



Management of cancer patients receiving radiotherapy with a cardiac implanted electronic device: A clinical guideline recommended for use by The Royal College of Radiologists, The Society and College of Radiographers and The Institute of Physics and Engineering in Medicine.

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## Overview

A national review of cardiac device policies in use in radiotherapy departments across the UK in 2013 reported that most policies do not reflect current best evidence.<sup>1</sup> The Royal College of Radiologists, the Society and College of Radiographers and the Institute of Physics and Engineering in Medicine formed a multidisciplinary working party comprising clinical oncology, cardiology, therapeutic radiography and medical physics expertise to develop evidence-based guidelines for the management of cancer patients receiving radiotherapy with a cardiac implanted electronic device.

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## 1. Introduction

The number of cancer patients with cardiac implantable electronic devices (CIEDs) receiving radiotherapy is increasing.<sup>2-4</sup> There are two main categories of CIED: permanent pacemakers and implantable cardioverter defibrillators (ICDs). Electronic monitoring devices (eg implantable loop recorders) have no direct connection to the heart and are not covered in this guideline. Most permanent pacemakers (referred to as 'pacemakers' in this document) are implanted in patients who either have inappropriate bradycardia, or who are at risk of bradycardia. Bradycardia pacemakers generally only pace the heart when the patient's heart rate is excessively slow (usually <50 beats/minute), otherwise the pacemakers simply monitor and therefore an ECG may appear "normal" and not show any pacemaker activity. Cardiac Resynchronisation pacemakers coordinate the sequence of cardiac contraction and are used in patients with heart failure. As such, these pacemakers tend to pace the heart continuously and an ECG usually shows paced beats. ICDs are more sophisticated devices; in addition to normal pacing capabilities (for bradycardia and/or for resynchronisation), ICDs have the ability to monitor the patient's cardiac rate and rhythm and deliver shock therapy when certain criteria are met. The simplest shock criteria involve heart rate; thus when sensed heart rate exceeds a pre-programmed value (usually >220 beats/minute), shock therapy is delivered. Inappropriate shock therapy may arise when the ICD senses the cardiac rhythm incorrectly.

Although most medical treatments pose little danger to the functioning of CIEDs, radiotherapy has the potential to alter device function. CIEDs may be affected in two ways: electromagnetic interference (EMI) and direct damage via ionising radiation, both of which may cause temporary or permanent device malfunction.<sup>5</sup> Over the past three decades, the design and technology of CIEDs has evolved. The use of complementary metal oxide semiconductor (CMOS) circuits within CIEDs has increased.<sup>6</sup> These are more sensitive to ionising radiation than the bipolar semiconductor devices previously used, with the potential of increased damage and catastrophic device failure.<sup>7,8</sup> CIEDs are also now more complex in design, they are smaller, have thinner housing, less shielding and have limited battery capacity. These CIEDs use random access memory (RAM) to hold patient-related data. Ionising radiation can damage the RAM and can lead to complete loss of CIED function.<sup>9</sup>

It is not possible to predict the exact behaviour of a CIED when it is within or close to a radiotherapy treatment field.<sup>10</sup> In addition, published results are not consistent in their findings or recommendations. Radiotherapy has been shown to cause malfunction of CIEDs, ranging from inappropriate triggering and device reprogramming to device failure.<sup>10-13</sup> However, other investigators have reported minimal effect of radiotherapy on CIEDs.<sup>14-17</sup>

