PLACE 2022 - Cardio-Oncologia: Update 2022

Gestione dei PMK-ICD nella Chirurgia Oncologica e nella RadioTerapia del Torace-Testa-Collo

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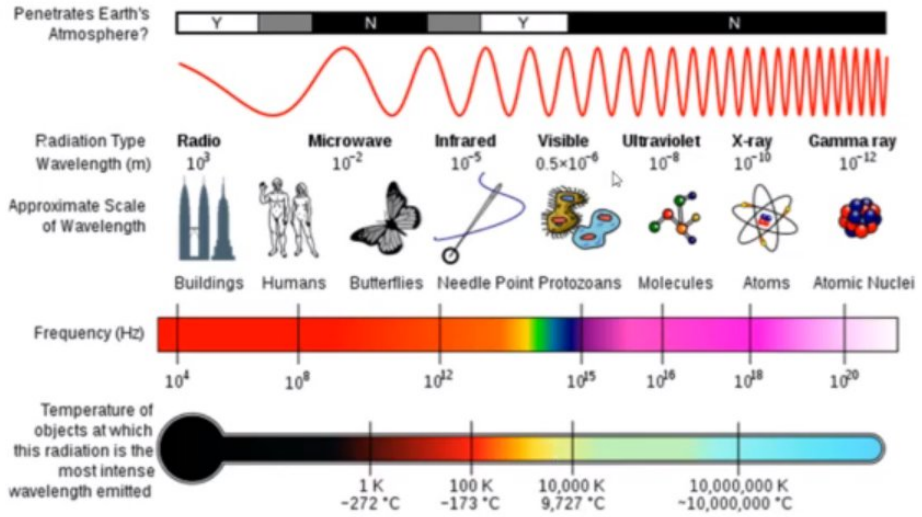
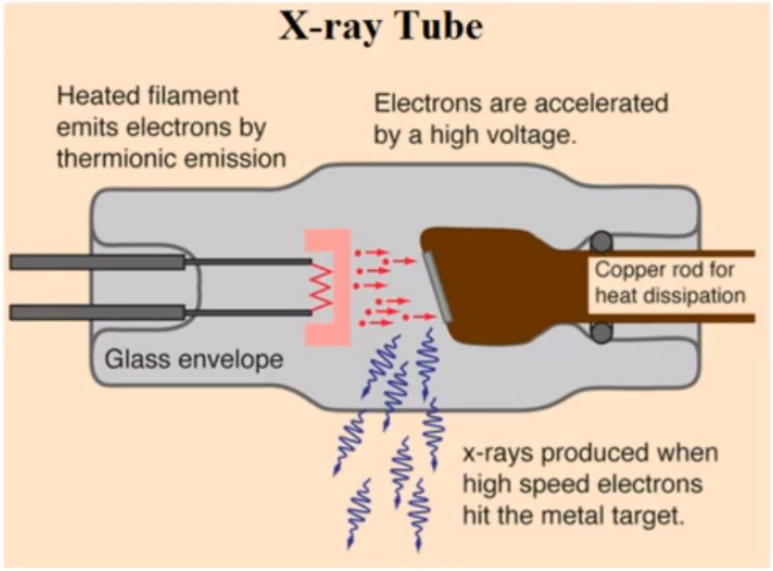
Divisione di Cardiologia

Ospedale S. Maria del Carmine – Rovereto (TN)

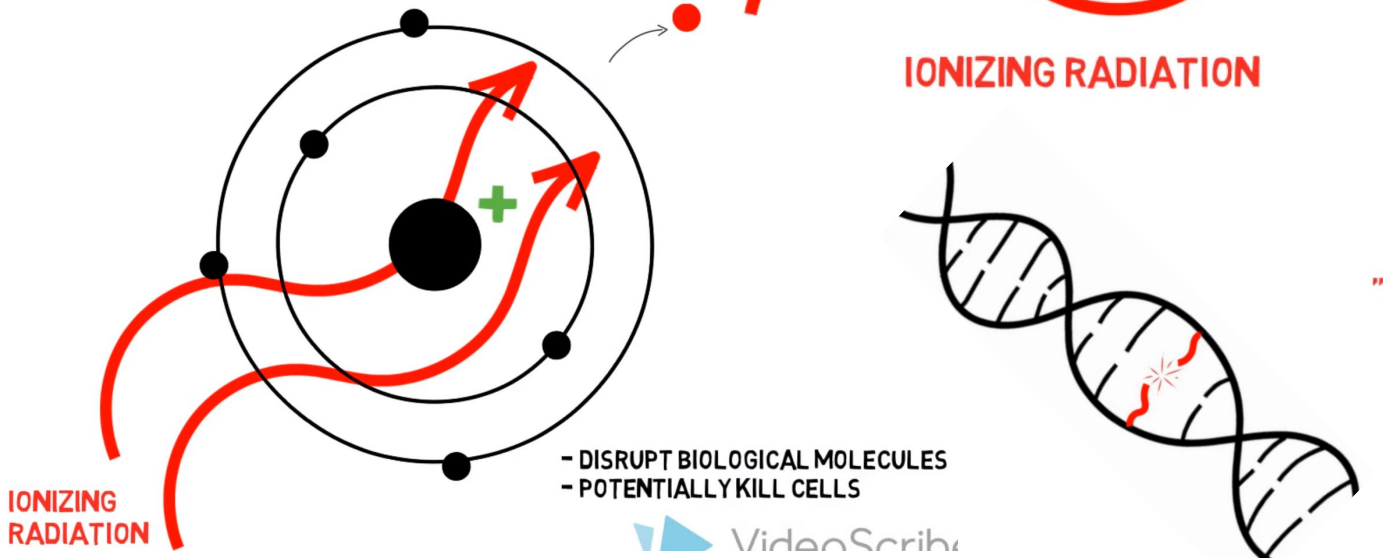
Roma – PLACE 9^ Edizione – 30 settembre 2022

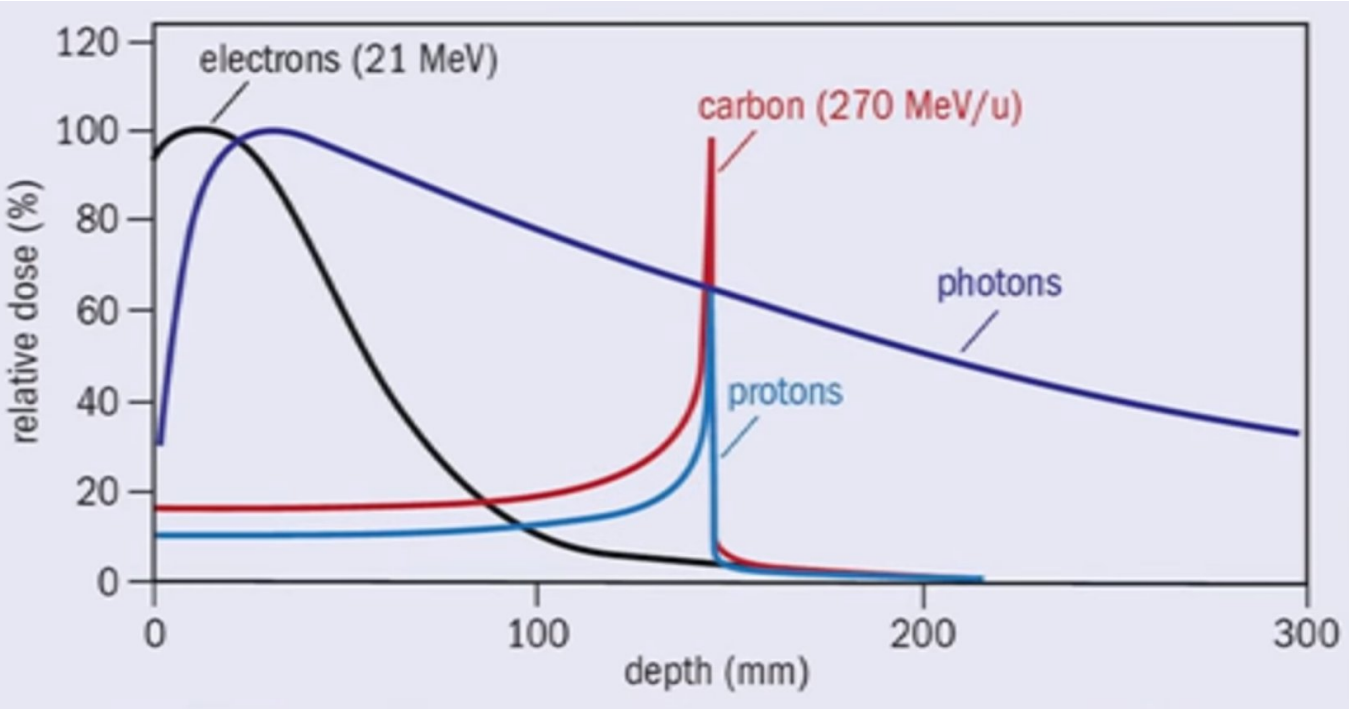
What are X-rays?

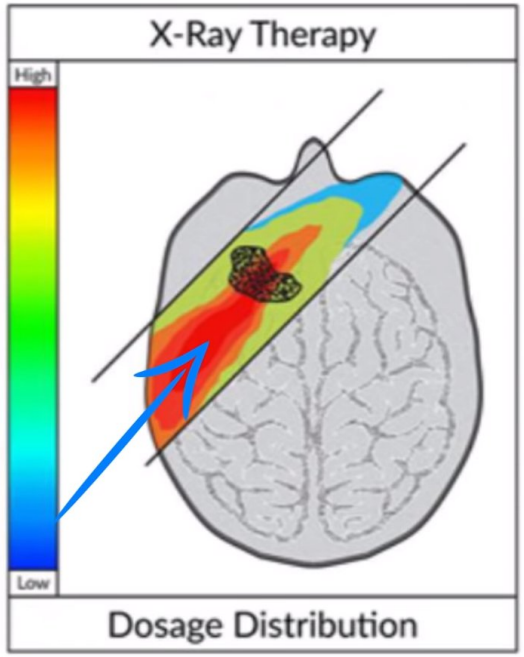


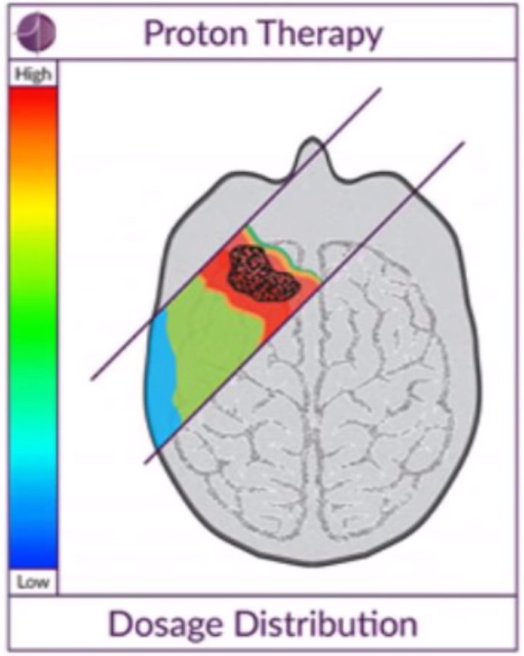


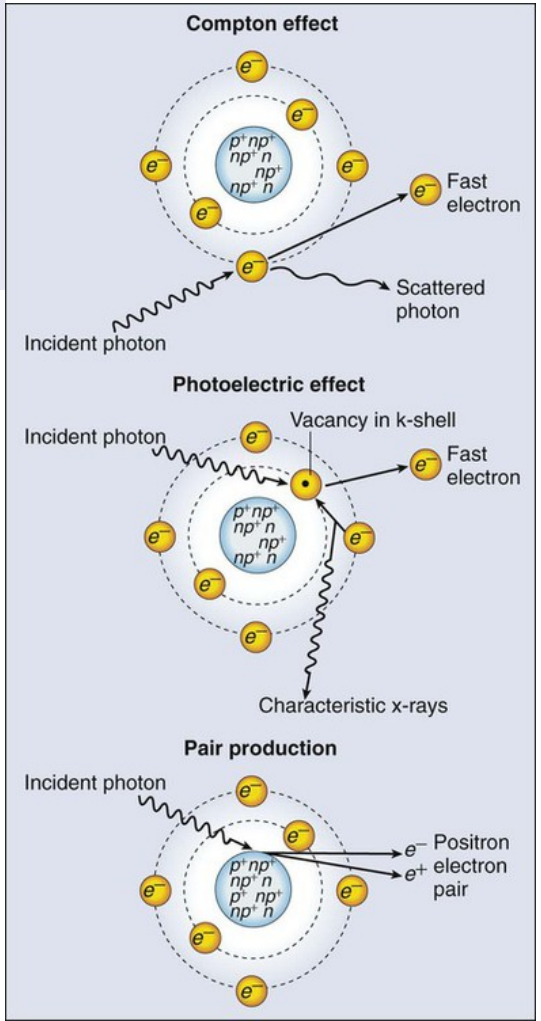
Making Radiation: the "linear accelerator" (linac)

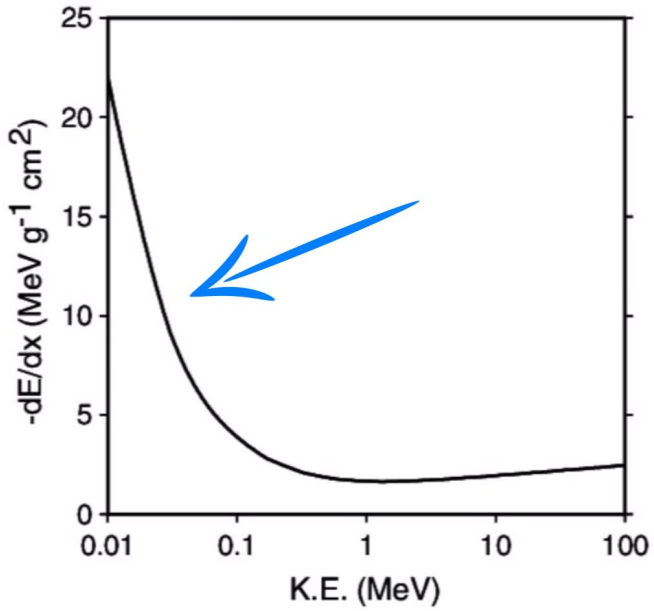



electrons (21 MeV)
carbon (270 MeV/u)
photons
protons
relative dose (%)
depth (mm)
0
20
40
60
80
100
120
0
100
200
300


