Safe delivery of radiation therapy in a patient with Implanted Cardiac Pacemaker - Tips and Pitfalls

Sharief K Sidhique
Christian Medical College
Swathi B
Christian Medical College
Ebenezer Suman Babu
Christian Medical College
Patricia Sebastian
Christian Medical College
Selvamani Backianathan
Christian Medical College
Anand Manickavasagam
Christian Medical College
John Roshan
Christian Medical College
Rajesh Balakrishnan (drrajeshb77@gmail.com)
Christian Medical College

Case Report

Keywords: Implanted Cardiac pacemaker, Radiation therapy, Guidelines, Treatment Algorithm

Posted Date: April 18th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1555816/v1

Abstract

Background: There are clinical scenarios when it is required to deliver Radiotherapy (RT) to patients who have implanted pacemakers and it is challenging when treatment portals are close to pacemaker. The cumulative dose to the pacemaker needs to be less than 2 to 5 Gy as per the current recommendations.

Aim and Methods: To describe the steps undertaken for safe delivery of mediastinal radiotherapy for a patient with Hodgkin's lymphoma and implanted pacemaker.

Case presentation: Sixty-year-old gentleman who had implanted dual-chamber rate adaptive (DDDR), magnetic resonance imaging (MRI) compatible, permanent pacemaker for complete heart block presented with lymphadenopathy and was diagnosed with Classical Hodgkin's Lymphoma stage IV. He received consolidation RT (30 Gy in 15 fractions) to the mediastinum after completion of chemotherapy. An algorithm was developed based on AAPM (The American Association of Physicists) report for necessary steps to be taken at various stages of radiotherapy planning and treatment delivery. This approach made it possible to reduce cumulative dose to the pacemaker to < 2Gy.

Conclusion: RT can be safely delivered to the patients with cardiac pacemakers. Close follow-up of the patients in conjunction with the Cardiologist, before, during and after radiation is essential for the patient's safety.

Introduction

Management of the patients with cardiac implanted electronic devices (CIED) like pacemakers receiving RT requires a structured multidisciplinary approach involving cardiac electrophysiologists, radiation oncologists, physicists, and radiation technologists.

There are more than 30 lakh people with CIED. According to 11th world survey of cardiac pacemaker (2009), around 20,000 permanent pacemakers were implanted annually in India and more are being added each year. The increasing life expectancy noted in the current era in turn can increase the incidence of non-communicable diseases such as cancer and cardiac diseases. In view of this, radiation oncologists are likely to encounter increasing number of the patients with CIED [2]. While the CIED leads themselves may not get significantly affected by radiation, various components present within the pulse generator are susceptible to temporary or permanent damage depending on the dose and type of radiation used.

We report how RT was delivered for a patient with a pacemaker who had been diagnosed to have mediastinal stage IV Classical Hodgkin's lymphoma.

Case Capsule

A 60-year-old gentleman with no comorbidities was evaluated for light headedness and breathlessness in October 2016. His electrocardiogram (ECG) showed complete heart block confirmed by Holter. He underwent a permanent MRI dual-chamber rate-modulated pacemaker implantation in left infraclavicular area on October 2016. He was not pacemaker dependent.

In December 2017, he presented with intermittent fever for three weeks. Clinical examination revealed hepatosplenomegaly. CT showed multiple intra-abdominal

necrotic lymph nodes, hepatosplenomegaly with multiple hypodense lesions in the liver and spleen. He underwent USG guided splenic lesion biopsy and histopathology was consistent with Classical Hodgkin's lymphoma, mixed cellularity subtype; Immunohistochemistry was positive for CD15, CD30.

PET CT revealed multiple metabolically active nodes in the right supraclavicular fossa, mediastinum, upper abdomen, with lesions in liver and spleen. The maximum standard uptake value (SUV) noted in the mediastinum was 10.02 and the largest nodal size was 1.6cm. The disease was staged as Classical Hodgkin's Lymphoma stage IV. He received chemotherapy with 6 cycles of EBVD regimen (Etoposide, Bleomycin, Vinblastine, and Dacarbazine). Doxorubicin was not given so as to avoid anthracycline induced cardiotoxicity. Reassessment PET CT at the end of chemotherapy had shown disease response and he was advised RT to the mediastinum.

Radiation Therapy

An in-house workflow algorithm (Fig:1) was developed for patients with pacemaker requiring radiotherapy.

Pretreatment Discussion

When a patient with a pacemaker requires RT, the possibility of malfunctioning of pacemaker during radiation that would necessitate replacement of the same should be considered. In conjunction with the cardiologist, a consensus was reached to proceed with radiation therapy without relocating the pacemaker as there was a low likelihood of interaction between the CIED and radiation therapy.

