Management of Radiotherapy Patients with Implanted Cardiac Devices

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What is in this presentation?

- Types of ICDs and ICPs.
- Current guidelines – protocol (TG-34).
- What are the issues with cardiac device and radiation deliveries?
- Review of literature since TG-34 area.
- Failures – case reports and scattered guidelines.
- Sensitivities and potential failures.
- Cardiac devices and RT patients.
- Dose estimation. During RT processes.
- Recommendations.

Implantable Cardioverter-Defibrillators

An overwhelming majority of sudden cardiac deaths from coronary disease (approximately

FIG. 3. [Top]: Five ICDs [Left to Right]: InSync Maximo model 7304, Concerto model C154DWK (VVE-DDDR), Entrust model D154ATG, Maximo DR model 7278, and Virtuoso model D154AWG; [Below]: four implantable pacemakers: Adapta model ADDR01, Versa model VEDR01, Sensia model SEDR01, and Enpulse2 model E2DR01.

b. c.

TG-34 … ology Patients with … kers (1994)

VII. SPECIFIC RECOMMENDATIONS

The following protocol is suggested when evaluating patients for radiation therapy who have an implanted cardiac pacemaker. The task group is cognizant that each patient must be addressed individually and that in some cases it may be in the best interests of the patient to diverge from the recommendations.

(1) Pacemaker implanted patients should not be treated with a betatron.

(2) Pacemakers should not be placed in the direct (unshielded) therapy beam. Some accelerator beams can cause transient malfunction.

(3) The absorbed dose to be received by the pacemaker should be estimated before tre… can be found in the literature…

(4) If the total estimated d… exceed 2 gray, the pacemaker… prior to therapy and possibly a… week of therapy. Since total an… ers has been seen at cumulati… gray and significant functional changes have been observed between 2 and 10 gray, early changes in pacemaker parameters could signal a failure in the 2-10 gray region.[6]

(5) Although transient malfunction from electromagnetic interference is unlikely from contemporary therapy accelerators and cobalt irradiators, the patient should be closely observed during the first treatment with a linear accelerator and during subsequent treatments if magnetron or klystron misfiring (sparking) occurs.

(6) Studies to date have dealt with linear accelerators, betatrons, and cobalt irradiators only. Use of other radiation therapy machines should be evaluated on an individual basis and approached with caution.

From Med Phys Listservs

045205	2010-03-19	08:53	69	Re: Disposal of an explanted Pu-powered pacemaker: Shipping container, and who pays for disposal?	MEDPHYS
044931	2010-02-18	13:47	53	FW: Pacemakers and Defibrillators	MEDPHYS
044926	2010-02-18	07:50	31	Pacemakers & Defibrillators (3)	MEDPHYS
044914	2010-02-17	09:29	73	Re: Pacemakers & Defibrillators	MEDPHYS
044912	2010-02-17	08:25	24	Pacemakers & Defibrillators	MEDPHYS
044906	2010-02-16	07:59	24	Pacemakers & Defibrillators	MEDPHYS
044540	2010-01-06	19:41	21	Re: Pacemaker measurements etc.	MEDPHYS
044488	2010-01-04	09:40	106	Re: Pacemakers	MEDPHYS
044486	2010-01-04	08:26	52	Pacemaker measurements etc.	MEDPHYS
044483	2010-01-03	16:24	66	Pacemakers	MEDPHYS
044405	2009-12-09	12:54	30	Pacemaker Dose Limits	MEDPHYS
043902	2009-09-10	00:28	29	For Peter Biggs	MEDPHYS

[1] [2] [3] [4] [Next]

INSTITUTE OF PHYSICS PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY
Phys. Med. Biol. 47 (2002) 2879–2893 PII: S0031-9155(02)32606-X

Dose rate study

Influence of high-energy photon beam irradiation on pacemaker operation

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Online at stacks.iop.org/PMB/47/2879

In conclusion, warnings given by manufacturers about the maximum tolerable cumulative radiation doses for safe operation of irradiated pacemakers (5 Gy), even reduced to 2 Gy, are not reliable. The spread of cumulative doses inducing failures is very large since our observations show an important failure at 0.15 Gy, while ten pacemakers withstood more than 140 Gy of cumulative dose. The safe operation of pacemakers under irradiation depends mainly on type and model. It depends also on dose rate. From our observations, for the safe operation of pacemakers, a recommendation of a maximum dose rate of 0.2 Gy min^{-1} rejecting direct irradiation of the pacemaker at a standard dose rate for tumour treatment (2 Gy min^{-1}) is made.