X-Ray Therapy
High
Low
Dosage Distribution


Proton Therapy
High
Low
Dosage Distribution


Compton effect
Fast electron
Scattered photon
Incident photon
Photoelectric effect
Incident photon
Vacancy in k-shell
Fast electron
Characteristic x-rays
Pair production
Incident photon
Positron electron pair


-dE/dx (MeV g-1 cm2)
K.E. (MeV)
0
5
10
15
20
25
0.01
0.1
1
10
100

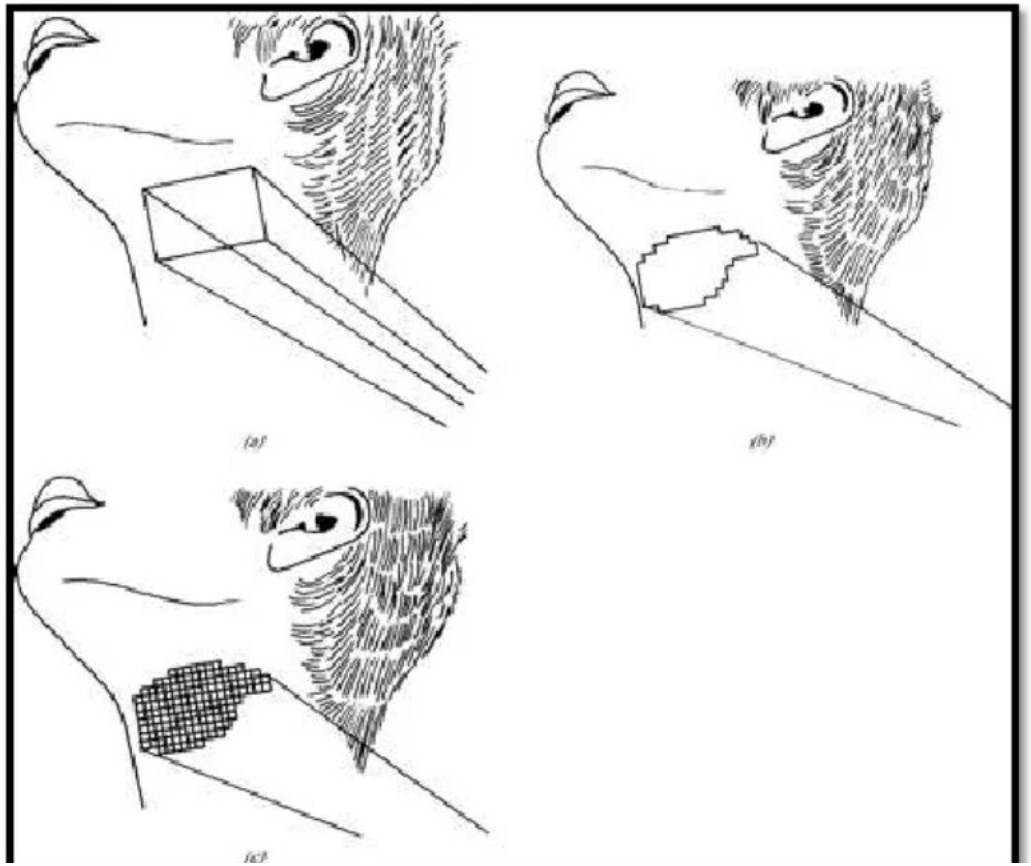
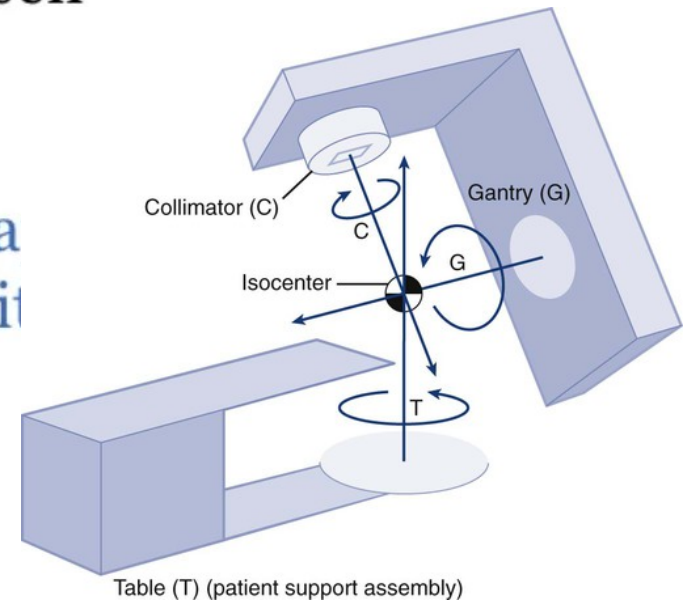


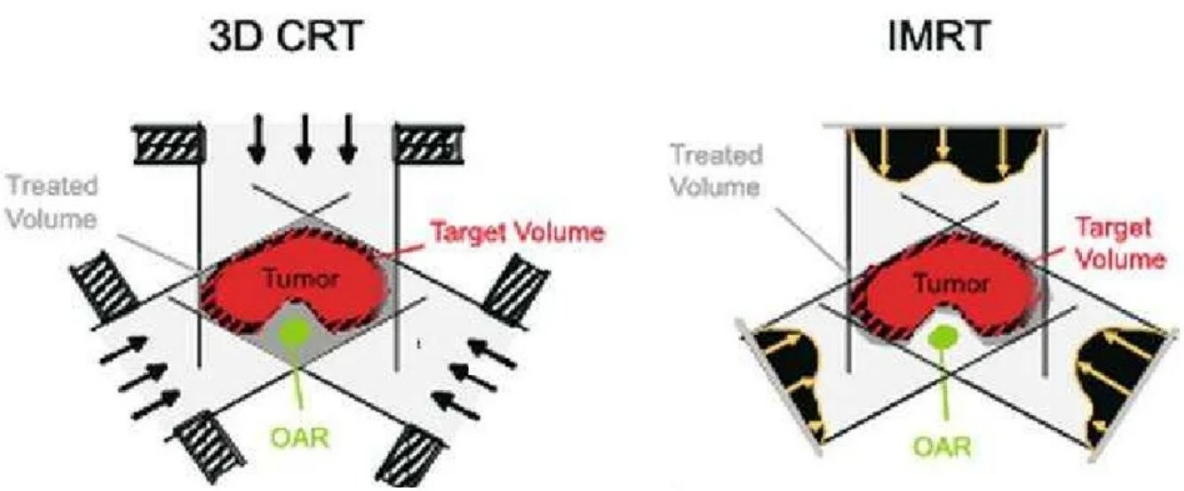
Figure: differences between

(a) conventional radiotherapy,

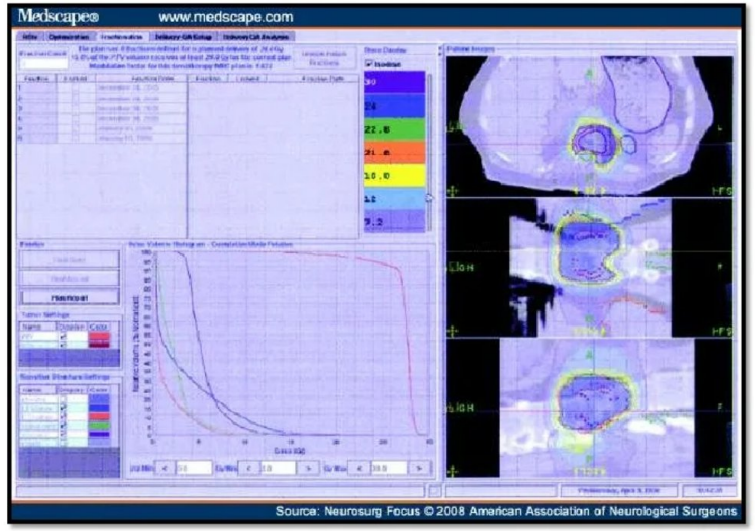
(b) conformal radiothera (CFRT) without intensit modulation and

(c) CFRT with intensity modulation (IMRT).



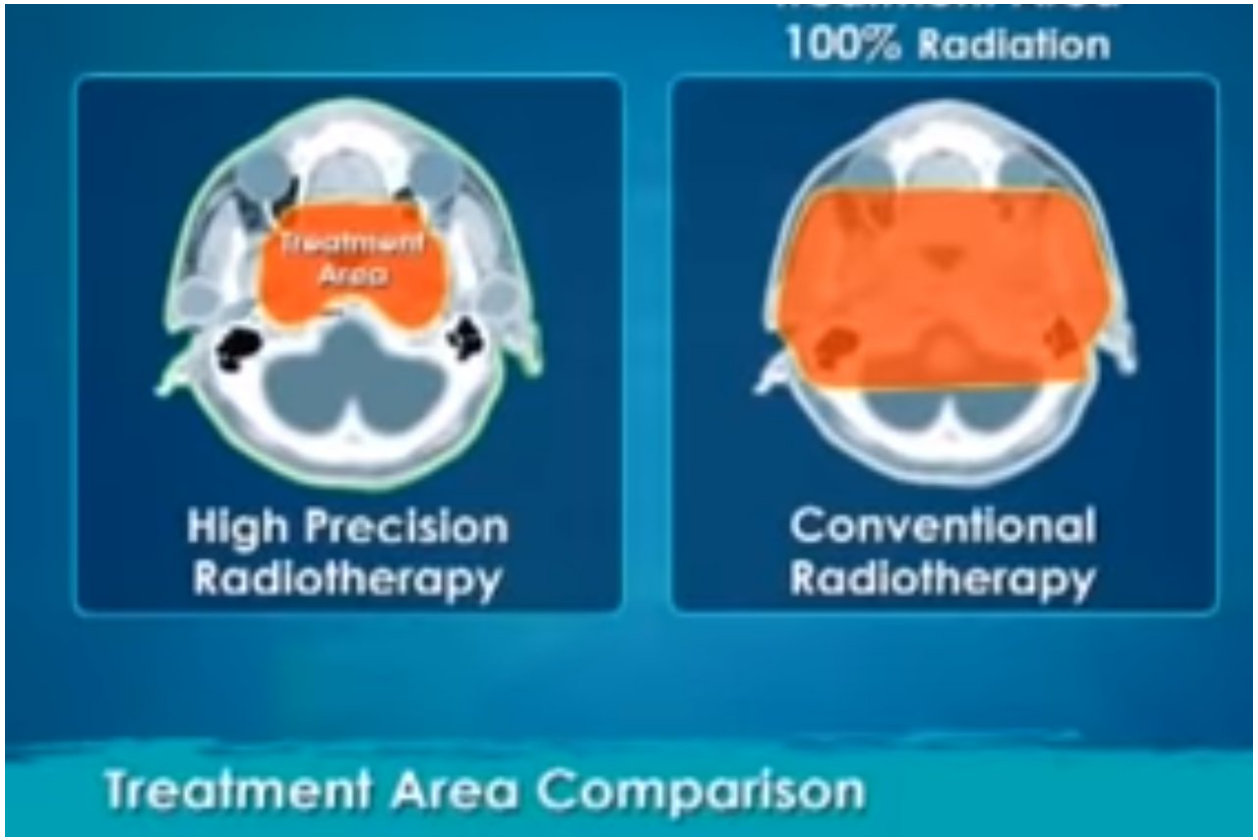


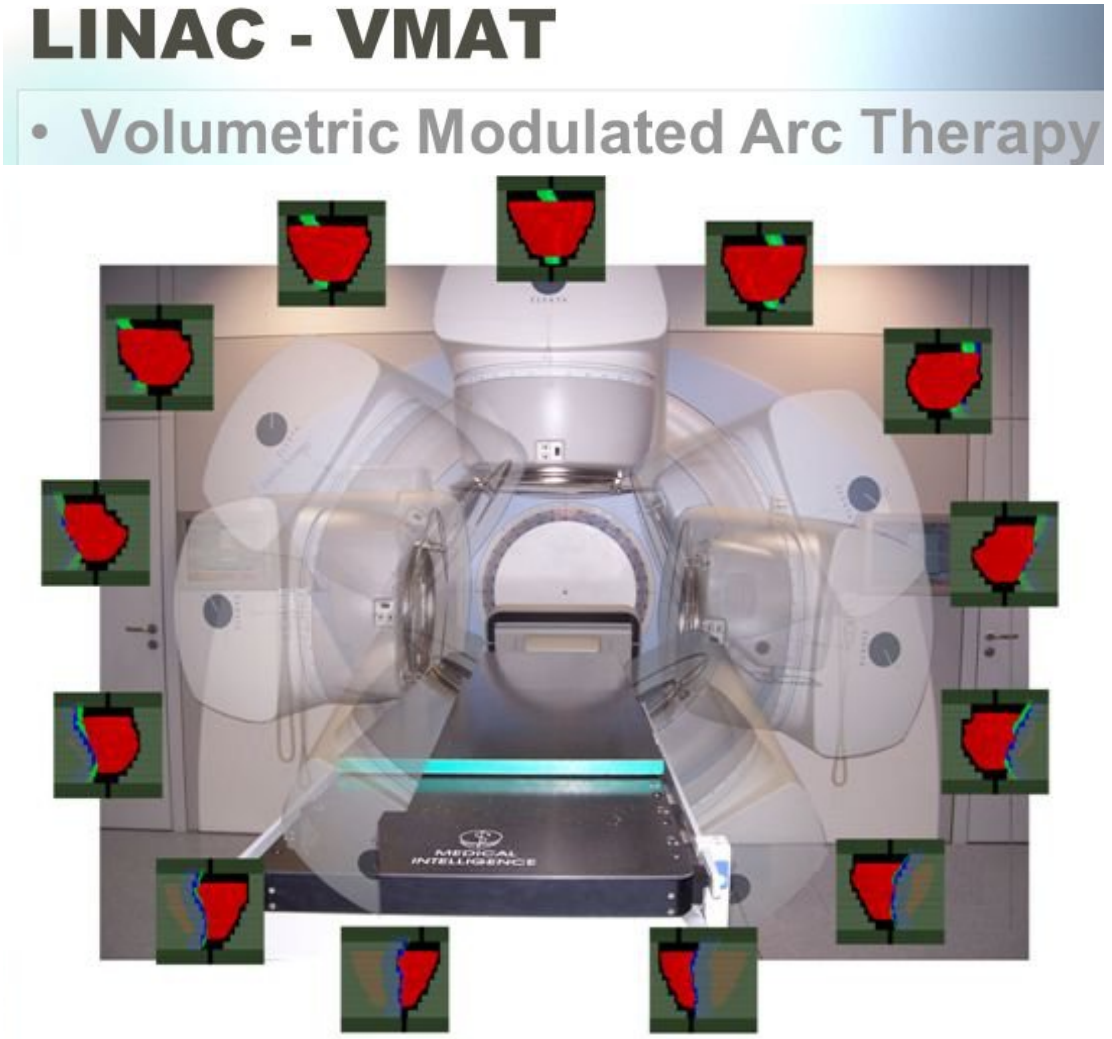
Dose volume histogram



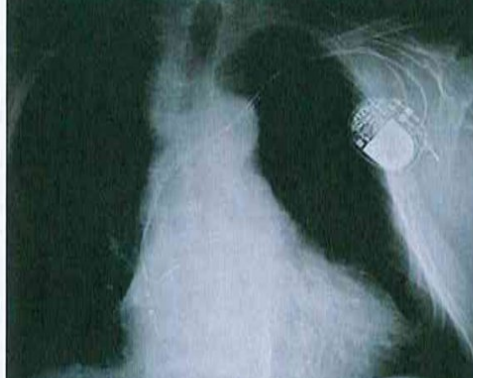
DVH is to summarize 3D dose distributions in a graphical 2D format