Radiation Therapy Planning and Simulation

It would be ideal to do the post chemotherapy disease evaluation imaging as a planning CT/PETCT to avoid excess radiation to the pacemaker. The patient was immobilized with a vacloc cushion with arms abducted above the head in supine position. Simulation CT was taken in Siemens Somatom CT Simulator machine with slice thickness 5mm and pitch of 1. As per AAPM TG 203, CT imaging involving helical scan with pitch >1 is preferred to prevent long periods of direct irradiation of the device.

Contouring

The target volume and organs at risk were delineated as per the International Lymphoma Radiation Oncology Group (ILROG) guidelines. The pulse generator and the leads were also contoured (Fig:2).

Treatment Planning

AAPM TG 203 recommends avoiding protons and instead to use photon energies ≤10MV in order to reduce neutron induced upsets in memory or logic circuits of the pacemaker. Anteroposterior fields were avoided to minimize the cardiac dose and considering the close proximity of the pacemaker to the PTV. AAPM TG 34 recommends a dose of <2Gy to the pacemaker whereas AAPM TG 203 recommends to restrict the dose to <5Gy for CIEDs in low -medium risk categories [1,3]. This patient belonged to the low-risk category as per the risk stratification by AAPM TG 203 [1] as the patient was not pacemaker dependent and the expected dose to the pacemaker was < 2 Gy.

The planning was done with 6 MV photons and the prescribed dose was 30 Gy in 15 fractions using rapid arc technique. It is advisable to limit the number of fractions so as to reduce the radiation exposure to the pacemaker. A full arc with appropriate blocks to prevent entry and exit of beams through the pacemaker were used. AAPM TG 203 has recommended in vivo measurement of the dose if the device is from 3 to 10 cm from the field edge. The pacemaker was at 7.14, 5.99 and 1.30 cm from the isodose 50%(15Gy), 25%(7.5Gy) and 5%(1.5Gy) lines respectively (Fig:2). The dose to the pacemaker was found to be 1.28 Gy (treatment planning system calculated) and 1.15 Gy (in-vivo dosimetry with optically stimulated luminescent dosimeter).

Treatment Execution

The position and function of the pacemaker was confirmed by the cardiac electrophysiologist. CIED monitoring was done twice weekly during RT to rule out malfunctioning and treatment delivery was in the midday.

For the patient position and the tumour location verification, Cone Beam Computed Tomography (CBCT) was done for the first three days followed by once a week up to a total of 5 CBCTs. It was ensured that the pacemaker was not included in the range of the CBCT to help reduce the dose to the pacemaker. RT was delivered in Aug-Sept 2018, two years after the implantation of the pacemaker.

Post-treatment Follow Up

Cardiac Evaluation

The patient had undergone regular clinical evaluation and pacemaker interrogation under the guidance of the cardiac electrophysiologist. The Pacemaker interrogation was done once a year and no abnormality has been detected in the last two and half years (Table-1). The last interrogation done in March 2021 showed normal pacemaker functioning

Table: 1. The Pacemaker interrogation was done at 1, 1.5 and 2 years after radiation therapy. The pacemaker was found to have normal function. There were no signs of radiation induced damage.

Parameter		One year after Implantation (Aug 2017)	One year after radiation Therapy (Aug 2019)	One and half years after radiation therapy (March 2020)	Two and a half years after radiation therapy (March 2021)
Sensing (millivolt)	Ventricular	14.5	16.3	V: 13.7	V: 14.1
	Atrial	4.2	3.9	3.7	3.4
ThresholdV@0.4ms	Ventricular	0.7	V: 0.4	V:0.5	V:0.5
	Atrial	0.6	0.4	0.5	0.4
Impedance (ohms)	Ventricular	621	V:624	V: 585	V: 585
	Atrial	721	624	585	585
Longevity (years)		13 years	9 years 6 months	9 years 1month	8 years 6 months
Impression		Normal Function	Normal Function	Normal Function	Normal function

Oncological Evaluation

PET CT done 3 months and one year after completion of RT showed interval reduction in the size of the node and SUV. He was clinicoradiologically disease free at the last follow up in Sep 2021

Discussion

CIED and Radiation

Modern CIEDs contain Complementary Metal Oxide Semiconductor (CMOS) technology. In the presence of high radiation doses and especially when beam energy >6 MV are used, both software and hardware errors may occur.