…ND … reports … t … and … lines. … ices … Gy tolerance … artial) … e to … other??

Recent Review Articles

Int. J. Radiation Oncology Biol. Phys., Vol. 59, No. 3, pp. 897–904, 2004
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0360-3016/04/$–see front matter
doi:10.1016/j.ijrobp.2004.02.038

1. Identify patient with ICP/ICD. Notify department personnel involved in direct patient care (i.e., residents, nurses, therapists, and physics staff) and flag treatment chart with readily visible identifier.
2. Determine whether generator is located outside direct, unshielded RT field, and, if not, have device moved. If not possible, have new generator placed at a distance and existing generator deactivated.
3. Estimate cumulative IR dose to generator from proposed treatment and move generator as in No. 2 above for dose estimate >2 Gy for ICP or >1 Gy for ICD.
4. Cardiologist should determine whether patient is pacemaker dependent or nonpacemaker dependent, provide deactivation instructions for ICDs, and full baseline interrogation of ICP/ICD.

Patient management during RT

Results: The published documentation of potential life-threatening malfunction of ICP and ICD devices exposed to electromagnetic interference and ionizing radiation is considerable. However, major discrepancies exist among manufacturer recommendations and wide variations are present among radiation oncology facilities regarding patient management precautions.
Conclusion: Precautions are necessary to minimize the risk to patients with ICP and ICD devices during radiotherapy. Practical management guidelines are presented that can be readily adopted by any busy clinical radiation oncology practice. © 2004 Elsevier Inc.

Limit: 2 Gy scattered dose

Recent Review Articles

CANCER TREATMENT REVIEWS (2005) 31, 474–486

7. The authors suggest categorising the patient into three risk groups based on potential clinical risks. (Low, Medium and High risk groups). Low risk patients are those who are not pacemaker dependent, the pacemaker is not directly in the radiation field and the dose to the pacemaker is likely to be less than 2 Gy of scattered radiation. Medium risk patients are those who are pacemaker dependent, the pacemaker is not directly in the radiation field, and the dose to the pacemaker is likely to be less than 2 Gy of scattered radiation. High-risk patients are those who are pacemaker dependent, the pacemaker is not directly in the radiation field and the dose to the pacemaker is likely to be more than 2 Gy of scattered radiation. Patients with pacemakers directly in the radiation field fall into a high-risk category irrespective of the total radiation dose. Direct radiation of pacemakers at therapeutic levels should be strictly avoided in a pacemaker dependent patient unless a backup system is in place. It has to be noted that the 'radiation dose to a pacemaker' is the 'dose to any part of the device' and is not the dose averaged over the volume of the device.

KEYWORDS Artificial pacemaker; Implantable defibrillators; Radiotherapy; Linear accelerators; Electromagnetic Fields; Radiation damage

Limit: 2 Gy scattered dose

Recent Review Articles

Int. J. Radiation Oncology Biol. Phys., Vol. 63, No. 1, pp. 282–289, 2005
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0360-3016/05/$–see front matter

- The ICD should always be located outside the irradiation field.
- The absorbed dose to be received by the ICD should be estimated before treatment for documentation purposes. Estimation methods can be found in the literature (17).
- Program the ICD temporarily to "monitor only" before each individual irradiation fraction. After consultation with the patient's cardiologist, consider switching the ICD to "monitor only" before the first irradiation fraction and only switch back to therapy mode after the complete treatment is given. Consider that even if the ICD is turned off and on with every treatment fraction, no guarantee can be given that the ICD is still able to deliver a shock if needed.
- Monitor the ECG and have ICD-qualified personnel stand by at every fraction. The treating radiation oncologist might consider omitting (part of) these safety measures if consensus is reached on this aspect with the patient's cardiologist and responsible clinical physicist.
- Have standard cardiopulmonary resuscitation equipment directly available.
- If any change in ICD functioning is observed, directly consult with the patient's cardiologist to decide which steps should be taken next.
- Monitor the ICD during the first months after radiotherapy. If functional changes are observed, consider replacement of the ICD.