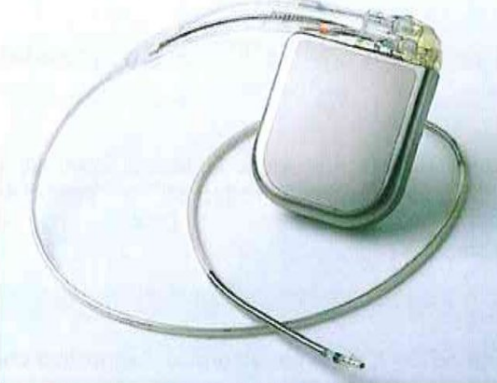
Intensity-modulated radiation therapy (IMRT)

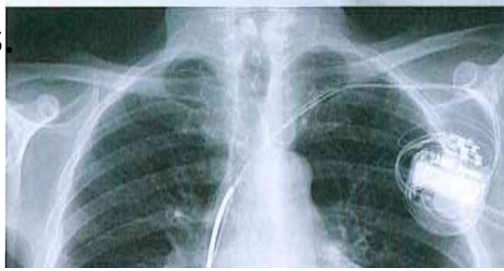




VMAT consente una distribuzione di dose altamente conformata con una migliore copertura della massa tumorale, garantendo un maggior risparmio dei tessuti sani rispetto alle tecniche di radioterapia convenzionali. La VMAT ha anche il vantaggio di ridurre il tempo di erogazione del trattamento con un tempo medio di trattamento di circa 5-7 minuti per seduta rispetto ai 20 minuti delle tecniche a intensità modulata a fascio statico (**IMRT**).







Modern CIEDs require **50.000.000 CMOS Transistors** vs <1000 in the most advanced 1994 bipolar designs.

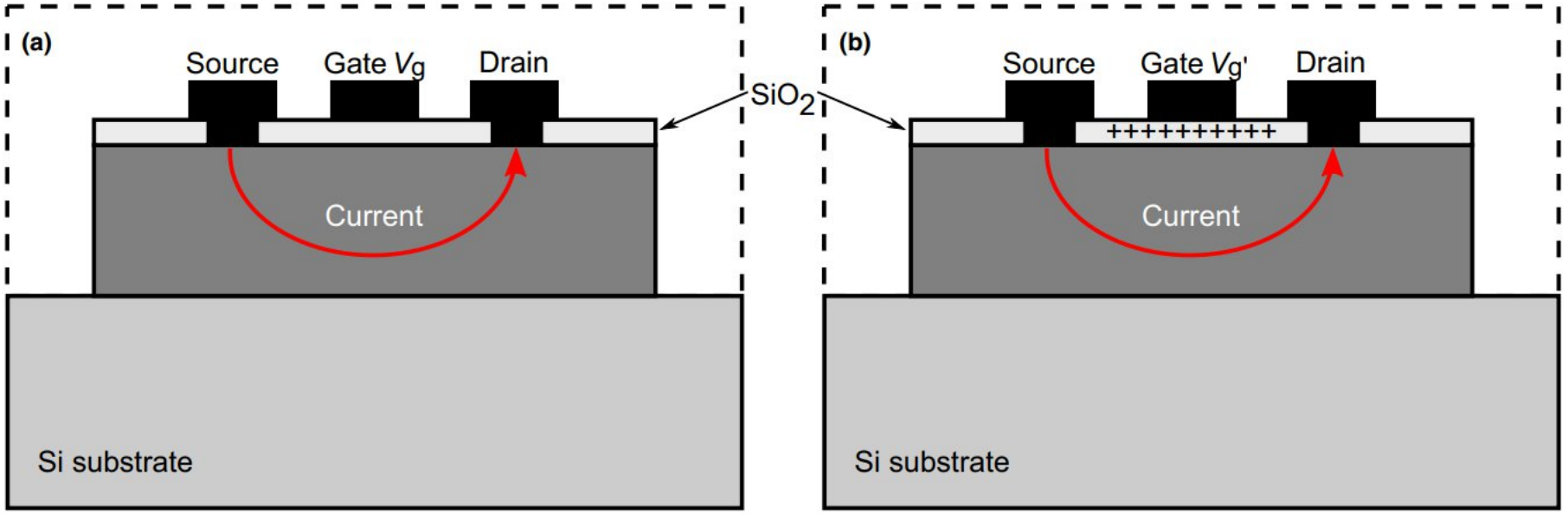
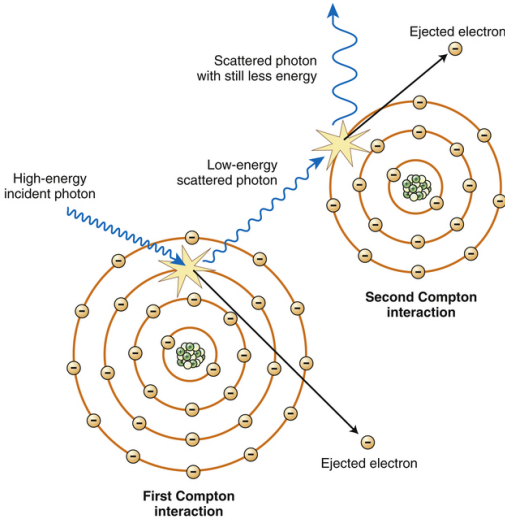
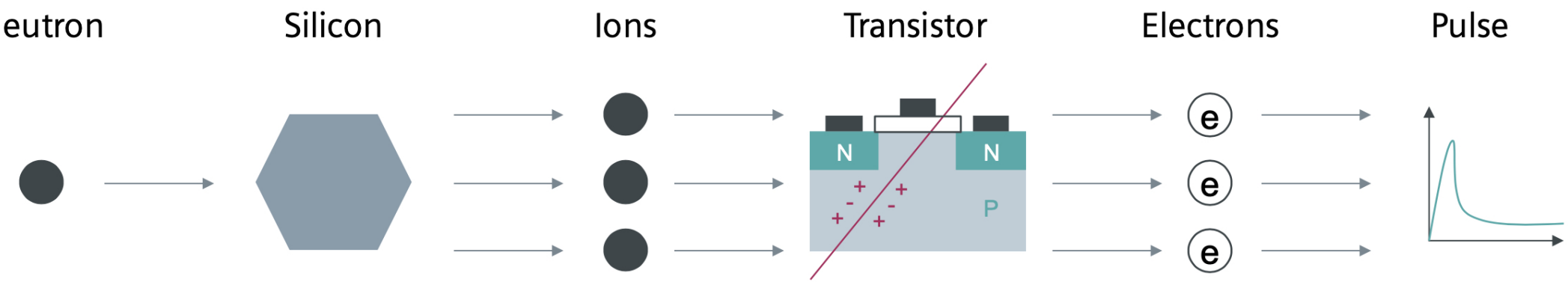


FIG. 2. Schematic diagram of complementary metal oxide semiconductor device illustrating radiation-induced charge, which modifies the threshold voltage. (a) shows the normal operation with current flow for a gate voltage, V_g. (b) shows the buildup of the radiation-induced charge in the SiO_2 layer causing a shift in the threshold voltage, $V_{g'}$ for current flow.





SE – Single Event

A single event is the interaction of an energetic particle such as a neutron with a semiconductor. The impacting particle gives off energy to the material, which is known as LET (Linear Energy Transfer). The occurrence is random and depends largely on the energy of the particle.

The effects of single events are observable and measurable errors. A distinction is made between a hard error and a soft error. In the event of a soft error, “only” data is corrupted. A hard error, on the other hand, which requires very high radiation, irreversibly destroys the semiconductor. The latter case can almost be ruled out when using numerical protection devices in their typical locations.

SEU – Single Event Upset

A single event upset is the change in a logical state (bit flip) in a writable, electronic memory cell (soft error) caused by a single event.

The different types of collision can result in a variety of secondary products, which cause a current pulse at the output of the attacked transistors. This can lead to a change in the charge distribution and thus to a “switching” of a p-n junction

Disfunzioni Transitorie o Permanenti

- Disfunzioni associate a **transitoria** interferenza elettromagnetica (**EMI**) ***solo durante irradiazione*** (inappropriato triggering):

- Inibizione del pacing ventricolare o oversensing atriale con elevata frequenza di stimolazione ventricolare;
- Inappropriato pacing alla frequenza massima del sensore;
- In caso di ICD: inappropriato riconoscimento diagnostico come TV/FV ed anche terapia inappropriata di pacing e/o shock.

- *Irradiazione* con **generazione di Neutroni**:

- Reset con riprogrammazione nella modalità di pacing di «back-up»

- Risolubile con **riprogrammazione** clinica o mediante **intervento degli ingegneri** della ditta costruttrice;

- *Irradiazione* **diretta**:

- Danno **permanente** del device

Electromagnetic interference (EMI)

Induced effects from EMI may result in **sensing the field as myocardial** potential resulting in

1. **inhibition of the output,**
2. **shut-off of the reed switch** (electrical switch operated by applied magnetic fields sensor susceptible to EMI) that would result in **fixed pacing rate**,
3. **triggering of output**,
4. isolated serious **permanent disruption of function** and **inappropriate reprogramming**.

CIED within or close to an RT treatment volume

- It is not possible to predict the behavior of a **CIED within or close to an RT treatment volume**.
- General recommendations should be followed to **minimize** patient risks.

RT-induced CIED malfunction

- They can manifest in:

- 1) ***transient interference*** (EMI), with inappropriate triggering during the irradiation only;
- 2) a ***reset***, reverting to backup settings, recoverable with device reprogramming, due to neutron contamination;
- 3) rarely, ***permanent damage*** to the device due to **direct** CIED irradiation.

Device Relocation

- Very rare and recommended only
- If the current location of the device interferes with adequate tumor treatment
- or in very selective high-risk patients

Risk of CDIE Malfunction with HEPhT

- Radiotherapy uses high-energy ionizing radiation including X-rays, gamma rays, and charged particles, which might cause software and hardware errors in CIEDs, especially when photon radiation beam energy exceeds 6-10 MV, and the radiation dose to the device is high (>2-10 Gy).
  - **Hard errors** are **rare**, and are most often due to **direct irradiation** to the device. This can cause **irreversible hardware damage**, requiring device **replacement**.
  - **Soft errors** are **more common**, and are associated with **secondary neutron production** by irradiation. Such errors typically include **resets** of the device without causing structural damage, and **can be solved** without replacement (**device reprogramming**).

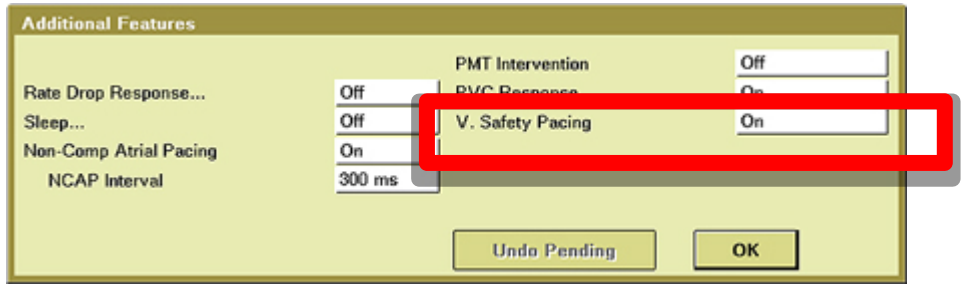
2) a ***reset***, reverting to backup settings, recoverable with device reprogramming;

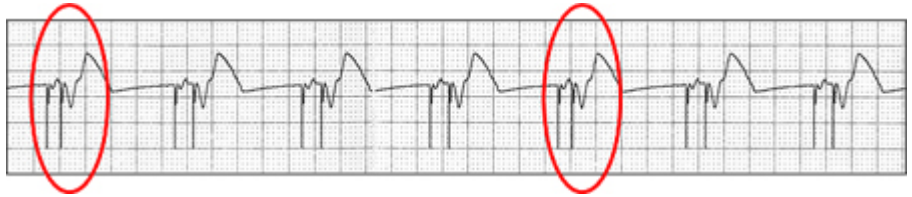
- **Transient reset oversensing** might lead to inappropriate VT/VF diagnosis and/or ICD shocks;
- **Transient** reversion to **backup pacing** recoverable with the reprogramming of the device assisted by electrophysiologists or engineers.