Malfunctions can be:

1. transient (due to electromagnetic interference and occurring only during radiation exposure)

2. reset to back-up setting, which can be reverted by CIED programming

3. permanent reset requiring CIED substitution

Electromagnetic interference could lead to

● Inappropriate pacing inhibition, particularly dangerous, even if brief in pacing-dependent patients

● Inappropriate antitachycardia therapies (including ICD shock) when long enough to be binned by the device as significant arrythmia (5–10s) [4].

Guidelines

There are various guidelines and recommendations available. In 1994, AAPM issued guidelines for pacemaker irradiation; this was updated in 2019 in AAPM TG-203 [1]. Last et al (1997), Royal College of Radiologist (2015), Heart Rhythm Society (2017), Japanese Society for Radiation Oncology (2020) and the Japanese Circulation Society (2020) and manufacture specific guidelines are the various other guidelines [5-7].

AAPM TG 203 has defined a three-level risk stratification of patients as low risk, medium risk and high risk [1]. Based on the risk, the guidelines give the preparatory steps to be taken for radiation planning: the measures to be carried out before, during and after radiation.

Critical recommendations of AAPM TG - 203 task group were:

1. Neutron-producing treatments to be avoided

2. Cumulative dose to the CIED should be kept below 2 - 5 Gy as much as possible for pacing-dependent and pacing-independent patients, respectively.

Other Recommendations of AAPM – TG 203:

1. Management of the patients should be based on device risk levels

2. CT irradiation of CIED for longer than 3s should be avoided whenever possible

3. CIED compatibility with MRI should be verified prior to exposing the patient to a MR environment.

4. If >10 MV photon, proton, or neutron beams are used, the patient should be managed in the High-Risk category

5. Lower dose-rates are preferred

6. The generator of the device should be kept at least 5 cm from the collimated field edge if possible, including imaging fields by selection of the appropriate beam angles.

7. In-vivo dosimetry for the first fraction should be performed if the device is <10 cm from the treatment area. The treatment planning system should be used in lieu of a measurement if the device is within 3 cm (laterally) of the field edge or 5% isodose line for IMRT

8. Lead should not be used for shielding CIED during treatment

Conclusion

Radiotherapy can be safely delivered in the patients with CIED. Careful planning, treatment and dosimetry should be performed to ensure the least possible dose (2-5Gy) is delivered to the pacemaker to ensure the patient gets categorized under low or medium risk. Standardized protocols such as our proposed algorithm are necessary to improve patient management. Close follow up of the patients in conjunction with the cardiologists before, during and after radiation is essential for patient safety.

Abbreviations

Abbreviation	Explanation
RT	Radiotherapy
DDDR	Dual Chamber Rate Adaptive
MRI	Magnetic Resonance Imaging
AAPM	The American Association of Physicists
CIED	Cardiac Implanted Electronic Devices
ECG	Electrocardiogram
CT	Computed Tomography
PET CT	Positron Emission Tomography
SUV	Standard Uptake Value
ILROG	International Lymphoma Radiation Oncology Group
PTV	Planning Target Volume
CBCT	Cone Beam Computed Tomography
CMOS	Complementary Metal Oxide Semiconductor
IMRT	Intensity Modulated Radiation Therapy

Declarations

Ethics approval and consent to participate: Consent obtained from the patient

Consent for publication: Obtained

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing Interest: The authors declare that they have no competing interests"

Funding: Nil

Author’s Contributions: KS and SB compiled the patient data regarding the treatment given. The radiation therapy planning was done and reviewed by BS. PS, SB, and RB were the major contributors in writing the manuscript. AM and JR were the major contributors from the Cardiology point of view. All authors read and approved the final manuscript

Acknowledgments:

Department of Radiation Oncology, CMC Vellore

Department of Cardiology, CMC Vellore

References

1. Miften M, Mihailidis D, Kry SF, Reft C, Esquivel C, Farr J, Followill D, Hurkmans C, Liu A, Gayou O, Gossman M, Mahesh M, Popple R, Prisciandaro J, Wilkinson J. Management of radiotherapy patients with implanted cardiac pacemakers and defibrillators: A Report of the AAPM TG-203†. Med Phys. 2019 Dec;46(12):e757-88. doi: 10.1002/mp.13838. Epub 2019 Nov 1. PMID: 31571229.
2. Munshi A, Agarwal JP, Pandey KC. Cancer patients with cardiac pacemakers needing radiation treatment: a systematic review. J Cancer Res Ther. 2013 Apr-Jun;9(2):193-8. doi: 10.4103/0973-1482.113348. PMID: 23771357.
3. Marbach JR, Sontag MR, Van Dyk J, Wolbarst AB. Management of radiation oncology patients with implanted cardiac pacemakers: report of AAPM Task Group No. 34. American Association of Physicists in Medicine. Med Phys. 1994 Jan;21(1):85–90. doi: 10.1118/1.597259. PMID: 8164594.
4. Zecchin M, Severgnini M, Fiorentino A, Malavasi VL, Menegotti L, Alongi F, Catanzariti D, Jereczek-Fossa BA, Stasi M, Russi E, Boriani G. Management of patients with cardiac implantable electronic devices (CIED) undergoing radiotherapy: A consensus document from Associazione Italiana Aritmologia e Cardiostimolazione (AIAC), Associazione Italiana Radioterapia Oncologica (AIRO), Associazione Italiana Fisica Medica (AIFM). Int J Cardiol. 2018 Mar 15;255:175–83. doi: 10.1016/j.ijcard.2017.12.061. Epub 2017 Dec 24. PMID: 29310933.
5. Last A. Radiotherapy in patients with cardiac pacemakers. Br J Radiol. 1998 Jan;71(841):4–10. doi: 10.1259/bjr.71.841.9534692. PMID: 9534692.
6. Indik JH, Gimbel JR, Abe H, Alkmim-Teixeira R, Birgersdotter-Green U, Clarke GD, Dickfeld TL, Froelich JW, Grant J, Hayes DL, Heidbuchel H, Idriss SF, Kanal E, Lampert R, Machado CE plus et al 2017 HRS expert consensus statement on magnetic resonance imaging and radiation exposure in patients with cardiovascular implantable electronic devices. Heart Rhythm. 2017 Jul;14(7):e97-e153. doi: 10.1016/j.hrthm.2017.04.025. Epub 2017 May 11. PMID: 28502708.

7. Ohno T, Soejima T, Sekiguchi Y, Hashimoto T, Koike I, Matsubara H, Nakamura K, Nitta K, Takahashi S, Tsujino K, Wakatsuki M, Yoden E. JASTRO/JCS Guidelines for radiotherapy in patients with cardiac implantable electronic devices. J Radiat Res. 2020 Dec 4;62(1):172–84. doi: 10.1093/jrr/rraa102. PMCID: PMC7779359.]