Conclusions: The effect of radiation therapy on the ... monitoring and therapy are functional ... antitachycardia therapy, often resulting in a shock ... had already failed at doses below 1.5 Gy. Guidelines ...

Cardioverter-defibrillator, Pacemaker, Radiotherapy

Limit: <1.5 Gy scattered dose

Recent Review Articles

Effects of Scatter Radiation on ICD and CRT Function

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Background: Effects of direct radiation on implantable cardiac devices have been well studied. However, the effects of scatter radiation are not as clear. Recommendations on management of patients with implantable cardiac devices undergoing radiotherapy are based on limited studies mostly involving pacemakers. We sought to elucidate the effects of scatter radiation on implantable cardioverter-defibrillators (ICDs) and cardiac resynchronization therapy (CRT)-ICDs.
Methods: We exposed 12 ICDs and eight CRT-ICDs to 400 cGy of scatter radiation from a 6-MV photon beam. Devices were programmed with nominal parameters and interrogated prior to radiation, after each fraction, upon completion of the radiation course and again 1 week later. A retrospective review of patients undergoing radiotherapy at the Mayo Clinic–Rochester between 2002 and 2007 in whom the device was outside the radiation field was also performed. There were 13 patients with devices undergoing radiotherapy during this time period, 12 of whom were interrogated prior to and after radiation.
Results: Interrogation reports were reviewed for device reset or parameter changes. There was no evidence of reset or malfunction during or after radiation. Also, no episodes of device reset, inappropriate sensing or therapy, or changes in programmed parameters were found in our review of patients undergoing radiotherapy.
Conclusions: Device reset or malfunction associated with scatter radiation likely represents an unpredictable, rare occurrence. While we see no clear contraindication to radiotherapy in patients with ICDs or CRT-ICDs, precautions should be taken to avoid direct radiation exposure and to closely evaluate patient outcomes before and after the radiation course. (PACE 2008; 31:727–732)

Recent Review Articles

Int. J. Radiation Oncology Biol. Phys., Vol. 73, No. 5, pp. 1525–1531, 2009
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0360-3016/09/$–see front matter
doi:10.1016/j.ijrobp.2008.06.1903

CLINICAL INVESTIGATION — Implanted Defibrillator

IMPLANTED CARDIAC DEFIBRILLATOR CARE IN RADIATION ONCOLOGY PATIENT POPULATION

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It is not only the direct photon exposure of a device that must be considered, but also the potential for a single hit neutron particle interaction. Much like radiation damage to a living. We, therefore, advocate that patients with ICDs be treated with low energy (<10-MV) photons whenever possible. Since the institution of that policy, we have not detected any further reprogramming events. We also continue to vigilantly observe these patients, together with their cardiologists, as they go through treatment.

Implanted cardiac defibrillator, Radiotherapy, Patient monitoring.

Single-event upset

Recent Review Articles

EXPERT REVIEWS

Radiotherapy-induced ... ble

Fernando Tondato, Daniel W Ng, Komandoor Srivaths..., Gregory T Altemose, Michele Y Halyard and Luis R Scott†
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Key issues

- There are an increasing number of patients with implantable devices who require radiotherapy (RT) for cancer treatment.
- Ionizing radiation can cause damage to sensitive circuitry existing in current implantable devices.
- There is a lack of clinical studies on effects of radiation on implantable devices but there are several reports of serious device dysfunction after RT.
- Implantable devices should not be placed in the direct therapy beam; however, it is important to emphasize that scattered radiation can also interfere with these devices.
- Other types of energy, such as electromagnetic, can be generated during RT. These can also cause interference with implantable devices.
- There are rare reports of transient device malfunction induced by radiologic imaging tests.
- Current guidelines are outdated and are restricted to pacemakers. Updated guidelines are required, including specific recommendations for implantable cardioverter defibrillators.
- Implantable devices should be closely monitored between radiation sessions.