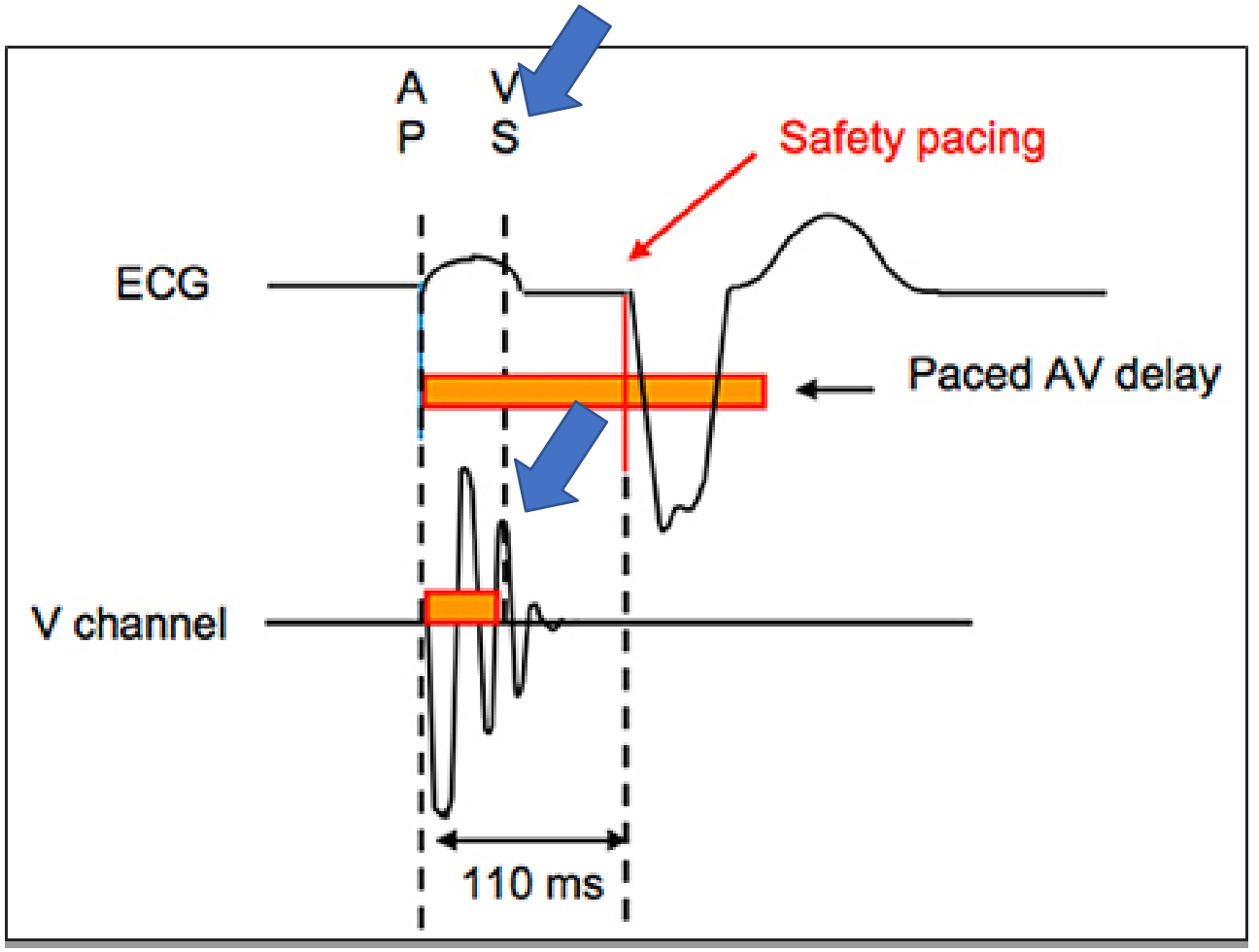
- **Permanent** reset requiring device replacement.

1) transient interference (EMI), with inappropriate triggering during the irradiation only

- inhibition of pacing;
- inappropriate pacing at maximum sensor rate;
- oversensing might lead to inappropriate VT/VF diagnosis and/or ICD shocks;


Additional Features
PMT Intervention
Off
Rate Drop Response...
Off
Sleep...
Off
V. Safety Pacing
On
Non-Comp Atrial Pacing
On
NCAP Interval
300 ms
Undo Pending
OK




A
P
V
S
Safety pacing
ECG
Paced AV delay
V channel
110 ms

Risk of CDIE Malfunction for PM/ICD pts

- Electromagnetic interference during radiotherapy can cause **oversensing**, although this **very rarely** occurs in clinical practice.

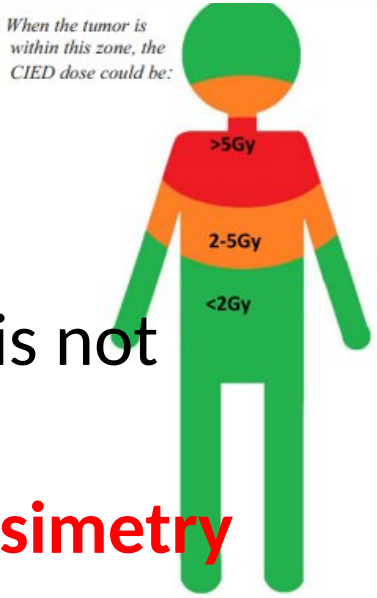
Device failure after radiation therapy

- 50% of malignancies require RT for either curative or palliative intent.
- Radiation doses used in cancer therapy are measured in Gys;
- 1 Gy = 1 Joule of absorbed energy of ionizing radiation per 1 Kg of matter.
- RT consists of several treatments over days or weeks, with daily fractions of tipically 1.8-2 Gy.
- Cumulative doses of up to 80 Gy are given of curative RT for solid tumours, with a total radiation dose of approximately 50 Gy for breast cancer and 60-66 for lung cancer.
- Photon are generated and delivered by a linear accelerator.
- By increasing the beam energy of the linear accelerator, the depth of the maximal delivered radiation dose increases: commonly 6-20 MV.
- Device failure after Radiation Therapy:

2.5% with PM

6.8 % with ICD

Cumulative dose to CIED



- CIED > 10 cm: cumulative dose will be **< 2 Gy**: *in vivo* dosimetry is not necessary
- CIED 3-10 cm from edge of Radiation treatment area: ***in vivo* dosimetry** over the CIED will be ***measured*** from the **first fraction**;
- CIED < 3 cm (5% isodose line): treatment planning system (TPS) will be used to ***estimate*** the maximum dose for the CIED.
- If ***measured*** or ***estimated*** cumulative dose **> 2 Gy**: treatment planning modifications can be considered or the pt should be managed according to the ***Medium/High-Risk*** category (> 5 Gy: High risk category).

Supplementary Table 23 **Recommendations from different cardiovascular implantable electronic device manufacturers on radiation therapy to patients with devices**

	Abbott-St. Jude Medical	Biotronik	Boston	Medtronic	Microport
Max dose (Gy)	No exact threshold determined	≤10 MeV (≤2 Gy total dose) but no safe radiation dose	No safe radiation dose	500 cGy (except for older models)	Not mentioned (betatrons are contraindicated)
Shield	Not mentioned	Recommended	Recommended	Conventional X-ray shielding does not protect against neutrons effect	Recommended
Relocation	Recommended if the device is in the field	Not mentioned (avoid direct irradiation)	Recommended if the device is in the irradiation field	Recommended if the device in the irradiation field	Recommended if the device is in the field
Evaluation of reset	Not mentioned	The devices are unable to identify reset	"Safe check" and interrogation may not be possible to unveil reset	Magnet may induce electrical reset Pacemakers: asynchronous pacing rate 65 b.p.m. ICD: high/low tone	Not mentioned
Device check	Pacemaker-dependent: once or twice during the treatment or in case of symptoms	After the treatment (any course?)	After the treatment (depending on recommendation of the attending cardiologist)	After the treatment	Not mentioned
Web-based information	https://manuals.sjm.com	https://www.biotronik.com/en-de/ healthcare-professionals	http://www.bostonscientific.com/ manuals/manuals/landing-page/ EU-english.html	www.medtronic.com/ manuals	www.sorinmanuals.com

b.p.m. = beats per minute; cGy = centiGray; Gy = Gray; ICD = implantable cardioverter-defibrillator; MeV = megaelectron volt.

ESC European Society of Cardiology

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EP WIRE

Approach to cardio-oncologic patients with special focus on patients with cardiac implantable electronic devices planned for radiotherapy: results of the European Heart Rhythm Association survey

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The aim of this European Heart Rhythm Association (EHRA) survey was to evaluate clinical practice regarding cardio-oncologic patients, with special focus on patients with cardiac implantable electronic devices (CIEDs) planned for anticancer radiotherapy (RT), among members of the EHRA electrophysiology research network. Of the 36 responding centres, 89% managed patients who were diagnosed or treated oncologically, and this diagnosis affected 1–5% of cardiovascular patients in majority of centres (57%). The main side effects of anticancer therapy in patients treated by cardiologists were thromboembolic complications and left ventricular dysfunction (both reported as 'frequent' by 43% of the centres). The main agents associated with complications were anthracyclines, RT, and monoclonal antibodies. Echocardiography was the most common method of screening for cardiovascular complications (93%), and 10% of the centres did not routinely screen for treatment-induced cardiotoxicity. Opinions on the safe radiation dose, methods of device shielding, and risk calculation prior to RT in CIED patients differed among centres. Precaution measures in high-risk CIED patients were very heterogeneous among centres. Our survey has shown that the awareness of cardiac consequences of anticancer therapy is high, despite relatively low proportion of patients treated oncologically among all cardiovascular patients. There is a consensus of which screening methods should be used for cardiotoxicity of anticancer treatment, but the apprehension of screening necessity is low. Methods of risk assessment and safety measures in CIED patients undergoing RT are very heterogeneous among the European centres, underscoring the need for standardization of the approach to cardio-oncologic patients.

Considering the **upper limit of cumulative dose** that can be **safely received by CIED** in patients undergoing RT, **14% of the respondents declared the limit of 2 Gy,** whereas for a smaller proportion of centres (10%), the limit depended on the CIED manufacturer, CIED type (ICD, resynchronization pacemaker, or 'standard' pacemaker), or was influenced by patients' characteristics (each reported by 10% of the centres). Of note, 7% of centres accepted as safe a dose of up to 5Gy, another 7% adopted no safety limit and treated all CIED patients undergoing RT the same way, and 38% of the respondents did not know which limit should be used.

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Original Article

Assessment of Radiation-Induced Malfunction in Cardiac Implantable Electronic Devices

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ABSTRACT

Background: Radiation therapy (RT) is a standard cancer treatment modality, and an increasing number of patients with cardiac implantable electronic devices (CIEDs) are being referred for RT. The goals of this study were as follows: (i) to determine the incidence of CIED malfunction following RT; (ii) to characterize the various types of malfunctions that occur; and (iii) to identify risk factors associated with CIED malfunction following RT.

Methods: A retrospective study of patients with CIEDs who received RT between 2007 and 2018 at 4 Canadian centres (Sunnybrook Health Sciences Centre, Kingston General Hospital, Hamilton Health Sciences

RÉSUMÉ

Contexte : La radiothérapie (RT) est une modalité standard de traitement du cancer, et un nombre croissant de patients porteurs de dispositifs cardiaques électroniques implantables (DCEI) doivent recevoir un traitement de RT. Les objectifs de cette étude étaient les suivants : (i) déterminer l'incidence d'une défaillance du DCEI après une RT; (ii) caractériser les différents types de défaillances qui se produisent; (iii) déterminer les facteurs de risque associés à la défaillance du DCEI après une RT.

Méthodologie : Une étude rétrospective des patients avec un DCEI ayant reçu une RT entre 2007 et 2018 dans quatre centres canadiens

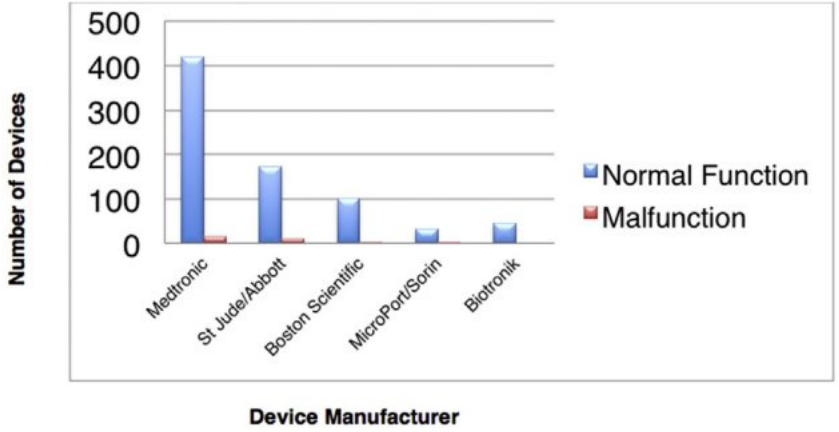

Figure 2. Incidence of cardiac implantable electronic device malfunction and normal function among devices from various manufacturers.

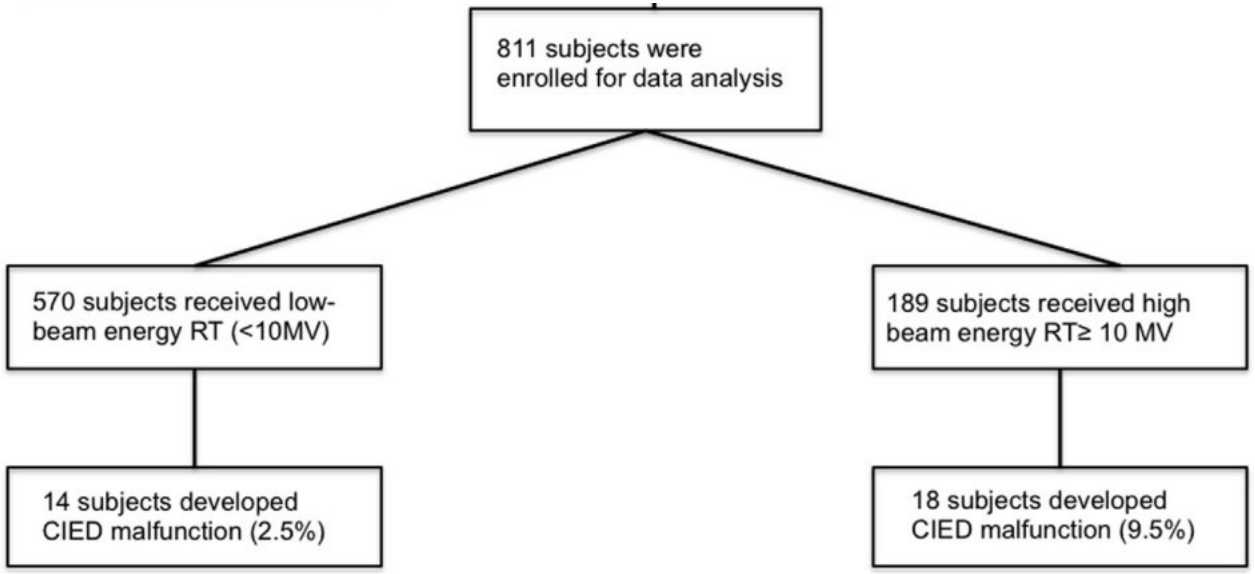

Table 1. Outcomes of patients with cardiac implantable electronic devices with radiation-induced malfunction compared to those for patients with devices with normal function

Characteristic	All patients	Normal function	Malfunction	*P*
Sex				
Male	575	545	30 (5.2)	
Female	236	234	2 (0.8)	0.004
Age, y		78.4 ± 9.4	79.3 ± 11.5	0.7
CIED type				
PM	624	600	24 (3.8)	
ICD	185	177	8 (4.3)	0.77
ILR	1	1	0	
Beam energy, MV				
≥ 10	189	171	18 (9.5)	< 0.0001
< 10	570	556	14 (2.5)	
Mean device radiation dose, cGy		65 ± 73	58.3 ± 288	0.71

Int J Radiat Oncol Biol Phys. 2013 November 1; 87(3): 570–575. doi:10.1016/j.ijrobp.2013.07.010.

