Practical Radiation Oncology (2017) **xx**, xxx–xxx

practical radiation oncology
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Teaching Case

Multiple myeloma and a mischievous pacemaker: A teaching case involving irradiation of a cardiovascular implantable electronic device

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Received 29 September 2017; revised 27 October 2017; accepted 30 October 2017

Introduction

Cardiovascular implantable electronic devices (CIEDs) include implantable cardioverter defibrillators (ICDs) and implantable cardiac pacemakers (ICPs).[1] ICDs generate a shock to correct lethal arrhythmias, whereas ICPs produce electrical stimuli to pace bradyarrhythmias. As the prevalence of cardiovascular disease rises, patients undergoing radiation therapy (RT) are more likely to have CIEDs[2] and to be at risk for cardiovascular death.[3] Limiting potential RT-induced CIED damage in our patients is therefore of increasing importance. We present a CIED-dependent patient who underwent RT to a tumor abutting his ICP and highlight considerations involved in palliative RT and CIED irradiation.

Our patient

A 59 year old with multiple myeloma and ICP-dependent complete heart block who failed stem cell transplant and numerous systemic therapies presented with a large, painful tumor abutting his ICP (Fig 1). Steroids and opioids did not control his pain. Following anesthesiology and cardiac electrophysiology (CEP) consultations, he was not a nerve block or ICP relocation candidate because of pancytopenia. The patient's medical oncologist anticipated a 10% response rate with additional systemic therapy and estimated his survival as <6 months. We were consulted for palliative RT.

Radiation-CIED interactions

Photons may interfere with CIEDs to produce battery depletion, stored event loss, device/parameter resets, and improper sensing, potentially resulting in inappropriate shocks or inhibition/triggering of pacing.[1] Additionally, high-energy photons may produce neutrons that interact with boron-containing CIED circuitry and cause device malfunction. During RT, magnet placement over a CIED may promptly identify inappropriate parameter changes, inhibit potential shocks resulting from improper sensing in ICDs, and cause fixed-rate pacing without sensing input ("asynchronous pacing") in ICPs, decreasing the risk of inappropriate inhibition/triggering of pacing.[4]

Two of the largest clinical studies examining CIED exposure to RT observed malfunction in 3% to 7% of exposures.[1,4] Both studies found CIED malfunction was associated with use of ≥15-MV photons, but not with tumor location or CIED absorbed dose. In the larger study,

Conflicts of interest: None.

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https://doi.org/10.1016/j.prro.2017.10.016

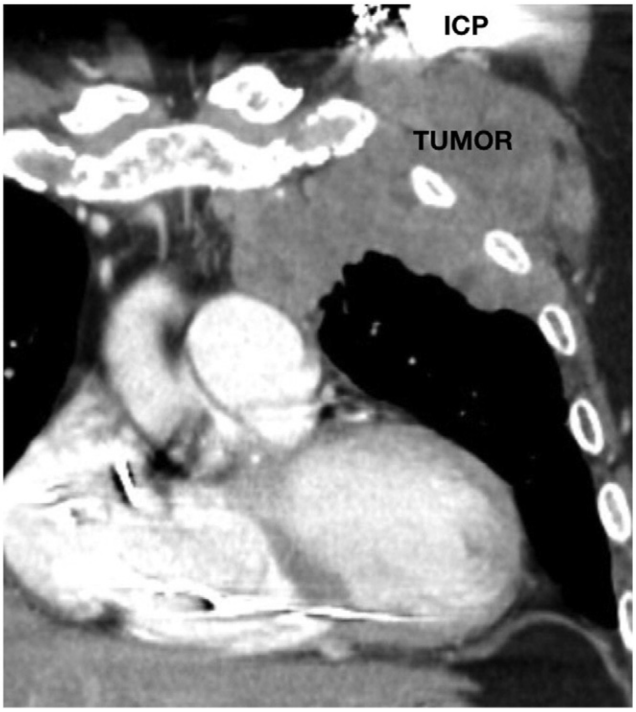

Figure 1 Coronal computed tomography image illustrating a chest wall tumor abutting an implantable cardiac pacemaker (ICP).

79% of malfunctions were electrical resets and there were no life-threatening malfunctions.[4]

Guidelines and recommendations regarding CIED irradiation

The American Association of Physicists in Medicine (AAPM) Task Group (TG) 34 report, published in 1994, counsels avoidance of direct CIED irradiation, estimating CIED absorbed dose, and regular CIED interrogations for absorbed dose >2 Gy.[5] AAPM TG-203 report (in progress) will provide updated guidelines more pertinent to contemporary CIEDs.

More recently, Dutch guidelines[6] risk-stratify patients based on CIED absorbed dose and CIED dependency. They advise using ≤10-MV photons to limit neutron production, visual monitoring during RT, and weekly CIED interrogation during RT for all patients. Additional measures, including readily available external pacing during RT, are suggested for higher risk patients.

Device manufacturers and clinical data suggest highly variable CIED dose tolerances. Literature provided by our patient's CIED manufacturer indicated that absorbed doses of 1 to 5 Gy and 5 Gy were safe for their current ICDs and ICPs, respectively.[7] Meanwhile, a recent study evaluating irradiation of contemporary CIEDs reported malfunction thresholds of up to 150 and 30 Gy for photon energies of 6- and 18-MV, respectively.[8]

Our recommendations for CIED patients being considered for RT are provided in Fig 2.

RT considerations and outcome

Given our patient's uncontrolled pain, poor prognosis, and limited therapeutic alternatives, we proceeded with RT. Standard multifraction palliative RT regimens did not allow compliance with AAPM[5] or manufacturer[7] CIED absorbed dose limits. Because low-dose RT for multiple myeloma has yielded >90% response rates,[9] 4 Gy/2 fractions and 8 Gy/1 fraction were favored. The latter was chosen because it represented a shorter treatment and delivered a higher biologic dose.

A computer-optimized intensity modulated RT plan using 6-MV photons was created. Dose constraints included ICP mean and maximum doses of 2 and 5 Gy, respectively.[7] Multileaf collimators were then adjusted to avoid direct ICP irradiation (Fig 3). The approved plan was prescribed to the 84% isodose line and covered 86% of the planning target volume (PTV) (gross tumor volume [GTV] + 1 cm) with 8 Gy (Fig 4). ICP mean and maximum doses were 2.0 and 3.5 Gy, respectively. Of note, 3-dimensional RT plans provided decreased PTV coverage and increased ICP dose while employing neutron-producing 18-MV photons.

Patient alignment was achieved with lasers and skin marks. Two optically stimulated luminescent dosimeters were placed under 2 cm of bolus centered over the ICP. Cone beam computed tomography was used for position verification. Our patient was visually monitored and CEP was prepared for external pacing during RT, which was delivered uneventfully. Device interrogation pre- and