Recent Review Articles

Journal of Medical Imaging and Radiation Oncology 54 (2010) 53–61

ORIGINAL ARTICLE

Planning

1 3D computer-assisted planning should be utilised (including CT data) to more accurately assess dose received by the pacemaker and aid in beam arrangement and shielding placement.

2 The device should be shielded and kept at least 5 cm from the collimated radiation field wherever possible (including open port films and electronic portal imaging [EPI]). All shielding should originate from the treatment head, such as multi-leaf collimators or pre-mounted lead shielding trays.

3 Total dose received by the pacemaker/ICD should be kept as low as possible.

- Max pacemaker dose should be kept to <2 Gy, or device relocation should be considered. At no point should the cumulative dose exceed 5 Gy
- Max ICD dose <1 Gy, or device relocation should be considered.

Limit: 2 Gy scattered dose ICP
1 Gy scatter dose ICD

Key words: complementary metal oxide semiconductor; implantable cardioverter defibrillator; pacemaker; radiation therapy.

Recent Review Articles

J. Radiat. Res., 52, 516–521 (2011) Regular Paper

Radiation Therapy in Patients with Implanted Cardiac Pacemakers and Implantable Cardioverter Defibrillators:

Patient management before initiation of radiation therapy

1. Identify patients with an ICP or ICD. Notify department personnel involved in direct patient care.
2. Determine whether the generator is located outside the direct, unshielded radiation therapy field, and if not, have the device moved.
3. Estimate the cumulative ionizing radiation dose to generator for dose estimates < 2 Gy for ICP or < 1 Gy for ICD.
4. Have the cardiologist determine whether the patient is pacemaker dependent or non-pacemaker dependent. Provide deactivation instructions for ICDs, and full baseline assessment of the ICP or ICD.

volume histogram in 26 patients (42%) and by measurement of actual doses in 9 (15%). In one patient, the maximum total dose was 2069 cGy; however, in the other patients, the ICP/ICD ... Function of ICPs and ICDs was checked before radiation therapy in 38 patie... apy in 32 (52%), and both before and after radiation therapy in 29 (47%). ... patient with prostate cancer treated by intensity-modulated radiation therapy to the prostate. Even when an ICP or ICD is not within the field of radiation, malfunction of the device may still occur. To minimize the risk to patients, precautions must be taken during the planning and administration of radiation therapy.

Limit: 2 Gy scattered dose IDP
1 Gy scattered dose ICD

Soon thereafter a lump was discovered in the right breast. A needle biopsy showed an infiltrating ductal carcinoma and a right simple mastectomy was performed. Postoperative radiation therapy was advised and consisted of delivery of 1000 rads per week through each of 5 ports. Treatments were given with 4-MeV photons at a source to skin distance (SSD) of 80 cm, using a Varian Clinac-4 linear accelerator. One port, the "right supraclavicular fossa" encompassed the area occupied by the pacemaker generator. When the first treatment was given in July, 1981, the electrocardiogram was monitored to determine whether there was any alteration in pacemaker function secondary to electromagnetic interference from the linear accelerator. There was no evidence of pacemaker malfunction.

At a dose of 3000-3600 rads she developed a tachycardia. The electrocardiogram, (Fig. 1) showed that the atrial pacemaker was firing irregularly at a rate of 320 beats/min.