Malfunctions of implantable cardiac devices in patients receiving proton beam therapy: incidence and predictors

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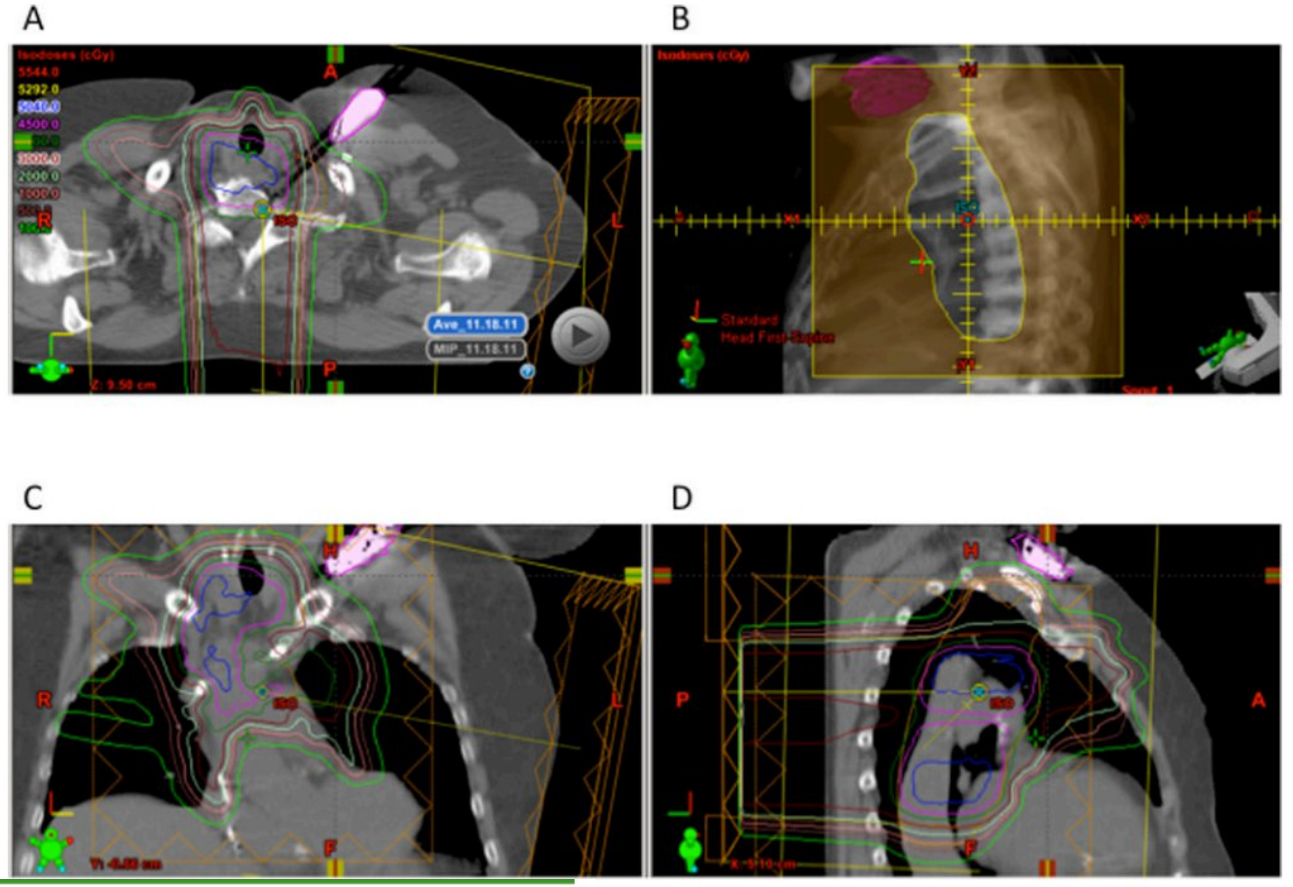

Patient 3 experienced a device reset of a pacemaker at delivery of 16.4 Gy(RBE) of a total 50.4 Gy(RBE) dose. The pacemaker (in pink) is shown in relationship to the treatment fields in the axial (A), coronal (C), and sagittal (D) planes and in relation to the aperture (B). The device was outside the radiation field and no beam range intersected the device. Estimated maximum proton and neutron doses were 1.82 Gy(RBE) and 536 mSv.

Table 3. Association Between Incident Radiation Dose Received by Cardiovascular Implantable Electronic Device (CIED) and Single-Event Upset

Characteristic	No. (%)						
	All (N = 249, RT Courses)	All Patients			Neutron-Producing RT (n = 71 Courses)[a]		
		No SEU	SEU	*P* Value[b]	No SEU	SEU	*P* Value[b]
Incident dose on CIED, median (range), Gy	0.50	0.44 (0-30.2)	0.18 (0.03-4.08)	.51[c]	0.47 (0-30.2)	0.18 (0.03-4.08)	.66[c]
Incident dose on CIED							
<2 Gy	202	189	13	.74	43	13	.50
≥2 Gy	47	45	2		13	2	
Incident dose on CIED per fraction, median (range), Gy	0.034 (0-6.03)	0.035 (0-6.03)	0.012 (0.0012-0.29)	.23[c]	0.033 (0-6.03)	0.013 (0.0012-0.29)	.45[c]

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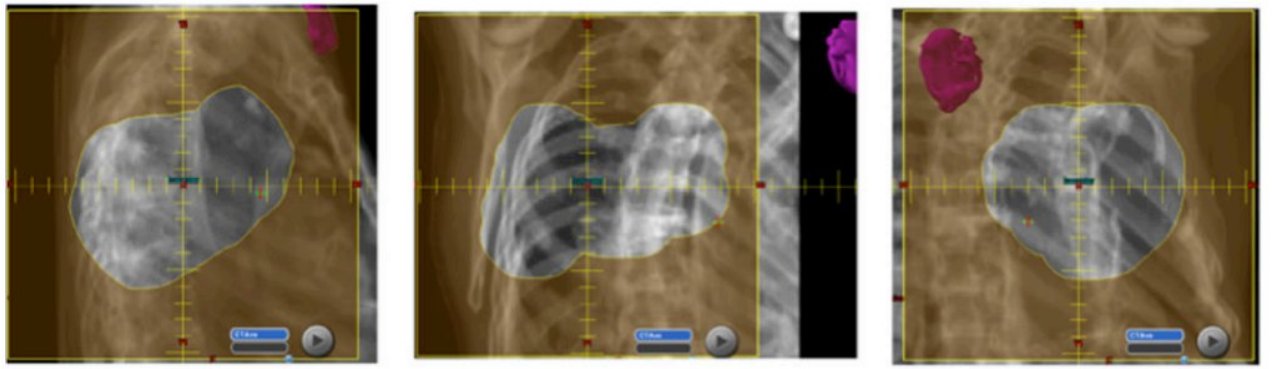


Figure 2.
Patient 4 experienced a device reset of a pacemaker at 4 Gy(RBE) of a total 60 Gy(RBE) dose. The apertures from each field demonstrate the position of the pacemaker (in pink) in relation to the radiation field. The distance from the edge of the field to the device was 3 cm, but the estimated maximum neutron dose was 484 mSv.

Characteristics of Device Malfunctions

Patient ID	Tumor Site	Device Type	Dose, Gy(RBE) / No. of Fractions	Distance from Device to Treatment Field, cm	Estimated Maximum Proton Dose±1σ[d], Gy(RBE)	Estimated Maximum Neutron Dose±1σ[e], Sv	Dose at Malfunction / Total Dose, Gy(RBE)	Nature of Malfunction
1	Thorax	ICD	74/37	5[a]	0.87±0.08	1.10±0.55	40/74	Reset[b]
2	Liver	ICD	67.5/15	18	0.17±0.05	0.33±0.17	67.5/67.5	ERI[c]
3	Thorax	Pacemaker	50.4/28	0.9	1.80±0.18	0.54±0.27	16.2/50.4	Reset[b]
4	Thorax	Pacemaker	60/30	3	0.21±0.02	0.48±0.24	4/60	Reset[b]
5	Thorax	ICD	87.5/35	8	0.10±0.02	0.50±0.25	32.5/87.5, 47.5/87.5	Reset[b]

[a]This patient was unique because one of the beams that was utilized in the treatment plan was directed towards the CIED. To minimize dose to the device, distal blocking of this beam was used.

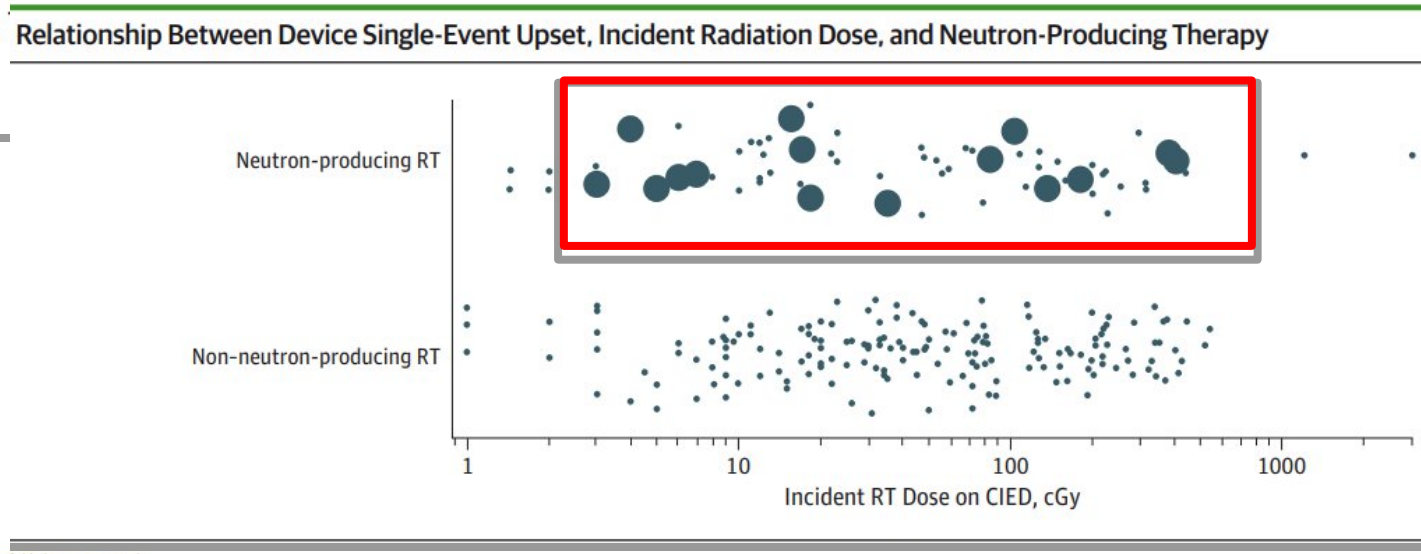
[b]Device reset resulting from radiation-induced change in pacing or sensing parameters (or both); reprogrammed by device clinic/manufacturer.

[c]Elective replacement indicator when the battery voltage dropped to 2.62 V, prompting a change of generator.

[d]Uncertainty, 1σ confidence level, was estimated based on the calibrated reading of the ion chamber detector array (doses obtained at very low dose levels)

[e]Uncertainty, 1σ confidence level, was estimated based on the largest error bars of the figures published by Wang etal.

Abbreviations: ICD=implantable cardioverter-defibrillator



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ORIGINAL ARTICLE

Particle therapy using protons or carbon ions for cancer patients with cardiac implantable electronic devices (CIED): a retrospective multi-institutional study

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Abstract

Purpose To evaluate the outcomes of particle therapy in cancer patients with cardiac implantable electronic devices (CIEDs).

Materials and methods From April 2001 to March 2013, 19,585 patients were treated with proton beam therapy (PBT) or carbon ion therapy (CIT) at 8 institutions. Of these, 69 patients (0.4%, PBT 46, CIT 22, and PBT + CIT 1) with CIEDs (64 pacemakers, 4 implantable cardioverter defibrillators, and 1 with a cardiac resynchronization therapy defibrillator) were retrospectively reviewed. All the patients with CIEDs in this study were treated with the passive scattering type of particle beam therapy.

Results Six (13%) of the 47 PBT patients, and none of the 23 CIT patients experienced CIED malfunctions ($p = 0.105$). Electrical resets (7) and over-sensing (3) occurred transiently in 6 patients. The distance between the edge of the irradiation field and the CIED was not associated with the incidence of malfunctions in 20 patients with lung cancer. A larger field size had a higher event rate but the test to evaluate trends as not statistically significant ($p = 0.196$).

Conclusion Differences in the frequency of occurrence of device malfunctions for patients treated with PBT and patients treated with CIT did not reach statistical significance. The present study can be regarded as a benchmark study about the incidence of malfunctioning of CIED in passive scattering particle beam therapy and can be used as a reference for active scanning particle beam therapy.