The American Association of Physicists in Medicine (AAPM) published a report in 1994 on the safe use of radiotherapy in patients with permanent

pacemakers.<sup>18</sup> The AAPM report is the basis of most of the current CIED departmental radiotherapy policies in the UK.<sup>1</sup> Frizzell published a more contemporary review in which a distinction was made between pacemakers and ICDs.<sup>19</sup> Both the AAPM and the Frizzell reports are widely referenced in the literature and, in our opinion, have the most robust evidence base to support them. The AAPM report is now nearly two decades old and does not take into account subsequent advances in CIED or radiotherapy technology and treatment delivery.<sup>1</sup> A Dutch update of the 1994 AAPM guidelines was published by Hurkmans et al, in 2012<sup>6</sup> and in 2015 Gauter-Fleckenstein et al published the DEGRO/DGK guidelines.<sup>9</sup> Both papers have been referenced in these guidelines where appropriate.<sup>6</sup> In the absence of more contemporary research on safely treating CIED patients with radiotherapy, it is reasonable to use the AAPM recommendations, the Frizzell review, the Dutch update and DEGRO/DGK guidelines as the basis of a UK guideline document.

Currently, there are no UK guidelines on the use of radiotherapy in patients with CIEDs. A national review of current cardiac device policies from radiotherapy centres across the UK reported that 30% of UK radiotherapy centres have no policy for managing patients with CIEDs.<sup>1</sup> Results showed that policies differ between radiotherapy centres and a significant number of policies do not adhere to current established tolerance doses for CIEDs. In the departments where there is a CIED policy, the majority do not reflect best evidence.<sup>1</sup> There is limited published research on the effect of radiotherapy on CIEDs, but there is evidence to show that radiotherapy even at low doses can cause malfunction or failure with potentially life-threatening consequences.<sup>11</sup> Given this risk, all radiotherapy centres should have policies in place to support the safe delivery of radiotherapy in patients with CIEDs.<sup>1</sup>

In 2014, a multidisciplinary working party was established with the aim of providing national guidance for clinicians, therapy radiographers and medical physicists on the management of cancer patients with a CIED who are receiving radiotherapy.

This document reviews the evidence and literature to determine current 'gold standard' practice and provides recommendations for the management of cancer patients who have a CIED and are receiving radiotherapy.

## **2. Summary of recommendations**

- CIEDs should not be placed directly in the radiotherapy treatment beam
- The cumulative radiotherapy dose received by a pacemaker should not exceed 2Gy
- Patients with rate-adaptive pacemakers should be reviewed by cardiology and consideration given to temporary deactivation of the sensor whilst receiving radiotherapy
- The cumulative radiotherapy dose received by an ICD should not exceed 0.5Gy
- The photon beam energy should be  $\leq 10\text{MV}$

- The dose contribution from on-treatment verification imaging should be taken into account when calculating cumulative radiotherapy dose
- The patient's cardiologist should be informed in advance of any planned radiotherapy for advice on monitoring during radiotherapy and subsequent follow-up
- Patients with CIEDs should be fully informed of the potential short and long-term risks of radiotherapy. This should be included in patient information available from the cardiology department in addition to radiotherapy patient information
- Patients should be allocated an appropriate risk categorisation group as defined in table 1
- Monitoring requirements based on the patient's risk categorisation group should be implemented
- Appropriately trained staff should be involved in CIED monitoring during radiotherapy

### **3. Patient management**

The management of CIED patients undergoing radiotherapy is summarised in table 2. The roles and responsibilities of staff involved in the management of these patients is summarised in table 3.

#### **3.1 Before radiotherapy**

All patients should be screened for the presence of a CIED as part of the radiotherapy planning process. Once these patients have been identified, CIED information should be annotated as stated on the patients' CIED identification card. Staff should be aware that some cardiologists place the CIED on the patients' right side if they are left-handed. Anecdotal evidence from a national review showed that in some cases, a CIED is not discovered until a patient attends for radiotherapy.<sup>1</sup> This results in treatment being delayed or proceeding without safety measures in place. Planned radiotherapy treatment details should be recorded as per standard practice. The cardiology team should be informed as soon as possible to facilitate patient review before radiotherapy with the aim of establishing CIED functionality. The purpose is to detect any possible change in pacing-dependency of the patient. If an examination of technical CIED function has not been conducted within the previous three months, it is recommended that it should be carried out prior to the patient commencing radiotherapy. The Cardiologist should also recommend appropriate CIED monitoring during and after radiotherapy. Patients with rate-adaptive CIEDs must be reviewed by cardiology before a planned course of radiotherapy begins and consideration given to deactivating the sensor.