...n Therapy

...BERT S. HEUSINKVELD, and

...rsity of Arizona Health Sciences Center,

...ion therapy. Pacemaker malfunction oc... upied by an A-V sequential pacemaker. ...function of the large scale integrated cir... duced effects. The newer multiprogram... hose previously available. (PACE, Vol. 5,

...acemaker

Analysis of the removed generator showed that pacemaker failure was due to malfunction of the large scale integrated-complementary metal oxide semiconductor (LSI-CMOS) circuit and the type of damage was consistent with radiation-induced effects.

CASE REPORT

The Cardiac Pacemaker Patient

Might the Pacer be Directly Irr...

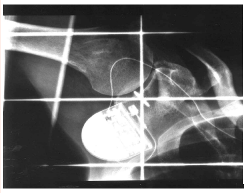
Alexander Tsekos, Felix Momm, Mi...

From the Universitätsklinikum Freiburg, Ge...

Correspondence to: A.Tsekos, MD, Radiolo... Freiburg, Germany

Acta Oncologica Vol. 39, No. 7, pp. 881–883, 2000

Received 13 January 2000
Accepted 22 June 2000



Radiotherapy course. The patient received radiotherapy as an inpatient. Figure 1 shows the pacer in the treatment field. During each fraction we performed an ECG and observed the rhythm on a monitor outside. The cardiologist was with us during the first fraction, and on stand-by for the further fractions. Pacer-function analyses were completed before, in the middle (3 weeks later) and after the radiation course. We irradiated the lymphatic nodes in the right axilla up to a dose of 50.4 Gy without problems. At a fractionation of 5× 1.8 Gy per week, it took us about 6 weeks. The pacemaker functioned without failure during every fraction, but the magnetic frequency of the pacer, which is usually an indicator of the battery load, began to decrease.

After the radiotherapy course, the magnetic frequency was below the recommended exchange criteria, but at no time was there a malfunction. At the next control the magnetic frequency was unchanged at 88/min. The pacemaker's stimulation frequency remained at the programmed rate. Four months later, the magnetic frequency returned to normal, indicating a normal battery charge.

Since the end of the radiation course, the pacemaker has functioned perfectly. Follow-up was at 26 months at the time of this report. The patient has been in complete remission since then.

ELSEVIER

International Journal of Cardiology 130 (2008) e37–e38

International Journal of Cardiology

www.elsevier.com/locate/ijcard

Letter to the Editor

Defibrillator reset by radiotherapy

Dennis H. Lau, Lauren Wilson, Martin K. Stiles, Bobby John, Shashidhar, Hany Dimitri, Anthony G. Brooks, Glenn D. Young, Prashanthan Sanders *

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Received 3 May 2007; accepted 30 June 2007
Available online 27 September 2007

Abstract

The number of patients with implantable cardioverter–defibrillator (ICD) is rapidly increasing due to their expanding indications. Amongst the various types of electromagnetic interferences, little is reported about the effects of radiotherapy. We report a case of electrical reset of a single chamber ICD by scattered irradiation from radiotherapy.

Keywords: Implant...

ICD response to therapeutic radiation is generally unpredictable and may potentially involve various parameters incorporated in individual ICD models. Recognition of other potential lethal events such as complete device failure, inappropriate shocks due to over-sensing and sudden death are vital in our management of such patient groups.

Case Reports of Failures

Case Reports

Angiology Volume 60 Number 4 August/September 2009 509-512 © 2009 The Author(s) 10.1177/0003319708315305 http://ang.sagepub.com

Life-Threatening Pacemaker Dysfunction ... Radiation:

...bert Hawlicek, MD,

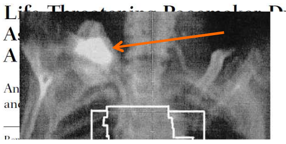
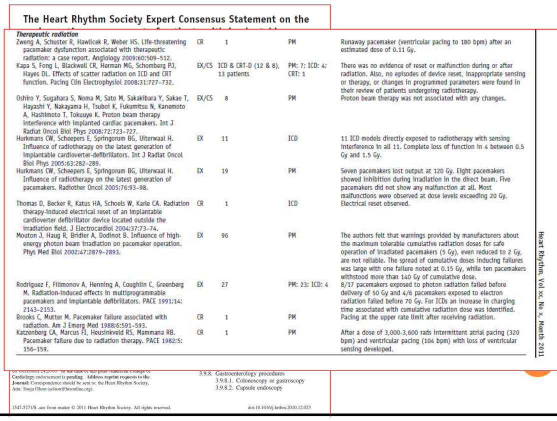