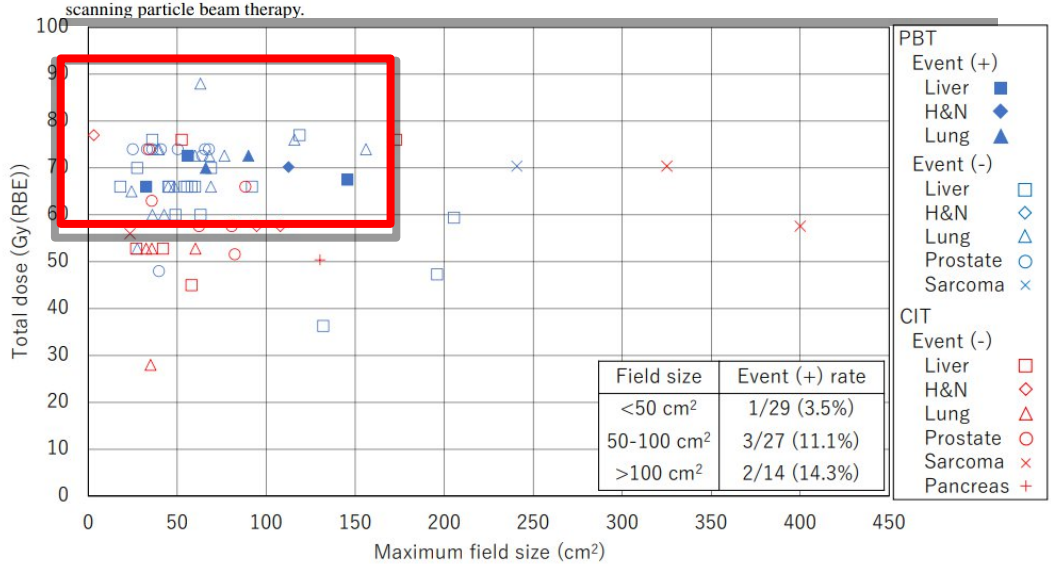

Fig. 2 Relationship between the maximum field size, prescribed dose, and CIED malfunctions

Table 3 Incidence of device malfunctions by treatment site and treatment modality

Treatment site	Treatments and malfunctions[a]			
	Proton		Carbon	
	Treatments	Malfunctions	Treatments	Malfunctions
Upper body	17	3	8	0
Head and neck	1	1	3	0
Lung	16	2	5	0
Middle body	20	3	8	0
Liver	20	3	7	0
Pancreas	0	0	1	0
Lower body	10	0	9	0
Prostate	9	0	6	0
Bone and soft tissue	1	0	3	0
Total	47	6	25	0

[a]When one patient was treated twice at different times, this was counted as two treatments

Table 4 Details of device malfunctions observed in the patients

No	Diagnosis	Stage	Age/ gender	Device type/ insertion site	Dose/fraction [Gy (RBE)/fr]	Modality/ energy	CIED model	Malfunction	Outcome
1	HCC	cT1N0M0 St. I	79/M	PM/ Unknown	66.0/10	Proton/ 155 MeV	St. Jude/ Affinity DR 5330	Reset at 39.6 Gy (RBE)	Recurrent-free at 31 mo Died suddenly of heart disease
2	NSCLC	cT2bN0M0 St. IIA	75/F	PM/ Left IR	72.6/22	Proton/ 200 MeV	Unknown	2 Resets at 24.0, 66.0 Gy (RBE)	Died of cancer at 17 mo
3	HCC	rT1N0M0 St. I	68/M	CRT-D/ Left IR	72.6/22	Proton/ 155 MeV	Medtronic/ Insync III Marquis 7279	Reset	Alive with disease at 4 mo
4	NSCLC	cT2aN0M0 St. IB	74/M	ICD/ Left IR	70.0/35	Proton/ 155 MeV	Biotronik/ Lexos DR	3 Over sensings	Recurrence-free at 110 mo Died of other disease
5	HCC	cT3bN0M0 St. IIIB	76/M	PM/ Left IR	67.5/25	Proton/ 210 MeV	St. Jude/ Integrity μ SR	2 Resets at 18.9, 27.0 Gy (RBE)	Died of cancer at 17 mo
6[a]	SMC	cT4bN0M0 St. IVB	69/F	PM/ Left IR	70.2/26	Proton/ 150 MeV	Biotronik/ Philos DR	Reset at 27.0 Gy (RBE)	Alive with disease at 21 mo

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META ANALYSIS

WILEY

A systematic review and meta-analysis on oncological radiotherapy in patients with a cardiac implantable electronic device: Prevalence and predictors of device malfunction in 3121 patients

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Abstract

Background: The number of patients with cardiac implantable electronic devices (CIEDs) undergoing radiotherapy (RT) for cancer treatment is growing. At present, prevalence and predictors of RT-induced CIEDs malfunctions are not defined.

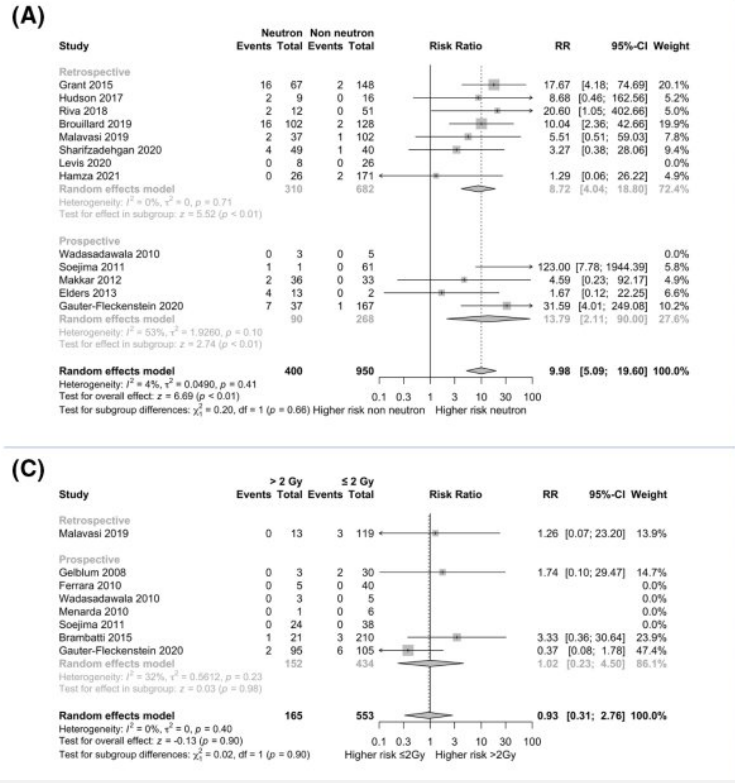
Methods: Systematic review and meta-analysis conducted following the PRISMA recommendations. PubMed, Scopus and Google Scholar were searched from inception to 31/01/2022 for studies reporting RT-induced malfunctions in CIEDs patients. Aim was to assess the prevalence of RT-induced CIEDs malfunctions and identify potential predictors.

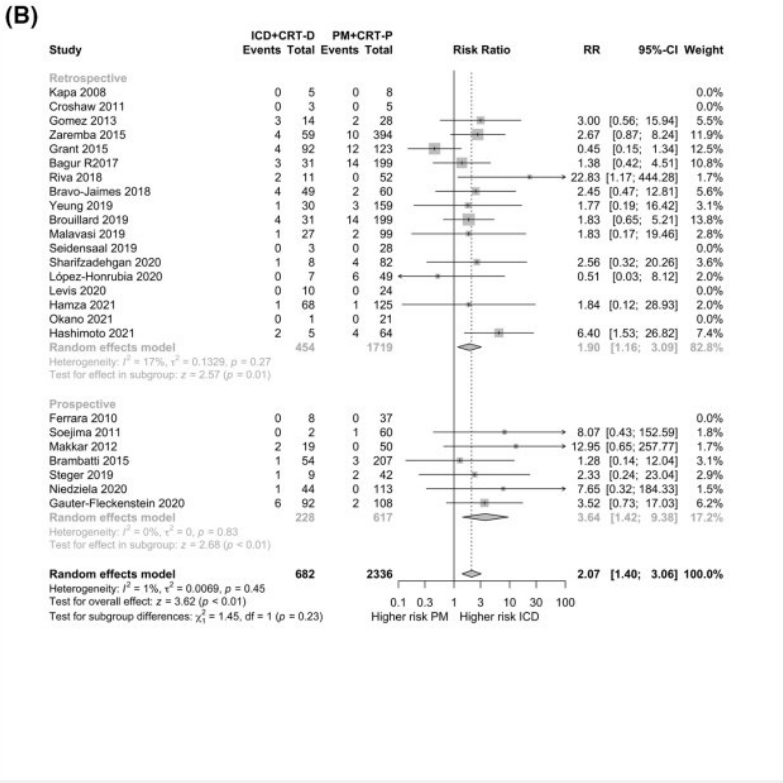
Results: Thirty-two out of 3962 records matched the inclusion criteria and were included in the meta-analysis. A total of 135 CIEDs malfunctions were detected among 3121 patients (6.6%, 95% confidence interval [CI]: 5.1%–8.4%). The pooled prevalence increased moving from pacemaker (PM) to implantable cardioverter defibrillator (ICD), and cardiac resynchronization therapy and defibrillator (CRT-D) groups (4.1%, 95% CI: 2.9–5.8; 8.2% 95% CI: 5.9–11.3; and 19.8%, 95% CI: 11.4–32.2 respectively). A higher risk ratio (RR) of malfunctions was found when neutron-producing energies were used as compared to non-neutron-producing energies (RR 9.98, 95% CI: 5.09–19.60) and in patients with ICD/CRT-D as compared to patients with PM/CRT-P (RR 2.07, 95% CI: 1.40–3.06). On the contrary, no association was found between maximal radiation dose at CIED >2 Gy and CIEDs malfunctions (RR 0.93; 95% CI: 0.31–2.76).

TABLE 2 Meta-analysis of risk factors for cardiac implantable electronic devices malfunctions associated with radiation therapy

	Studies (*n*)	Patients (*n*)	Malfunctions (*n*)	Risk ratio (95% CI)	*p*	I^2% (95% CI)	Egger's test *p*
Neutron-producing vs. non-neutron-producing energy	13	1350	65	9.98 (5.09–19.60)	<.0001	4 (0–61.7)	.472
PM/ CRT-P vs. ICD/ CRT-D	25	3018	123	2.07 (1.40–3.06)	.0003	1 (0–49.4)	.074
Dmax ≤2Gy vs. Dmax >2Gy	8	718	17	0.93 (0.31–2.76)	.8983	0 (0–84.7)	.282

Abbreviations: CRT-D, cardiac resynchronization therapy and defibrillator; CRT-P, cardiac resynchronization therapy and pacing; Dmax, maximal radiation dose at device; Gy, grey; ICD, implantable cardioverter defibrillator; PM, pacemakers.





In any case, the use of neutron-producing energies should be avoided whenever possible as this dramatically reduces the risk of CIED malfunctions, especially when ICD and CRT-D devices are involved. This should be possible in most patients, as energies >6MV are hardly needed when advanced techniques such as static intensity-modulated radiation therapy (IMRT)/ volumetric modulated arc therapy (VMAT) are used

Management of radiation oncology patients with implanted c pacemakers: Report of AAPM Task Group No. 34

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Contemporary cardiac pacemakers can fail from radiation damage at doses as low as 10 gr can exhibit functional changes at doses as low as 2 gray. A review and discussion potential problem is presented and a protocol is offered that suggests that radiation t patients with implanted pacemakers be planned so as to limit accumulated dose to the maker to 2 gray. Although certain levels and types of electromagnetic interference can pacemaker malfunction, there is evidence that this is not a serious problem around mos temporary radiation therapy equipment.

Key words: radiation oncology, pacemakers, treatment protocol, complications

I. INTRODUCTION

It is estimated that in 1986 more than 100 000 cardiac pacemaker implants were performed in the United States and that there were at least 500 000 pacemaker implanted patients.[1]

Cardiac pacemakers are either extrinsically or intrinsically attached to the heart muscle (outside or inside the heart). If, during open heart surgery, it is determined that a patient requires pacing, the leads are attached to the heart at that time and the pacemaker is usually fitted into the patient's upper abdomen. If surgery is not required, then the pacemaker leads are intrinsically attached to the apex of the right ventricle by passing them through an opening in the subclavian vein. The pacemaker is then placed under the skin on top of either pectoral muscle, usually laterally near either axilla. On occasion, a pacemaker is located underneath a breast for cosmetic reasons.

In 1992, it is estimated that 168 000 new cases of lung cancer were diagnosed in the United States.[2] In addition, an estimated 180 000 new breast cancers were discovered as well.

As with most cancers, treatment of lung and breast tumors depends somewhat on the staging as well as the cell type of the disease and, to some extent, the condition of the individual patient. Therapy involves the use of surgery, radiation, or chemotherapy or, often, a combination of two or all three. However, in 1990, 47% of all cancers were at least partially managed with radiation therapy.[3]

Thus, it is safe to assume that over 150 000 new cancer patients a year in the United States could present for radiation to that part of the anatomy that could include an implanted cardiac pacemaker. Further, the majority of pacemaker implants are in older patients who now utilize them for longer periods of time. increases with age, this further s numbers of patients could present makers.

Task group 34 was formed by Committee of the American Asso Medicine in 1985 with the charge of radiation on implanted pacemak ing radiation therapy and to form for the management of these patien line was formulated early and i throughout the radiation oncology

The interaction of a complex maker with the radiation environn clinical radiation therapy setting predict. Many variables can have a interactions and particularly on th the pacemaker. Thus, an optimum is difficult to determine based on and theoretical data. Since the pote ual patient is high, while the overal we are left to suggest precautions servative for some. The alternative pacemaker manufacturers to rede small percentage of patients or a re prove too high a risk to these spe dressing.

Cardiac pacemakers have fou spread use in the management of cardia since the early 1960s when ers were developed. These so-call stimulate the heart only when th function at the proper beating rat conventional bipolar transistors an

 0094-2405/94/21(1)/85/6/$1.20

2017 HRS expert consensus statement on magnetic resonance imaging and radiation exposure in patients with cardiovascular implantable electronic devices

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KEYWORDS Magnetic resonance imaging; Computed tomography imaging; Radiation therapy; Cardiac pacemakers; Implantable cardioverter defibrillators

ABBREVIATIONS **CIED** = cardiac implantable electronic device; **COR** = Class of Recommendation; **CRT** = cardiac resynchronization therapy; **CRT-D** = cardiac resynchronization therapy with implantable cardioverter-defibrillator; **CRT-P** = cardiac resynchronization therapy-pacemaker; **CT** = computed tomography; **dB/dt** = time-varying magnetic field; **DFT** = defibrillation threshold test; **ECG** = electrocardiogram; **EMI** = electromagnetic interference; **EO** = expert opinion; **EP** = electrophysiology; **ERI** = elective replacement interval; **FDA** = Food and Drug Administration; **Gy** = Gray, a measurement of absorbed radiation dose; **HR** = heart rate; **ICD** = implantable cardioverter defibrillator; **ILR** = implantable loop recorder; **LD** = limited data; **LINAC** = linear accelerator; **LOE** = Level of Evidence; **MR** = magnetic resonance; **MRI** = magnetic resonance imaging; **ms** = milliseconds; **MV** = megavolt; **mV** = millivolts; **NMR** = nuclear magnetic reset; **R** = randomized; **RCT** = randomized controlled trial; quency; **RT** = radiation treatment; **SAR** = specific absor Tesla, a measurement of magnetic field strength; **V** = volts ular tachycardia (Heart Rhythm 2017;14:e97–e153)

Developed in collaboration with and endorsed by the A of Cardiology (ACC), American College of Radiology (A Heart Association (AHA), American Society for Radia (ASTRO), Asia Pacific Heart Rhythm Society (APHRS), Rhythm Association (EHRA), Japanese Heart Rhythm S Pediatric and Congenital Electrophysiology Society (PA Society of Cardiac Arrhythmias (SOBRAC), and Latin Ame Cardiac Stimulation and Electrophysiology (SOLAECE) a tion with the Council of Affiliated Regional Radiation Onc (CARROS). **Address reprint requests and correspo** Rhythm Society, 1325 G Street NW, Suite 400, Washing E-mail address: clinicaldocs@hrsonline.org.