##### **3.1.1 Radiotherapy planning**

If the CIED is near or in the anticipated treatment field or volume, it should be included in the planning CT scan. This will allow accurate estimation of the cumulative radiotherapy dose received by the CIED. The CIED should not be in the planning target volume (PTV) in order to minimise the dose to the device. Radiotherapy beam energy no greater than 10MV should be used to

avoid neutron contamination.<sup>6,9,20</sup> The medical physics team should be informed of the presence of a CIED and every effort should be made in the planning process to limit the cumulative dose to the device.

### **3.1.2 Risk group**

It is not possible to predict the exact behaviour of any given CIED when it is in, or in close proximity to, the radiotherapy treatment field.<sup>9</sup> Research indicates that the risk of CIED malfunction increases as the cumulative radiation dose to the CIED increases. In addition, the risk to the patient is greater if the patient is pacing-dependent. These include patients whose pacemaker is pacing all the time (and who are at risk of asystole if the pacemaker malfunctions), and patients with a resynchronising pacemaker where the patient may be at risk of increased heart failure symptoms in the event of device malfunction.

Patients with a pacemaker should be allocated a risk group based on their pacing dependency and estimated cumulative radiotherapy dose received. In 2015, Gauter-Fleckenstein et al proposed a risk categorisation that incorporates these two parameters (table 1).<sup>9</sup>

#### **Low risk patients:**

- Pacemaker independent, and the device is anticipated to receive a cumulative radiotherapy dose of less than 2Gy.

#### **Medium risk patients:**

- Pacemaker dependent, and the device is anticipated to receive a cumulative radiotherapy dose of less than 2Gy
- Pacemaker independent and the device is anticipated to receive a cumulative radiotherapy dose of between 2Gy and 10Gy.

#### **High risk patients:**

- Pacemaker dependent, and the device is anticipated to receive a cumulative radiotherapy dose of between 2Gy and 10Gy
- All patients (pacemaker dependent and independent) and the device is anticipated to receive a cumulative radiotherapy dose of more than 10Gy.

Patients with an ICD in situ should be regarded as high risk. The estimated cumulative radiotherapy dose to the ICD should not exceed 0.5Gy.

For all CIEDs, the potential dose received from on-treatment verification imaging should also be taken into account. This is especially important with ICDs, which have a much lower recommended maximum cumulative radiotherapy dose of 0.5Gy.

In patients identified as being medium or high risk, the clinical oncologist should liaise with medical physics to discuss how to optimise the patient's radiotherapy plan and limit the cumulative dose to the CIED. If after optimisation of the radiotherapy plan the estimated cumulative dose exceeds those outlined above then a review of management options should take place.

If radiotherapy is felt to be the most appropriate management option, it is recommended that the clinical oncologist should liaise with the cardiology department.

### **3.1.3 Consent**

Patients consenting for any type of treatment need to be informed of potentially serious side effects related to that treatment. During the consent process the clinical oncologist should discuss the potential damage to the CIED during and after radiotherapy. Patients should be told they will be subject to close monitoring during treatment and further follow-up after radiotherapy has finished. Given the lack of contemporary research in this area, it is not possible to quantify this risk of damage or harm at present, but discussion of potential complications should take place for all patients with a CIED. Patients with rate-adaptive CIEDs may have their sensor deactivated for the duration of radiotherapy treatment. It is important that the implications and risks of this are fully discussed with the patient by the cardiology team before any planned radiotherapy. ICDs are considered susceptible to radiotherapy damage at lower doses than pacemakers. For this reason, all ICD patients should be informed about the possibility of malfunction or failure resulting from radiotherapy treatment as the complications may be life threatening. ICD patients should be informed in advance of radiotherapy that their device will be deactivated using a magnet during treatment.<sup>9,19,20</sup>