Table 1. Case Reports About Irradiation-Induced Pacemaker/ICD Failure

Reference No.	Year	Type of Radiation	Dose (Gy)	Type of Failure	Consequence	In/Out[a]	Device
8	2004	Linear accelerator	56	Electrical restart	None	Out	Medtronic/VVI-ICD
9	1988	Cobalt 60	35	Runaway	Replacement	In	Intramedics/DVI
10	2003	Not reported	50	Loss of communication	Replacement	In	Vitatron/DDD
11	1991	Linear accelerator/betatron	50	Deprogrammed device	Replacement	Out	Medtronic/?
12	1984	Linear accelerator	19.8	Fixed ventricular rate	Replacement	In	Intermedics/VVI
13	1986	Linear accelerator	84.6	Runaway	Replacement	Out	Intermedics/DVI
14	1982	Linear accelerator	36	Runaway	Replacement	In	Intermedics/DVI
15	1994	Neutrons	4.8	Runaway	Replacement	Out	Pacesetter/VVI
16	1983	Linear accelerator	20	Runaway	Replacement	In	Intermedics/DDD

Note: ICD = implantable cardioverter/defibrillator.
a. Device lying in or outside the radiation field.

HEART AND RHYTHM SOCIETY CONSENSUS STATEMENT (2011)



NEW TASK GRO

SENSITIVITIES AND POTENTIAL FAILURES

- Permanent damage from accumulated dose → circuitry is degraded in proportion to accumulated dose:
  - Decrease of output amplitude
  - Increase current drain (not obvious-can lead to sudden failure within months past RT)
  - Erroneous or failed sensor operation (including heartbeat sensing functions)
- Upsets in memory or logic circuits caused by neutrons-SOFT ERRORS:
  - Changes in stored values in memory or transient changes in micro-processor circuitry
  - May not be functionally recoverable
  - Reset of the device → reversion to default parameters
  - Rare cases where reset may delay for hours or even weeks past RT.
- Transient interference from high-dose-rate x-rays (not EMI):
  - Transient effect-no permanent damage, unless accumulated dose is high→
    - Inappropriate sensing of device that lead to ICD shock
    - Non-existent pacing output
    - Reset or other effects
- Electromagnetic interference (EMI) are minimal and of transient nature:
  - ICPs
    - May sense the field as myocardial potential → inhibition of output
    - Inappropriate re-programming
    - Shut off reed switch → fixed pacing
    - Triggering of output
  - ICDs
    - Possible re-programming, transient effect

SOURCES OF POTENTIAL MALFUNCTIONS FOR ICDS & ICPS DURING RT PROCESSES

- Imaging for treatment planning (CT mostly).
- Imaging for Image Guidance (CT, Rad., EMI)
- RT treatment delivery (photons, protons, neutrons, particles, other)
- Use of high energy photons, E>10 MV?
- Dose rate?
- IMRT, SBRT, VMAT, FFF beams, etc.
- Other…

PERIPHERAL DOSES IN PHOTON BEAMS

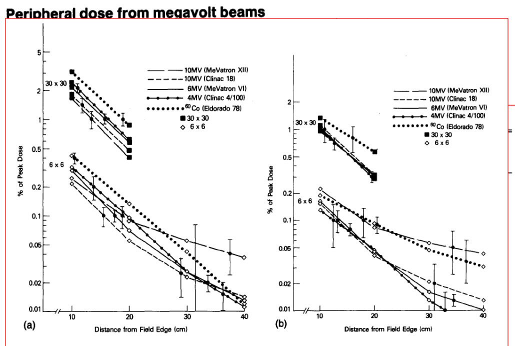


FIG. 7. Scatter component of the PD. (a) Data for 30×30 and 6×6 fields at 10-cm depth. (b) Same at depth = d_{max}. Error bars are indicative of spread between different methods of determination. See the text.
*Mevatron XII.