Management of radiotherapy patients with implanted cardiac pacemakers and defibrillators: A Report of the AAPM TG-203[†]

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Managing radiotherapy patients with implanted cardiac devices (implantable cardiac pacemakers and implantable cardioverter-defibrillators) has been a great practical and procedural challenge in radiation oncology practice. Since the publication of the AAPM TG-34 in 1994, large bodies of literature and case reports have been published about different kinds of radiation effects on modern technology implantable cardiac devices and patient management before, during, and after radiotherapy. This task group report provides the framework that analyzes the potential failure modes of these devices and lays out the methodology for patient management in a comprehensive and concise way, in every step of the entire radiotherapy process. © *2019 American Association of Physicists in Medicine* [https://doi.org/10.1002/mp.13838]

Key words: cardiac implantable electronic devices (CIED), device malfunction, implantable cardiac pacemakers (ICP), implantable cardioverter-defibrillators (ICD), patient management, radiation damage

Management of radiotherapy patients with implanted cardiac pacemakers and defibrillators: A Report of the AAPM TG-203[†]

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Managing radiotherapy patients with implanted cardiac devices (implantable cardiac pacemakers and implantable cardioverter-defibrillators) has been a great practical and procedural challenge in radiation oncology practice. Since the publication of the AAPM TG-34 in 1994, large bodies of literature and case reports have been published about different kinds of radiation effects on modern technology implantable cardiac devices and patient management before, during, and after radiotherapy. This task group report provides the framework that analyzes the potential failure modes of these devices and lays out the methodology for patient management in a comprehensive and concise way, in every step of the entire radiotherapy process. © *2019 American Association of Physicists in Medicine* [https://doi.org/10.1002/mp.13838]

Key words: cardiac implantable electronic devices (CIED), device malfunction, implantable cardiac pacemakers (ICP), implantable cardioverter-defibrillators (ICD), patient management, radiation damage

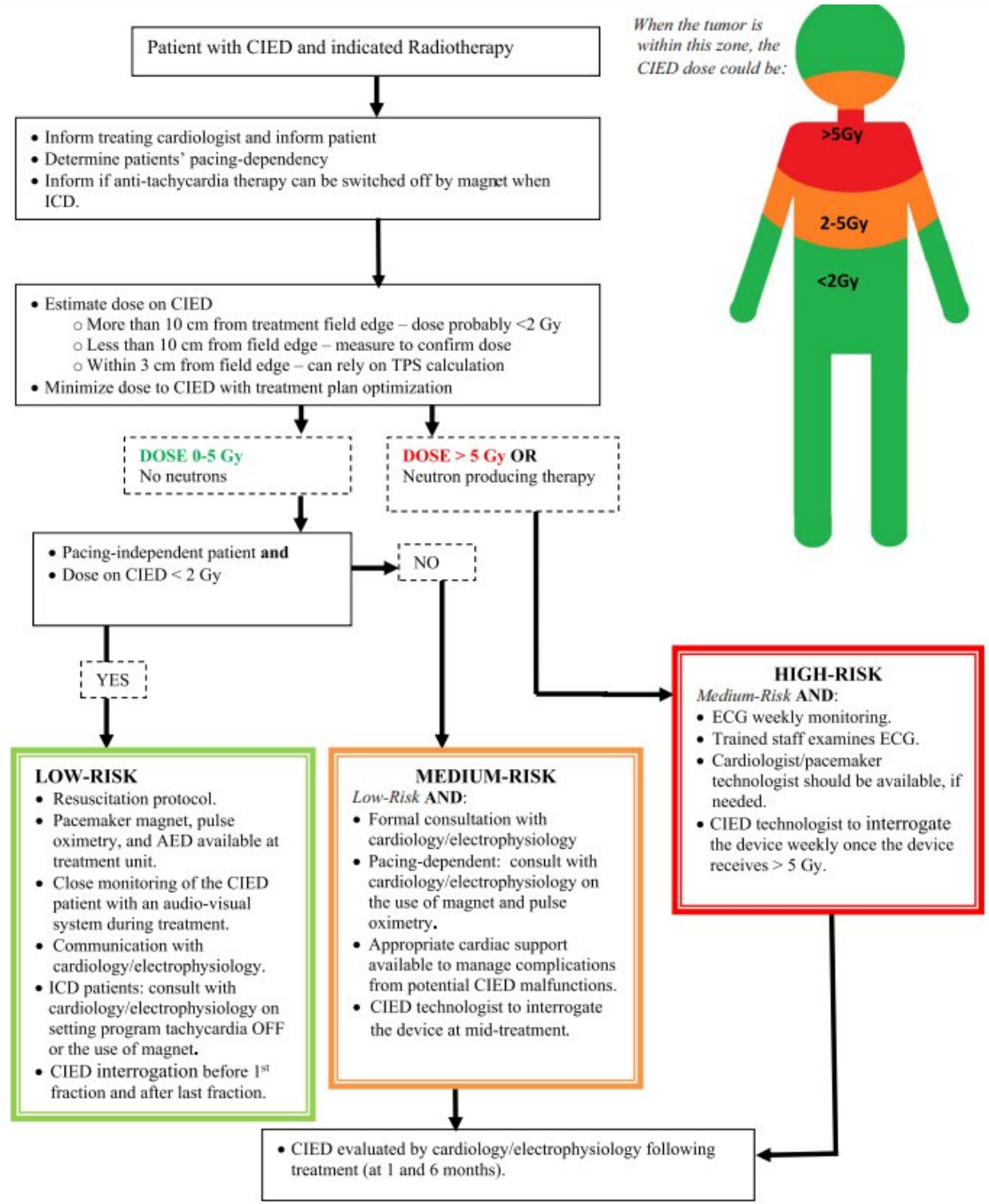

FIG. 5. Flowchart or recommended guidelines, definition of patient Risk Categories (adapted and modified from Hurkmans et al.[159]).

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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)

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ABSTRACT

The management of patients with a cardiac implanted electronic device (CIED) receiving radiotherapy (RT) is challenging and requires a structured multidisciplinary approach. A consensus document is presented as a result of a multidisciplinary working group involving cardiac electrophysiologists, radiation oncologists and physicists in order to stratify the risk of patients with CIED requiring RT and approaching RT sessions appropriately.
When high radiation doses and beam energy higher than 6 MV are used, CIED malfunctions can occur during treatment. In our document, we reviewed the different types of RT and CIED behavior in the presence of ionizing radiations and electromagnetic interferences, from the cardiologist's, radiation oncologist's and medical physicist's point of view. We also reviewed in vitro and in vivo literature data and other national published guidelines on this issue so far. On the basis of literature data and consensus of experts, a detailed approach based on risk stratification and appropriate management of RT patients with CIEDs is suggested, with important implications for clinical practice.

1. Purpose of the paper

The management of patients with a cardiac implanted electronic device (CIED) receiving radiotherapy (RT) is challenging and requires a structured multidisciplinary approach. The Italian Associations of Arrhythmologists (Associazione Italiana Aritmologia e Cardiostimolazione – AIAC), Radiation Oncologists (Associazione Italiana Radioterapia Oncologica – AIRO) and Medical Physicists (Associazione Italiana Fisica Medica – AIFM) formed a multidisciplinary working group to develop a consensus document for the management of patients with a cardiac implantable electronic device (CIED) undergoing radiotherapy (RT).

In patients with CIEDs, including cardiac pacemakers (PM) and implantable cardioverter-defibrillators (ICD), RT could compromise CIED function and, moreover, CIED could limit RT options.

In the presence of high radiation doses (in Gy) and especially when beam energy >6 MV are used, both software and hardware errors may occur [1]. Malfunctions can be:

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

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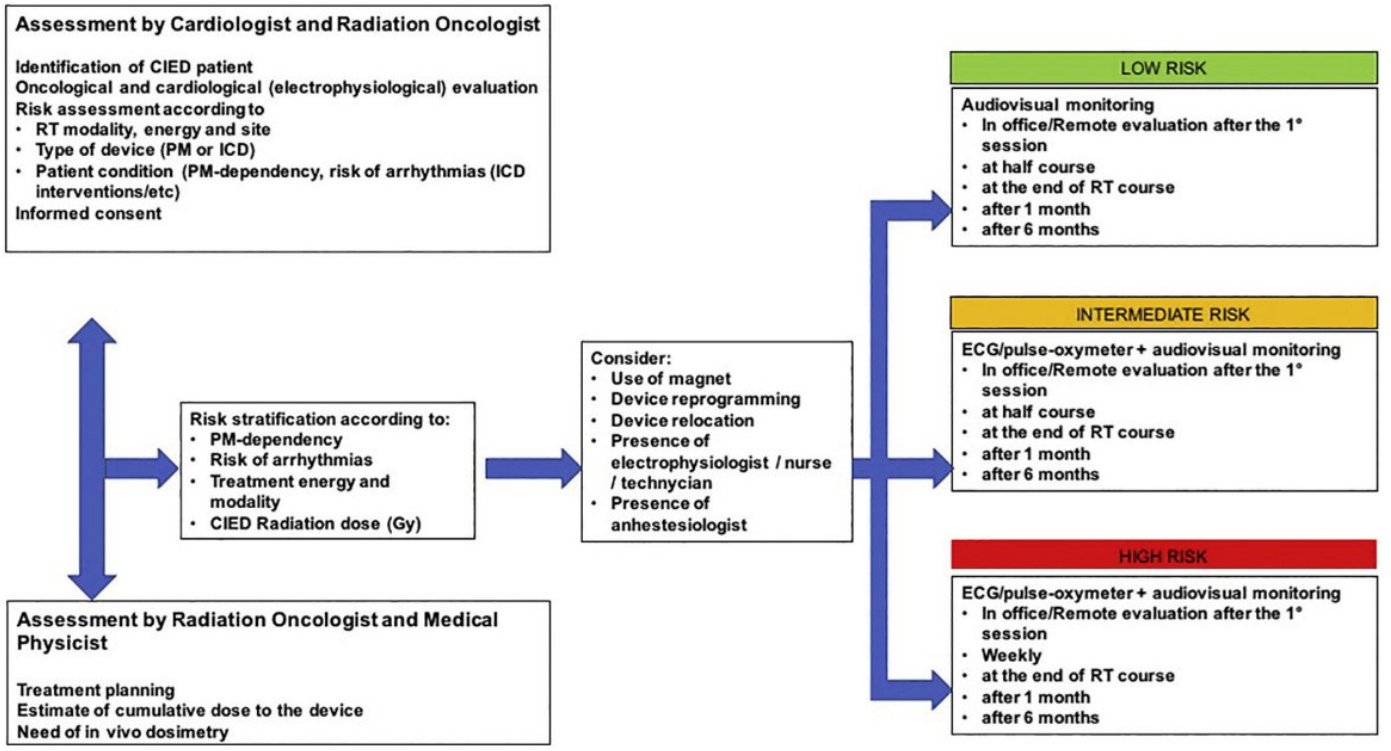
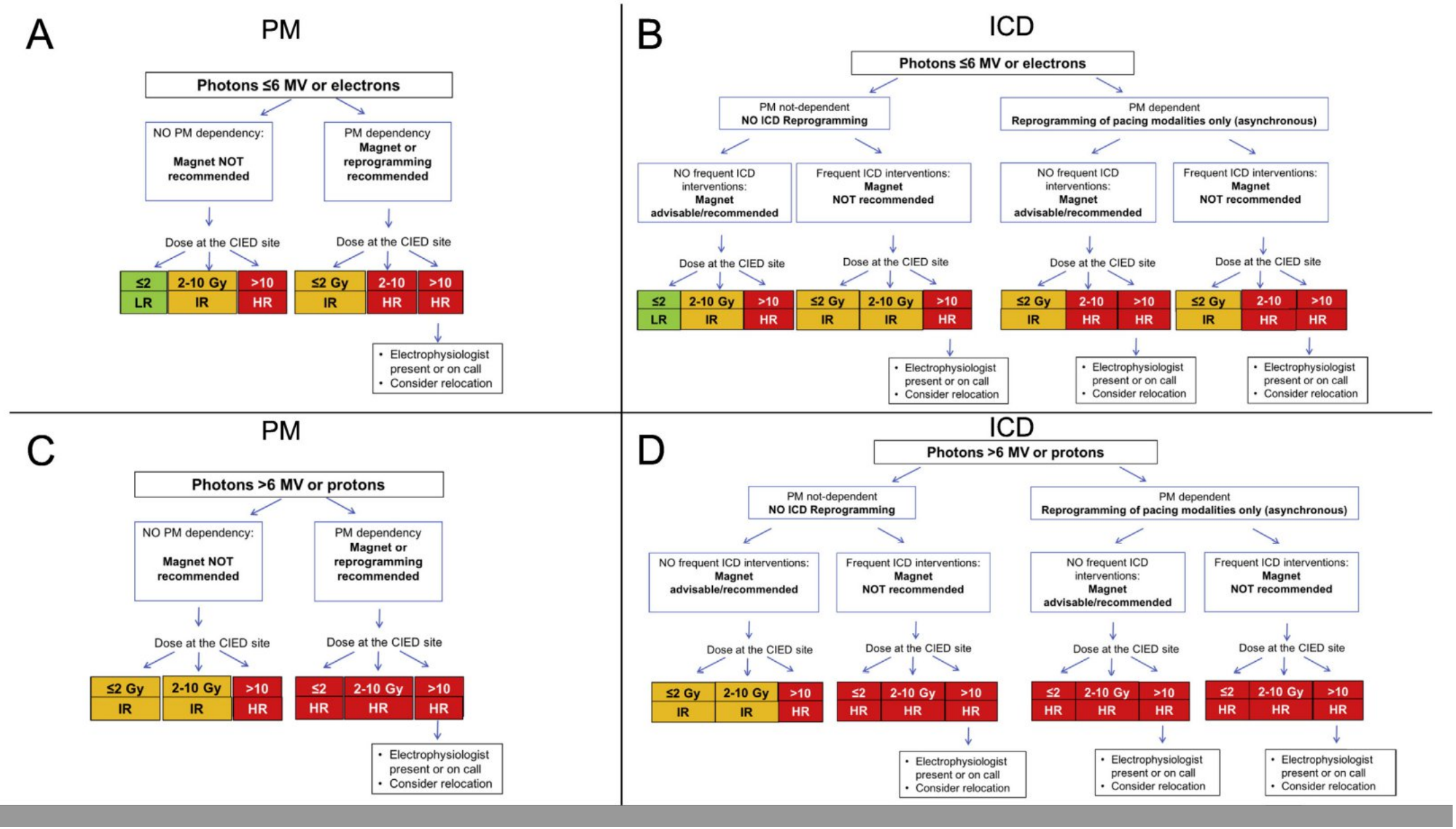


Fig. 1. Flow-chart of patient assessment and follow-up. RM: Remote Monitoring.