### **3.2 During radiotherapy**

All patients with CIEDs should be monitored with a continuous ECG strip during their first radiotherapy treatment.<sup>9,18-20</sup> This strip should then be reviewed for any evidence of pacing disruption when radiotherapy is being administered. Particular attention should be given to any pacing discrepancies when the radiation beam is turned on and off. If the patient is classified as low risk (cumulative dose to the cardiac device is <2Gy and the patient is non-pacemaker dependent) and there are no changes on the ECG monitoring, further monitoring is not required during the remainder of the radiotherapy treatments. If the patient is classified as medium or high risk (cumulative dose to the cardiac device is >2Gy or the patient is pacemaker dependent or has an ICD) they will require ECG monitoring throughout the course of their radiotherapy.<sup>6</sup> Patients who have an ICD require daily monitoring owing to their device being deactivated during radiotherapy treatment. The patient should be observed during treatment with audiovisual monitoring. Monitoring staff should document any changes in the patient's physical status, and any changes in the ECG trace should be documented and reviewed after every radiotherapy treatment. The minimum level of training received by monitoring staff should include Immediate Life Support (ILS) and appropriate resuscitation equipment should be available at all times. If therapeutic radiographers are monitoring patients, they should receive specific training on the management and monitoring of these patients. If at any point malfunction is suspected or detected, the clinical oncologist and cardiologist should be immediately informed.

ICDs have a much lower cumulative radiotherapy dose limit of 0.5Gy.<sup>9,19,20</sup> ICDs should be deactivated prior to the patient's daily radiotherapy treatment

by placing a magnet over the device to prevent inappropriate therapy or shock delivery as a result of accidental sensing of radiation interference. When deactivating ICDs, there should be the ability to externally pace the patient if appropriate. Defibrillation devices available should be able to deliver external pacing and staff with Advanced Life Support (ALS) training or an ability to deliver external pacing should be available.

### **3.3 After radiotherapy**

The importance of both short and long term follow-up monitoring for patients who have a CIED and have received radiotherapy was highlighted in a paper by Last.<sup>5</sup> Patients should have their cardiac device checked within two weeks of completion of their radiotherapy and then one, three and six months after treatment. Devices exhibiting signs of dysfunction should be followed-up with increased frequency. This will allow discrimination to be made between a temporary dysfunction that may occur owing to a build-up of charge within the semiconductor, and more permanent circuitry damage.<sup>21</sup> Should any additional changes be observed during the follow-up period then immediate device revision is likely to be necessary.

**Table 1:**

Risk categorisation determined by dependence and cumulative radiotherapy dose to pacemaker

	<b>&lt; 2Gy</b>	<b>2 – 10Gy</b>	<b>&gt; 10Gy</b>
<b>Pacing independent</b>	Low risk	Medium risk	High risk
<b>Pacing dependent</b>	Medium risk	High risk	High risk