Dose Estimation: Photon out-of-filed dose

Wedges

Physical wedges ➔ increase out of field dose by 2-4 times (Sherazi et al, 1985, Int J Radiat Oncol Biol Phys)

Dynamic or universal wedges ➔ no increase (Li et al, 1997, Int J Radiat Oncol Biol Phys)

MLC

Secondary MLC ➔ no impact on out-of-field dose (Mutic et al, 2002, J Appl Clin Med Phys)

Tertiary MLC is extra shieding ➔ decrease out of field dose by 30-50% (Stern, 1999, Med Phys)

Radiotherapy & Oncology

3.1. Constraints and limitations

When using the program the user has to realize that certain constraints have to be considered. The PD percentages which form the basis for the calculations, are related to the dose at d_{max}. This is easy for SSD treatments, but for isocentric techniques the user has to calculate the dose at d_{max} from the dose at isocentre. For non-coplanar, non-orthogonal beams, the program should be used with caution

$CRR = CRR \times f_{att}$ (step 10)

In these equations the parameters and correctio[…] are defined as follows:

PD% = peripheral dose in % of dose at d_{ma}[…]
f_{MV} = correction for photon energy
$f_{thickn.}$ = correction for patient thickness alo[…] axis
f_{depth} = correction for depth of PD point
f_{couch} = (optional) correction for couch atten[…]
f_{elong} = correction for field elongation
f_{wedge} = correction if wedge is used
f_{CRR} = fraction of PD contributed by c[…] related radiation
f_{block} = correction if shielding blocks are used
f_{att} = attenuation correction of CRR for depth of PD point

2.2. Tangential beams

The program also offers the option to calculate the PD for

Abstract

A software progra[…] calculation is based […] wedges and shieldin[…] Elsevier Science Ire[…]

Keywords: Peripheral […]

```
Total Number of Beams:                2

Contribution of Beam number 1:(Left anterior oblique)
          Peripheral Dose:            7.5 cGy
          Leakage and External Scatter:  5.9 cGy

Contribution of Beam number 2:(Right lateral)
          Peripheral Dose:            12.4 cGy
          Leakage and External Scatter:  9.8 cGy
```

Fig. 2. Print of the results of the 2-beam calculation for which the input is shown in Fig. 1.

Key words: radiation therapy, fetus

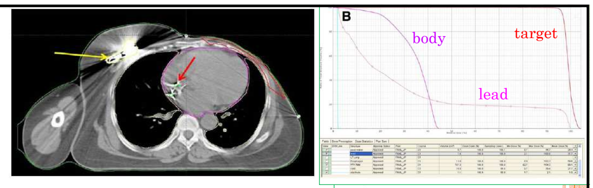
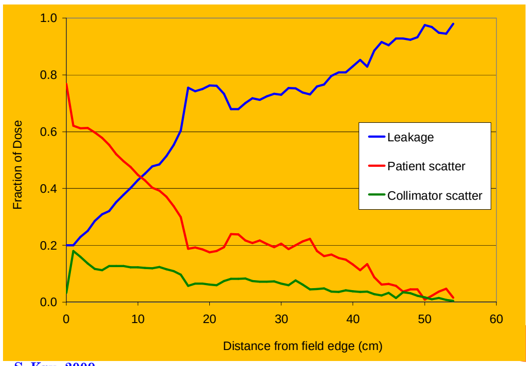


Fig. 1. Axial computed tomography slice showing contouring of the leads (red arrowhead) and body (yellow arrowhead) of a pacemaker in a case of left-sided breast cancer.

