VT Ablation with External Beam Radiotherapy

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Outline

- Introduction to Ventricular Tachycardia (VT)
- External beam as an alternative
- Review of recent preclinical and clinical
- Clinical workflow – intensive image guidance
- Heating up: future directions
What is Ventricular Tachycardia (VT)?

- Abnormal electrical signal in ventricles
- Heart rate >100 beats per minute
- Symptoms:
  - Dizziness, shortness of breath, lightheadedness, palpitations, chest pain
  - Loss of consciousness
  - Cardiac arrest (sudden death)
- Estimated 180K-450K sudden cardiac deaths/yr in US*

Current VT Treatment Paradigm

- Implanted Cardioverter Defibrillator (ICD)
  - 10K/month implanted in US*
- Antiarrhythmic medication
- Recurrent VT → VT Ablation
  - Source identification
    - Anatomic Substrate Imaging: MR, CT
    - Electrical mapping
      - Invasive electroanatomic mapping
      - 12-lead Holter monitoring
      - Body surface mapping (ECGi)
  - Catheter-based treatment w/challenges
    **thickness of LV wall**

Cather-based VT Treatment Outcomes

External Beam Radiation as an Alternative

• Advantages
  • Non-invasive
  • Fast
  • Homogeneous dose to any volume

• Challenges
  • Target definition
  • Respiratory and cardiac motion
  • Delay to effect
  • Proximity to critical normal structures

• Choice of external beam
  • X-rays
  • Particle beams (protons, carbon, …)
(Some) Preclinical Data

• Can focused radiation create a isolated lesion in cardiac tissue?
  
  CyberHeart™ in intact porcine model Sharma, A. et al. Non-invasive stereotactic radiosurgery (CyberHeart) for creation of ablation lesions in the atrium. *Heart Rhythm* 2010 (7) 802-810.

• If the lesion includes an AV node, is there a dose that creates AV block?
  


  **External beam radiation delivered in a single fraction of ≥25 Gy causes electrophysical and structural myocardial ablation effects.**

• If we target the left ventricle, what is the effect on cardiac tissue and function?
  

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Left ventricle lesion development

Twelve week follow-up of animal with 3 targets/40 Gy

Macroscopic pathology at 12 weeks

12-wk MR + def. dose

Lesion Border

Lesion Endocardium

Lesion Core

Dose Response: LVEF after 100 days

Two groups with different LV myocardium doses

- **High dose:** 3 targets to 40 Gy
- **Low dose:** 1 target to 30 or 40 Gy, 2 targets to 30 Gy

\[ \Delta \text{LVEF vs. } V_{20\text{Gy}} = -0.66 \ (p = 0.01) \]

Recent Clinical Data: VT ablation with photons


Clinical Workflow – Motion Management Strategy

- Respiratory motion:
  - Image & treat at end-expiration

- Cardiac motion:
  - Planning:
    - Cardiac ITV
    - 4D dose calculation
  - Delivery: Repaint the target

Foundation of every radiation oncology study:

Deliver the planned dose to the planned location
Clinical Workflow - Intensive Image Guidance

Target Definition

- Non-contrast respiratory 4DCT
- Non-contrast cardiac 4DCT (end-exhale)
- Contrast cardiac 4DCT (end-exhale)
- Delayed Contrast MR
- Previous Electroanatomical Mapping
- Current ECGi

Day of Treatment

- 2D/3D matching to bones and ICD leads
- Volumetric imaging (gated CBCT or 4DCT)
- Fluorography confirmation of ICD leads during respiratory and cardiac cycles

Follow-up

- Delayed Contrast MR to monitor lesion development and LVEF changes
Heating Up: Future Directions

- Several open questions for VT ablation
  - Mechanism of effect
  - Duration of effect
  - Risk to adjacent myocardium

- Preclinical work and clinical trials will both play a part

- Opportunity for innovation
  - Improved workflows for integrating EP and RadOnc systems
  - Cardiac gating
    - Increased image-guidance capabilities
    - 4D – dose calculation

Goal: Develop a safe, effective non-invasive treatment for cardiac arrhythmia