**Table 2:**  
Summary of management of CIED patients receiving radiotherapy

<b>Before radiotherapy</b>	
Consultant clinical oncologist highlights CIED status	
CIED information annotated as stated on the patient device identification card: <ul style="list-style-type: none"> <li>• Type of device: eg bradycardia pacemaker, resynchronising pacemaker, ICD, or combined pacemaker/ICD, resynchronising pacemaker/ICD</li> <li>• Manufacturer</li> <li>• Make</li> <li>• Model</li> <li>• Date of implantation</li> <li>• Implantation site</li> <li>• Patient dependence on CIED</li> </ul>	
Radiotherapy treatment details recorded <ul style="list-style-type: none"> <li>• Radiotherapy treatment site</li> <li>• Radiotherapy prescription</li> <li>• Radiotherapy treatment technique</li> </ul>	
Clinical oncologist should liaise with patient's cardiology department regarding: <ul style="list-style-type: none"> <li>• Monitoring requirements</li> <li>• Requirement for device reprogramming or deactivation</li> <li>• Follow-up and review appointments</li> </ul>	
CIED to be included in CT planning scan if close to anticipated radiotherapy treatment field	
Medical physics calculate estimated cumulative radiotherapy dose to the CIED	
Patients allocated a risk categorisation	
Patients with CIEDs should be fully informed on the potential short and long term risks of radiotherapy and consent appropriately	
<b>During radiotherapy</b>	
Low risk patients	Day one of radiotherapy – audio-visual and ECG monitoring by appropriately trained staff
	Appropriately trained staff determine patient's monitoring requirements for subsequent radiotherapy treatments
Medium risk patients	Audio-visual and ECG monitoring by appropriately trained staff for every fraction of radiotherapy treatment
	Weekly CIED check by patient's cardiology department
High risk patients	Potential CIED relocation
	Audio-visual and ECG monitoring by appropriately trained staff for every fraction of radiotherapy treatment
	Weekly CIED check by patient's cardiology department
ICD patients	Day one of radiotherapy – 12 lead ECG should be performed by an appropriately trained staff member as a baseline
	Appropriately trained staff member must deactivate the ICD during radiotherapy treatment by placing the specialist magnet over the ICD
	Audio-visual and ECG monitoring by appropriately trained staff for every fraction of radiotherapy treatment
	Weekly ICD check by patient's cardiology department
<b>After radiotherapy</b>	
CIED device check up, two weeks after radiotherapy treatment by cardiology department	
Cardiology follow-up one, three and six months after radiotherapy treatment or as advised by cardiology department	

**Table 3:**

Roles and responsibilities of staff involved in the management of CIED patients receiving radiotherapy

<b>Clinical oncologist</b>
Identify patient's CIED status and highlight on radiotherapy referral form
Contact patient's cardiology department before commencing their radiotherapy treatment
Request cardiology assessment / CIED device check
Provide medical physics with information to calculate cumulative radiotherapy dose to CIED
Check the dose to the pacemaker does not exceed 2Gy
Check the dose to the ICD does not exceed 0.5Gy
Consent – patient aware of potential adverse effects of radiotherapy on CIED
Consent – patient aware that ICD will be switched off during radiotherapy
<b>Planning radiographers</b>
Annotate patient's CIED status
CIED included in CT planning scan if in/close to the radiotherapy treatment field
Medical physics informed of patient's CIED status
No direct placement of CIED in radiotherapy beam.
Limitation of radiotherapy beam energy to 10Mv.
Contact consultant clinical oncologist if the CIED is within the radiotherapy treatment field or the estimated cumulative dose is too high
<b>Appropriately trained radiographers</b>
Assess patient prior to commencing their radiotherapy treatment
Highlight patient's monitoring requirements
Monitor the patient during their radiotherapy treatment
If the patient has an ICD, deactivate the device during each fraction of radiotherapy treatment
Arrange follow-up appointment with the patient's cardiology department
<b>Treatment radiographers</b>
Do not commence patient's radiotherapy treatment without ensuring correct procedure has been followed
Do not commence patient's radiotherapy treatment without the presence of the appropriately trained staff to monitor the patient
Read and be conversant in CIED department policy
<b>Medical physics</b>
Calculate estimated cumulative radiotherapy dose to the CIED and leads prior to the patient commencing radiotherapy treatment. Previous radiotherapy courses received must be taken into consideration.

## **4. Evidence review**

### **4.1 Methodology**

A multidisciplinary working party was established to provide guidance for the management of cancer patients with a CIED who are receiving radiotherapy. The Cochrane Library and Medline via OVID were searched for articles, guidelines and systematic reviews. The search was performed in January 2014, combining search terms 'radiotherapy' or 'radiation therapy', 'pacemaker', 'ICD'. In addition 'hand searching' of relevant clinical journals, guidelines and meeting abstracts was carried out.