Pre-radiotherapy

Take a detailed cardiac history.
Consult a cardiologist for recording baseline cardiac and pacemaker function (full device interrogation and electrocardiography).
Liaise with a cardiologist and a pacemaker centre to know dependency rates, the need to reprogramme pacemakers and threshold doses.
Assess the necessary level of cardiac monitoring for individual patients.
Estimate the absorbed dose to the pacemaker and keep <10 Gy using asymmetric jaws, blocks, multileaf collimators and wedges wherever appropriate.
Reposition the pacemaker if a safe dose cannot be achieved or if pacemaker is located within 3 cm of proposed radiotherapy portal to avoid inaccuracies in dose calculation.
Notify department personnel involved in direct patient care.
Avoid using magnetic resonance imaging or positron emission tomography in radiotherapy planning as these are potential sources of electromagnetic interference .
Always contour the pacemaker body, electrode and lead separately as an organ at risk.
Treatment on a linear accelerator has a higher chance of electromagnetic interference than a cobalt unit, may be considered in select high-risk patients.
Always opt for another non-radiotherapy treatment modality if it will be safer and equally valid.
Consider using brachytherapy in appropriate cases.

What about IMRT?



S. Kry, 2009

What about SBRT and filter-free beams?

ORIGINAL ARTICLE

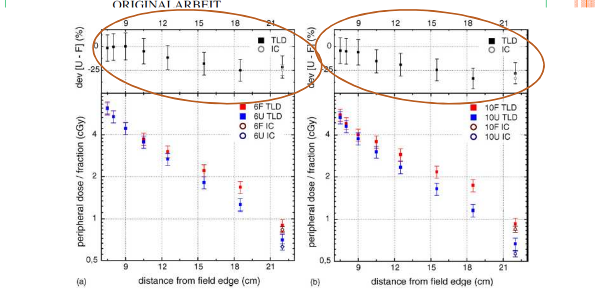
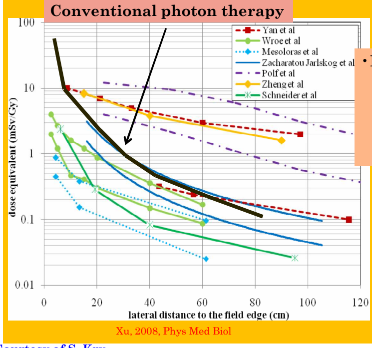


Figure 5. Results of peripheral dose measurements (in the isocentric plane) as a function of the distance from the field edge for the lung SBRT plans with a) 6 and b) 10 MV flattened and unflattened beams. The relative percentage reduction in peripheral dose (dev [U - F]) achieved by using FFF beams when compared to FF beams is indicated in gray in the top part of the figure.

scattered dose outside the field.

Dose Estimation: Proton out-of-filed dose

- *How much dose equivalent is there?*



Xu, 2008, Phys Med Biol

Variations in beam

- Photons:
  - More dose near treatment field
  - Comparable dose beyond 10-20 cm from field edge

Size and material of phantom, manufacturer of accelerator

Challenges in Dosimetry
Lack of high energy response

Unique machines

Courtesy of S. Kry

Check list for patient management

- **Initial Consultation**
  - CIED alert added to patient's chart
  - Copy of CIED card made and filed in patient's chart
  - Appointment with Cardiac Electrophysiology (EP) scheduled
- **Simulation Check**
  - Patient was evaluated by EP to verify dependence on device
  - Verify CIED alert added to patient's chart
  - Verify treatment planning directive completed by physician
  - Note added to planning directive to only use 6X photons and avoid wedges where possible
  - Contact vendor for dose limit recommendations

- **Planning check**
  - Verify only 6X photons used for treatment

- **Dose to pacemaker > 2 Gy (?)**
  - Inform Rad-Onc physician
  - Contact EP to inform them of dose and discuss monitoring strategy
    - Move device
    - Adjust monitoring frequency
    - Schedule EP follow on-set for all treatment fractions
    - No monitoring necessary

  - Verify imaging field does not irradiate CIED
  - Read dosimeter and generate summary of reading for physician

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  - **2012 AAPM Scientific Planning Committee and Program Directors.**

THANK YOU