Predicting Maximum Pacemaker/ICD Dose in SAVI HDR Brachytherapy

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Background

- Aging population - Number of patients with cardiac pacemakers presenting for radiotherapy treatment increasing.
- Clinical practice there are a variety of different pacemakers in use.¹
  - Implantable internal pacemakers (PM)
  - Implantable Cardioverter Defibrillators (ICD)
- Pacemaker manufacturers use CMOS circuits – more sensitive to ionizing radiation than bipolar semiconductor circuits used previously.²
- Increased sensitivity can lead to damage to both the hardware and software components of the pacemaker³
  - Transient damage and / or serious and permanent damage.
Motivation

• According to AAPM TG 34 Report 45
  – The absorbed dose to be received by the pacemaker should be estimated before treatment.
  – If the total estimated dose to the pacemaker might $> 2$ Gy, the pacemaker function should be checked prior to therapy and possibly at the start of each following week of therapy.

• Manufacturer guidelines vary greatly for each specific PM/ICD
  – $< 20$-30 Gy for St. Jude Medical (Little Canada, MN).
  – $< 10$ Gy for Biotronik (Berlin, Germany).
  – $< 5$ Gy for Medtronic (Fridley, MN).
  – $< 2$ Gy for Boston Scientific (Natick, MA).
  – Guidant (Indianapolis, IN) does not specify any maximal dose limit and instead the manufacturer addresses “no safe radiation dose” for the device.
  – ICD is less tolerant to radiation and Solan et al. suggest $< 1$ Gy.$^8$
Accelerated Partial Breast Irradiation (APBI) is the delivery of larger/doses/fraction of RT to lumpectomy cavity (plus 1-2cm margin).

- APBI has been attractive to breast cancer patients than whole breast irradiation (WBI) because of the decreased overall treatment time (5 days vs. 5-7 weeks) and the reduction in the irradiated volume of uninvolved breast and adjacent critical organs.

- It is important to estimate dose to pacemaker (PM)/Implantable Cardioverter Defibrillator (ICD) before undertaking APBI using HDR brachytherapy.

Motivation
Kim et al. have reported HDR PM/ICD dose using a Mammosite single-source balloon applicator\(^6\).

- They proposed a Look Up Table (LUT) to approximately predict the maximal device dose based on the measurement of minimal distance between lumpectomy and the device before balloon implantation for the suitability of balloon HDR brachytherapy.

To the authors’ knowledge, there have so far not been any published PM/ICD dosimetry literature for the Strut Adjusted Volume Implant (SAVI, Cianna Medical, Aliso Viejo, CA).
This study aims to fill this gap by generating a LUT to predict maximum dose to the PM/ICD in SAVI HDR brachytherapy.
SAVI

• The SAVI applicator is a single insertion multicatheter device.
• It has 6-10 catheters that surround a central catheter depending on the device size.
• This allows the radiation dose to be tailored to the shape of the lumpectomy cavity.
• These surrounding catheters allow geometric optimization of the dwell positions to account for close proximity of skin or pectoralis muscle, or cavity asymmetry.
1. CT scans for 3D Dosimetric planning were acquired for four SAVI applicators (6-1-mini, 6-1, 8-1 and 10-1) expanded to their maximum diameter in air.

2. The CT datasets were imported into the Elekta Oncentra TPS for planning and each applicator was digitized in a multiplanar reconstruction window.

3. A dose of 340 cGy was prescribed to the surface of a 1 cm expansion of the SAVI applicator cavity.

4. Cartesian coordinates of the digitized applicator were determined in the TPS leading to the generation of a dose distribution and corresponding distance-dose prediction LUT for distances from 2 to 20 cm (10-1).

5. The deviation between the LUT doses and the dose to the cardiac device in a clinical case was evaluated.
Results

- Figure 1 shows the screenshot of the corresponding SAVI 10-1 isodose distribution obtained from Oncentra TPS for comparison.
- Figure 2 shows the screenshot of a clinical SAVI plan containing ICD using a 10-1 applicator.
Results

Table shows a section of the distance dose look up table for SAVI 10-1 applicator where the along and away distance varies from 2-20 cm. The yellow highlighted values show the location of the ICD.

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Results

Distance-dose look up table were compared to clinical SAVI plan and the discrepancy between the max dose predicted by the LUT and the clinical plan was found to be within 3% of the prescription dose.
Conclusions

• The proposed distance-dose Look up table enables to approximately predict the maximal device dose before SAVI implantation for the suitability of HDR brachytherapy.

• This information can greatly benefit in planning of breast HDR brachytherapy cases where the PM/ICD are on the same side as the breast.
Future Work

• Distance dose look up tables for all applicators.
• Generate a set of case studies based on clinical usefulness.
• Scarcity of patients with PM/ICD
• Assemble a cohort of patients (sans PM/ICD) with most probable placement and generate comparative statistics between TPS dose and LUT dose.
References


7. Evans, Lauren. 'Study To Investigate The Safe Levels Of Radiotherapy That Can Be Administered To Patients Who Have An Implanted Cardiac Device.' 2012. Presentation.

Acknowledgements

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- Byongyong Yi, Ph.D.
- Mu-Han Lin, Ph.D.
Additional Slides
PM/ICD Radiation Damage

- Two processes have been reported for the radiation damage to the PM/ICD device.
- Electromagnetic interference (EMI) can occur in the electronic circuit of the device owing to the change of electromagnetic fields in the medical linear accelerator (Linac), in particular, during radiation beam-on and off. Although the EMI was a clinical concern with a betatron, it is not an issue with current Linacs (5, 7). However, EMI may be an issue for gated radiation delivery because there is frequent radiation beam-on and off depending on the changes in breathing patterns (8).
- The major concern with a modern Linac is direct/scatter radiation interaction with the cardiac pacing device. Depending on the direct/scatter radiation dose level to the device, the device can result in partial/full malfunction or total death of device. To avoid direct radiation, no treatment plan is allowed if the device is located within any treatment field. To reduce leakage radiation from treatment head and scatter radiation from patient and beam modifier (i.e., collimator and physical wedge), all available shielding options for the Linac and the device are recommended.