### **4.2 CIED technology**

The number of patients with CIEDs undergoing radiotherapy treatment is increasing.<sup>2,3,4</sup> Although most medical treatments pose little danger to the functioning of CIEDs, radiotherapy has the potential to cause device malfunction.<sup>5</sup> The design and technology of CIEDs has evolved, allowing improved efficiency and functioning. Over the past three decades the use of complementary metal-oxide semiconductor circuits in cardiac devices has expanded.<sup>6</sup> These are more sensitive to ionising radiation than the older bipolar semiconductor devices used previously, possibly resulting in damage to the hardware and software components.<sup>7</sup> Damage could be transient, with dropped beats, transient inhibition, altered sensitivity, increased or decreased pulse width and frequency or triggering of pacemakers. Severe damage caused by radiation may lead to catastrophic failure of the cardiac conduction system in the device.<sup>8</sup>

### **4.3 Pacemakers**

The AAPM report recommends that the maximum dose to a pacemaker should be limited to less than 2Gy.<sup>18</sup> A study by Mouton et al supported the AAPM recommendations.<sup>8</sup> In their in vitro study, ninety-six patients having thoracic radiotherapy whose pacemakers were adjacent to the radiotherapy treatment field exhibited a range of short and long-term side effects. Results showed that one pacemaker exhibited clinically significant disturbances at a dose rate of 0.2Gy/min at a cumulative dose of only 0.15Gy, two pacemakers exhibited defects at a cumulative dose of 1Gy and nine pacemakers failed at a cumulative dose of 2Gy.<sup>8</sup> Hurkmans et al directly irradiated nineteen new pacemakers; the commonest damage reported was loss of output.<sup>11</sup> In contrast, in the Mouton study only one pacemaker malfunctioned below 50Gy, suggesting modern pacemakers may be relatively radioresistant.<sup>8</sup> The authors concluded that the AAPM recommendations were still valid. Importantly, in the Mouton study, pacemakers were not returned to the manufacturers for a more detailed analysis after irradiation, so potentially significant damage may have been missed. There is little in the academic literature on the effect of radiotherapy on rate-adaptive CIEDs. It is the authors' observation (unpublished) that they may be influenced by radiotherapy, causing temporary increased sensor rate and tachycardia. Other potential effects of radiotherapy on CIEDs include temporary loss of sensing, temporary device inhibition, temporary loss of capture and device reset [St Jude Medical – Effect of Therapeutic Radiation on St Jude Medical

Implantable Cardiac Rhythm Devices, October 2013]. This observation is also recognised in the Frizzell review.<sup>19</sup>

#### **4.4 ICDs**

Frizzell published a more contemporary review of CIEDs and radiotherapy, concluding that the AAPM recommendations were no longer comprehensive as ICDs were not discussed.<sup>19</sup> ICDs are more sophisticated and have the ability to automatically defibrillate the heart by monitoring the patient's heart rate and deliver the appropriate electrical therapy. Frizzell recommended a lower radiotherapy tolerance dose of 0.5Gy for ICDs. This tolerance dose is partly based on work by Hurkmans et al who directly irradiated 11 ICDs. This study observed that the dose at first malfunction was as low as 0.5Gy.<sup>19</sup> It is also recommended that ICDs should be deactivated prior to each fraction of radiotherapy by placing a magnet over the device to prevent inappropriate therapy or shock delivery as a result of accidental sensing of Electromagnetic Interference (EMI).