Figures

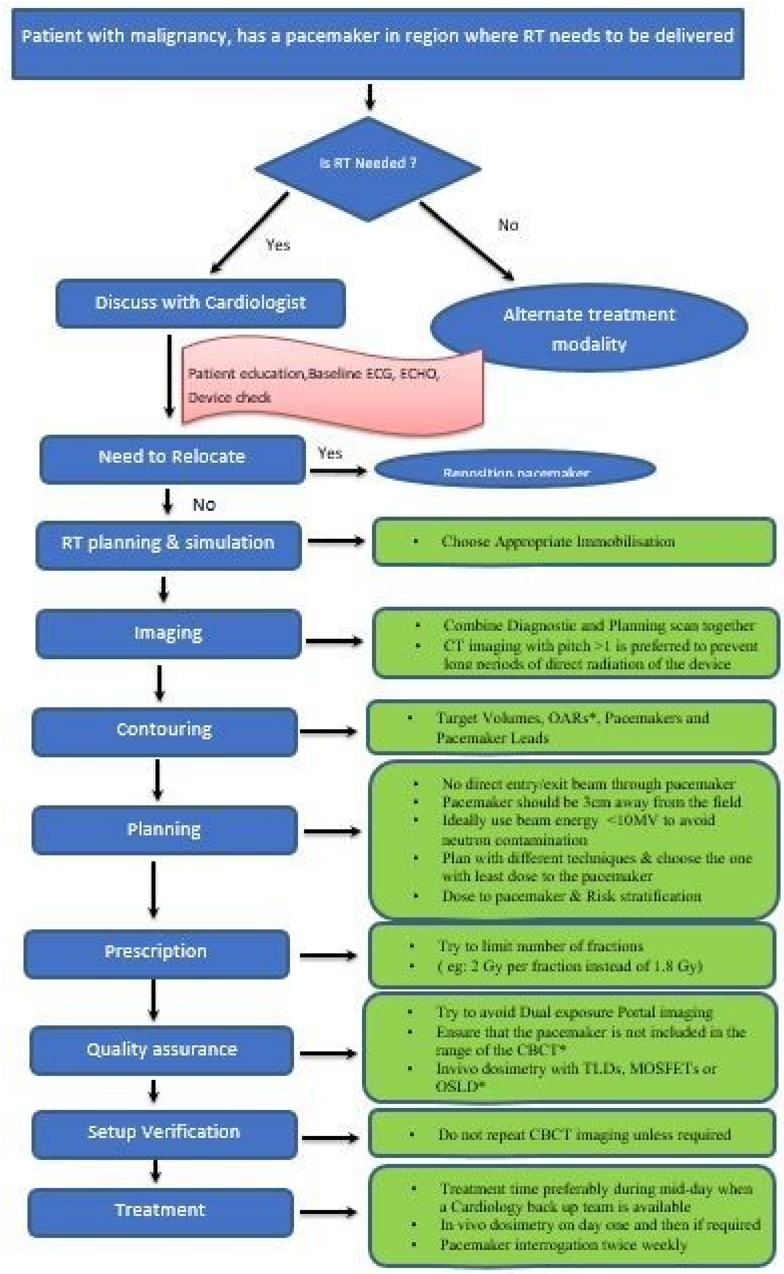

Figure 1

The algorithm from decision making to treatment execution in a patient with pacemaker

OARs:- Organs at risk; CBCT:- Cone Beam Computed Tomography; TLD: - Thermoluminiscent Dosimeter MOSFET:- Metal oxide Semiconductor field effect transistor; OSLD: - Optically stimulated

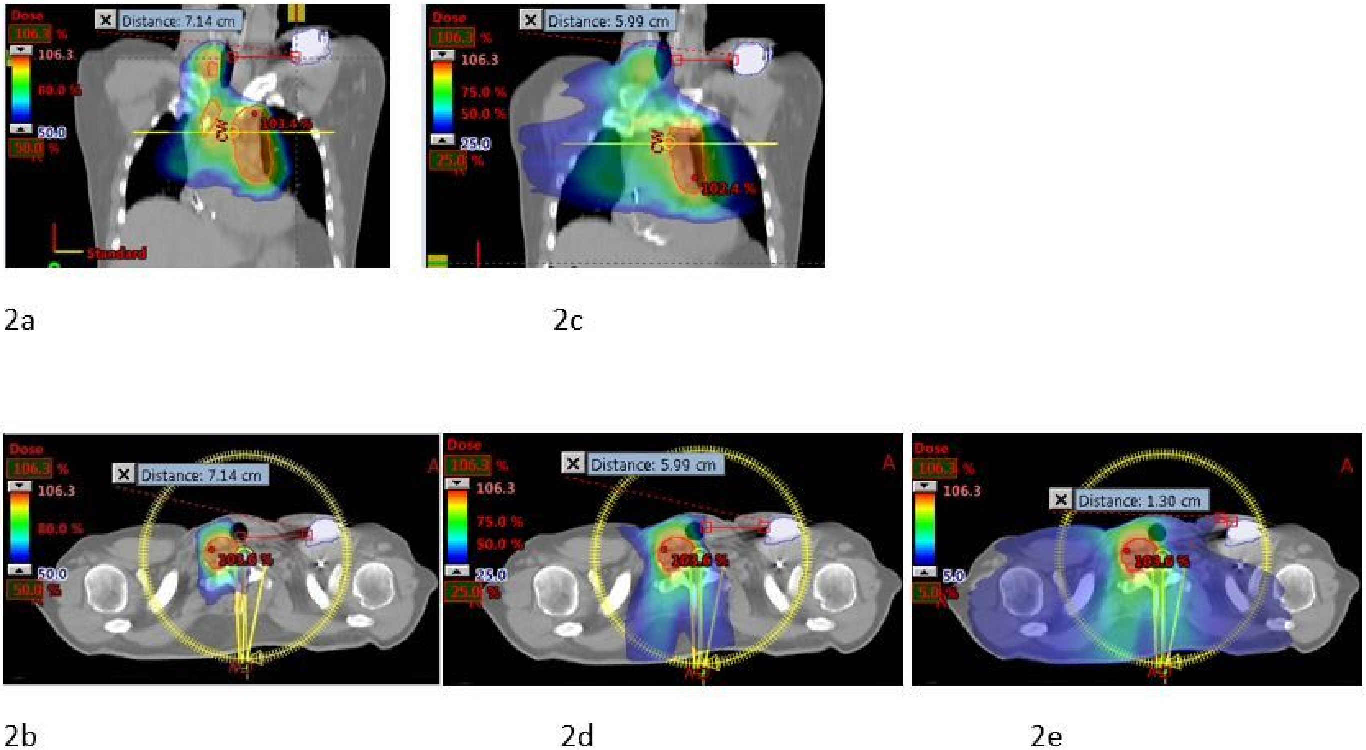

Figure 2

Depicting the position of the pacemaker pulse generator [PPG] in relation to various isodose

2a and 2b: PPG was at a distance of 7.14 cm from the 50% isodose – Coronal and axial view respectively

2c and 2d: PPG was at a distance of 5.99cm from 25% isodose – Coronal and axial view respectively.