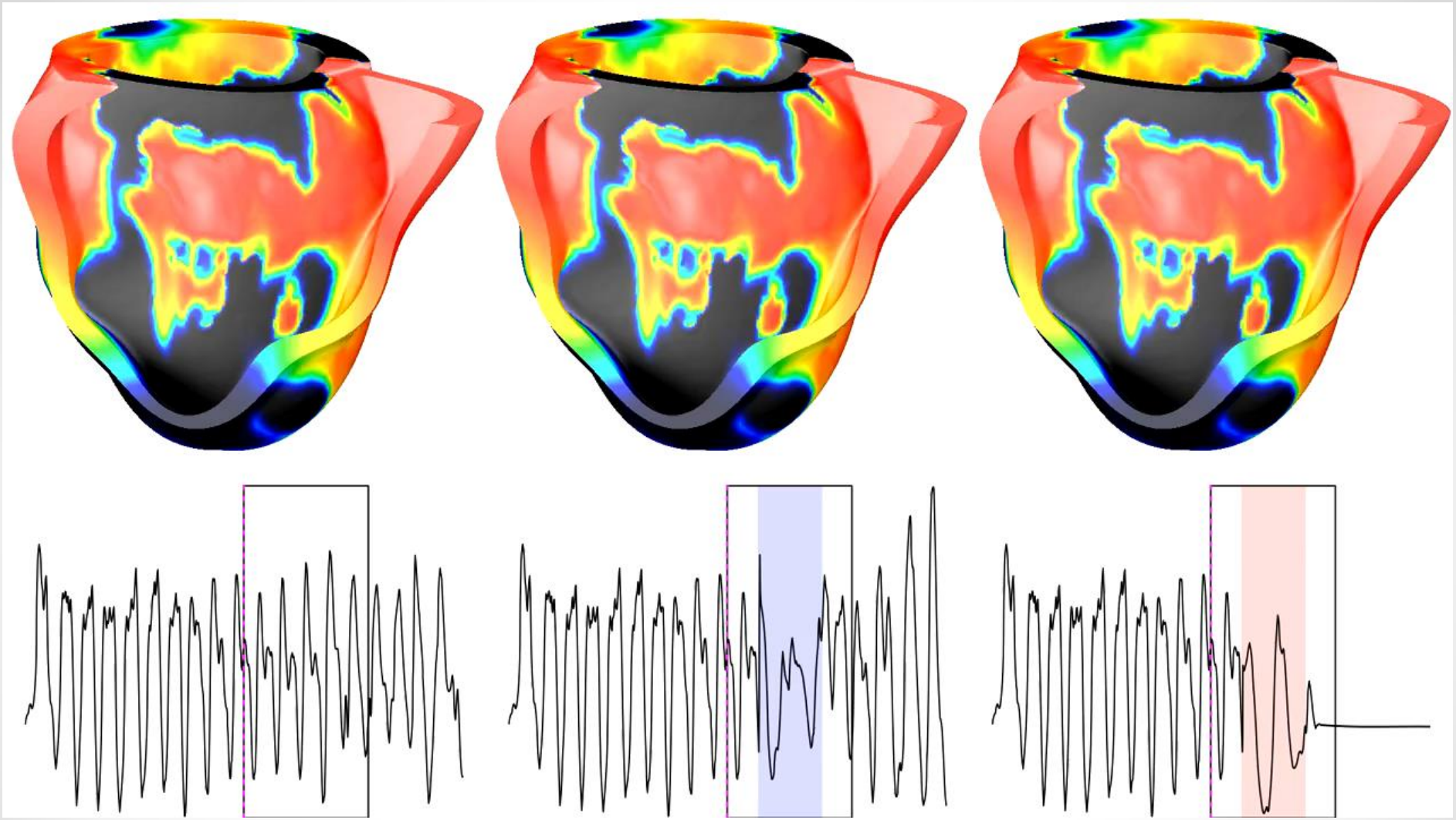
Optogenetics

- Use transgenic mice with light-sensitive channel channelrhodopsin-2 (ChR2) expressed in cardiac tissue
  - Blue light can optically pace the heart in vivo
  - Red light can perform optical defibrillation



- Optical mapping
  - Mapping the entire surface of the heart

Bruegmann T et al *J Clin Invest* 2016
Boyle PM et al *JACEP* 2018



Thank you!