#### **4.5 Beam energy**

Gelblum et al reported on 33 patients with ICDs receiving radiotherapy. Two ICDs were reset to the factory settings during treatment for pelvic cancers with 15MV photon beams.<sup>20</sup> Elders et al reported on 15 patients with ICDs who underwent radiotherapy treatment on linear accelerators with beam energies of between 6 and 18MV. In total, six ICD malfunctions were found, and all occurred with beam energies  $\geq 10$  MV.<sup>22</sup> Both authors postulated that the cause of the ICD malfunctions was related to neutron production with higher energy beams. This has led to other guidelines recommending that photon beam energy is kept to  $\leq 10$  MV when treating patients with CIEDs.<sup>6</sup>

#### **4.6 CIED leads**

No published guidelines make reference to lead dose. The consensus view is that leads are relatively insensitive to radiation damage compared to CIEDs.<sup>6</sup> However, there is no evidence to inform dose constraints to CIED leads and so, in the authors' view, every effort should be made to keep the leads out of the treatment field. If this is not possible, then the dose to the lead should be kept as low as possible.

#### **4.7 On-treatment verification imaging**

No published guidelines make recommendations on the potential contribution of imaging techniques to the CIED cumulative dose. Murphy et al reported that the dose from a kilovoltage cone beam CT scan is likely to be in the region of 10-80mGy.<sup>23</sup> Kan et al reported mean skin doses of 6.4cGy per kilovoltage cone beam CT chest scan.<sup>24</sup> Even using the lower limit of 10mGy from Murphy et al, it is possible that daily cone beam CT in a 20-fraction radical lung treatment may contribute as much as 0.2Gy. Using the Kan et al skin dose estimates, it is possible the CIED may get significantly more than 0.2Gy. An estimation of the dose contribution from the image verification method used should be made, and this should be taken into consideration when allocating CIED patients to a risk group.

## **5. Audit procedure**

Radiotherapy centres should conduct a regular audit looking at guideline implementation.

The following compliance standards should be included in the audit:

- Radiotherapy tolerance doses used for the specific CIEDs
- Classification of patient risk category
- Adherence to patient management pathway and implementation
- Adherence to monitoring procedures
- All staff members aware of their roles, responsibilities and scope of practice

## **6. Implementation**

Radiotherapy centres should circulate this document to all relevant staff. Consideration should be given on how best to implement the recommendations and audit adherence to these recommendations. Adaptation of the guideline may be appropriate to best reflect local practice and expertise.

## **7. Staff and department requirements**

- All staff involved in the requesting, planning and delivery of radiotherapy should be aware of the guideline and their role in ensuring appropriate and safe management of patients with CIEDs
- Communication links between the radiotherapy and cardiology departments is vital. Staff should be aware of who to contact and how to seek advice
- Monitoring staff should receive specific training on the management of CIED patients
- The radiotherapy department is responsible for training the staff
- The radiotherapy department is responsible for the availability of appropriate equipment for monitoring of patients

## **8. Conclusion**

This is a guideline on the safe management of patients with a CIED receiving radiotherapy. It is based on current best evidence, and should be used and adapted to best suit local practice in radiotherapy departments.

## 9. Pacemaker manufacturer documents

### **Biotronik:**

Biotronik, Product information 512, Radiation Exposure of Implanted Pacemakers. 1-2, Berlin, Germany, 5/18/2001; 2001. p. 1-2.w

### **Boston Scientific:**

Boston Scientific (2012) Therapeutic radiation and implantable device systems.

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### **Medtronic:**

Medtronic (2013) Therapeutic radiation.

[http://www.medtronic.com/wcm/groups/mdtcom\\_sg/@mdt/@corp/documents/documents/crdm\\_sl\\_radiation.pdf](http://www.medtronic.com/wcm/groups/mdtcom_sg/@mdt/@corp/documents/documents/crdm_sl_radiation.pdf)

### **St. Jude Medical:**

St. Jude Medical (2014) Effects of Therapeutic Radiation on St. Jude Medical Implantable Cardiac Rhythm Devices

<http://www.sjm.com/~media/pro/resources/emi/med-dental/fl-therapeutic-radiation-110513.ashx?la=en>.

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