A
PM
Photons ≤6 MV or electrons
NO PM dependency:
Magnet NOT recommended
PM dependency
Magnet or reprogramming recommended
Dose at the CIED site
≤2
LR
2-10 Gy
IR
>10
HR
≤2 Gy
IR
2-10
HR
>10
HR
• Electrophysiologist present or on call
• Consider relocation
B
ICD
Photons ≤6 MV or electrons
PM not-dependent
NO ICD Reprogramming
PM dependent
Reprogramming of pacing modalities only (asynchronous)
NO frequent ICD interventions:
Magnet advisable/recommended
Frequent ICD interventions:
Magnet NOT recommended
C
PM
Photons >6 MV or protons
D
ICD
Photons >6 MV or protons

Journal of *Clinical Medicine*

MDPI

Article

Patients with Cardiac Implantable Electronic Device Undergoing Radiation Therapy: Insights from a Ten-Year Tertiary Center Experience

Simone Gulletta [1,*,†], Giulio Falasconi [1,†], Lorenzo Cianfanelli [1], Alice Centola [2], Gabriele Paglino [1], Manuela Cireddu [1], Andrea Radinovic [1], Giuseppe D'Angelo [1], Alessandra Marzi [1], Simone Sala [1], Nicolai Fierro [1], Caterina Bisceglia [1], Giovanni Peretto [1], Nadia Di Muzio [1], Paolo Della Bella [1], Pasquale Vergara [1,‡] and Italo Dell'Oca [1,‡]

Abstract: Background: The number of patients with cardiac implantable electronic devices (CIEDs) receiving radiotherapy (RT) is increasing. The management of CIED-carriers undergoing RT is challenging and requires a collaborative multidisciplinary approach. Aim: The aim of the study is to report the real-world, ten-year experience of a tertiary multidisciplinary teaching hospital. Methods: We conducted an observational, real-world, retrospective, single-center study, enrolling all CIED-carriers who underwent RT at the San Raffaele University Hospital, between June 2010 and December 2021. All devices were MRI-conditional. The devices were programmed to an asynchronous pacing mode for patients who had an intrinsic heart rate of less than 40 beats per minute. An inhibited pacing mode was used for all other patients. All tachyarrhythmia device functions were temporarily disabled. After each RT session, the CIED were reprogrammed to the original settings. Outcomes included adverse events and changes in the variables that indicate lead and device functions. Results: Between June 2010 and December 2021, 107 patients were enrolled, among which 63 (58.9%) were pacemaker carriers and 44 (41.1%) were ICD carriers. Patients were subjected to a mean of 16.4 (±10.7) RT sessions. The most represented tumors in our cohort were prostate cancer (12; 11%), breast cancer (10; 9%) and lung cancer (28; 26%). No statistically significant changes in device parameters were recorded before and after radiotherapy. Generator failures, power-on resets, changes in pacing threshold or sensing requiring system revision or programming changes, battery depletions, pacing inhibitions and inappropriate therapies did not occur in our cohort of patients during a ten-year time span period. Atrial arrhythmias were recorded during RT session in 14 patients (13.1%) and ventricular arrhythmias were observed at device interrogation in 10 patients (9.9%). Conclusions: Changes in device parameters and arrhythmia occurrence were infrequent, and none resulted in a clinically significant adverse event.

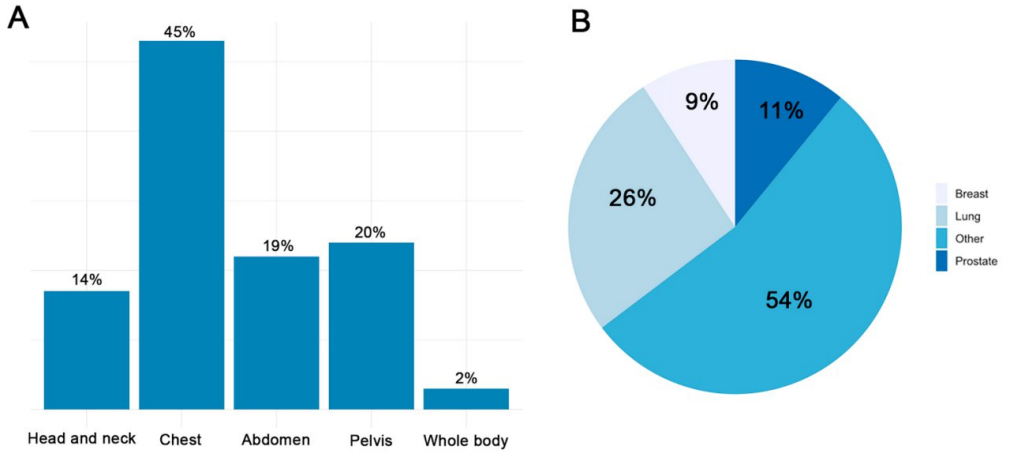


Figure 1. The proportion of body areas (**A**) and location of the tumor (**B**) treated with radiation therapy.

Table 1. Patients' devices and radiotherapy data.

	Total Patients (n = 107)	Pacemaker Carriers (n = 63)	Implantable Cardioverter Defibrillator Carriers (n = 44)	*p* Value
Age (years)	75.8 ± 7.0	77.4 ± 7.5	74.2 ± 6.3	0.07
Manufacturer				
Medtronic	45 (42.1)	31 (49.2)	14 (31.8)	
Biotronik	16 (15.0)	7 (11.1)	9 (20.5)	
St. Jude/Abbott	26 (24.3)	10 (15.9)	16 (36.4)	
Boston	15 (14.0)	11 (17.5)	4 (9.1)	
Sorin	5 (4.7)	4 (6.3)	1 (2.3)	
RT sessions	16.4 ± 10.7	17.2 ± 10.6	15.1 ± 11.0	0.38
RT total dose (Gy)	46.4 ± 15.5	46.9 ± 15.4	45.7 ± 15.7	0.79
RT fractions	16.0 ± 10.3	16.3 ± 10.7	15.7 ± 9.9	0.87
Device Maximum Dose (Gy)	2.8 ± 3.8	3.0 ± 4.2	2.6 ± 3.1	0.83
Device Mean Dose (Gy)	1.0 ± 1.3	0.9 ± 1.1	1.0 ± 1.6	0.69
Lead Maximum Dose (Gy)	22.5 ± 18.8	22.5 ± 18.8	22.5 ± 19.2	0.89
Lead Mean Dose (Gy)	5.4 ± 6.5	5.7 ± 6.5	4.9 ± 6.5	0.30

Results are reported as n (%) for categorical variables and mean ± standard deviation for continuous variables. RT = Radiotherapy.

Journal of
Clinical Medicine

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Article

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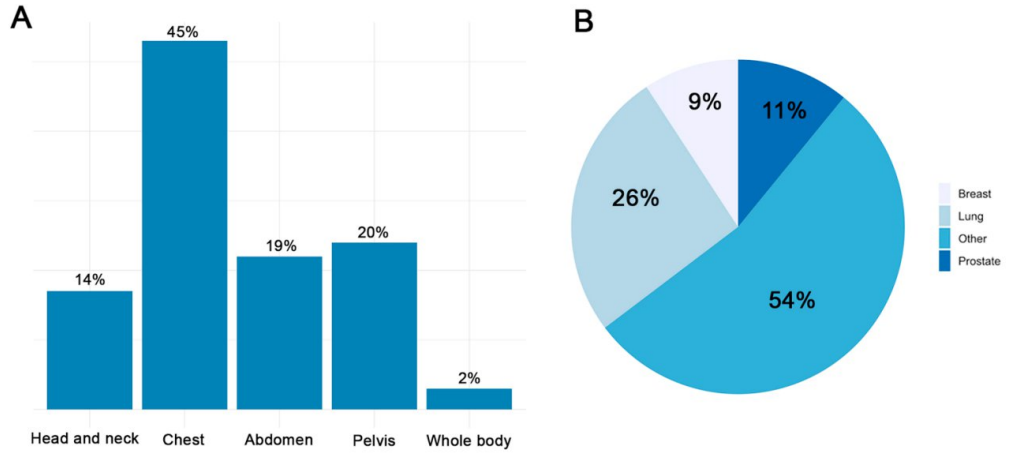

Figure 1. The proportion of body areas (**A**) and location of the tumor (**B**) treated with radiation therapy.

Table 4. Post-radiotherapy outcomes.

	Total Patients (n = 107)	Pacemaker Carriers (n = 63)	Implantable Cardioverter Defibrillator Carriers (n = 44)	*p* Value
Generator failures	0 (0)	0 (0)	0 (0)	0.99
Power-on resets	0 (0)	0 (0)	0 (0)	0.99
Changes in pacing threshold requiring system revision or programming changes	0 (0)	0 (0)	0 (0)	0.99
Changes in sensing threshold requiring system revision or programming changes	0 (0)	0 (0)	0 (0)	0.99
Battery depletions	0 (0)	0 (0)	0 (0)	0.99
Pacing inhibitions	0 (0)	0 (0)	0 (0)	0.99
Inappropriate therapies	0 (0)	0 (0)	0 (0)	0.99
Atrial Arrhythmias during RT session period	14 (13.1)	10 (15.9)	4 (9.1)	0.39
Ventricular Arrhythmias during RT session period	10 (9.9)	5 (8.5)	5 (11.9)	0.74

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STRUTTURA OSPEDALIERA DI TRENTO
U.O. DI RADIOTERAPIA ONCOLOGICA
U.O. DI CARDIOLOGIA

PROCEDURA PER LA GESTIONE DEL PAZIENTE PORTATORE DI PACEMAKER/DEFIBRILLATORE DURANTE SEDUTA DI RADIOTERAPIA

6. MATRICE DELLE RESPONSABILITÀ/ATTIVITÀ

Medico-Elettrofisiologo: identificazione della classe di rischio per il paziente sottoposto a trattamento radioterapico.

Medico-Elettrofisiologo/Infermiere certificato EHRA: controllo device pre-procedurale, con eventuale riprogrammazione del device a seconda delle condizioni cliniche del paziente, monitoraggio parametri cardiaci del paziente (ECG esterno consigliato per visualizzazione corretta del segnale cardiaco) e controllo device post-procedura, con controllo dei parametri elettrici degli elettrocateteri e valori di batteria.

Competente del dispositivo: medico o infermiere in grado di effettuare le verifiche di funzionalità del dispositivo, nonché di settarlo in modalità compatibile all'esecuzione del trattamento radioterapico.

Medico Radioterapista: responsabile della prescrizione della radioterapia.

Fisico Medico: pianificazione dosimetrica del trattamento e valutazione della dose impartita al CIED durante il trattamento radioterapico mediante dosimetria su TAC di centratura e/o dosimetria in vivo.

TSRM Radioterapia: set-up del paziente in sala di terapia, somministrazione della terapia e monitoraggio continuo del paziente mediante telecamere interne al bunker.

Controllo cardiologico prima della radioterapia

Il medico elettrofisiologo o un infermiere certificato EHRA controlla il device prima della seduta di radioterapia.

Nella maggior parte dei casi, i pazienti portatori di CIED vengono controllati presso l'ambulatorio della S.C. di Cardiologia con follow-up regolari nel tempo (6 mesi per ICD, 1 anno per pacemaker) o in remoto. Il medico elettrofisiologo o l'infermiere certificato EHRA è in grado di reperire la maggior parte delle informazioni dal SIO (ultimo follow up, possibile malfunzionamento pregresso, paziente in follow up dedicato, etc..).

Di seguito viene elencato cosa deve essere controllato durante il controllo device pre procedura:

a. Elettrodipendenza.
b. Stato della batteria. La longevità residua del dispositivo dovrebbe essere idealmente maggiore di 3 mesi, in quanto se non lo fosse vi potrebbe essere maggiore sensibilità del dispositivo a interferenze da radiazioni ionizzanti. Se le sedute di radioterapia dovessero essere ripetute per un periodo di tempo prolungato e il dispositivo fosse vicino all'ERI, è consigliabile la sostituzione dello stesso prima di iniziare il ciclo di terapie.
c. Modalità di Programmazione. Importante è anche la conoscenza della modalità di stimolazione (VVI, VVIR, DDD, DDDR, etc..) in quanto i CIED moderni possiedono algoritmi in grado di modificare la modalità di stimolazione in base alle richieste fisiologiche del paziente (AAI-DDD). Se non si tenesse conto di questo fatto, si potrebbero confondere modifiche di modalità di stimolazione con problematiche relative al device.
d. Controllo elettrocateteri. Misurazione impedenza e soglia di stimolazione. Si raccomanda solitamente di avere un margine sulla soglia di stimolazione degli elettrocateteri almeno con un rapporto 2:1 (per eventuale catetere sinistro questo margine può essere anche inferiore). Molti dispositivi di nuova generazione permettono di attivare la misurazione ed adeguamento automatico della soglia di stimolazione, con un margine di uscita che viene impostato a meno di 2 volte la soglia stessa.
e. Risposta al magnete. Ultimo aspetto da verificare è quale sia la risposta al magnete del dispositivo in oggetto. Nella maggior parte dei pacemaker, un magnete programma una stimolazione temporanea del pacemaker in modalità asincrona ad una frequenza che varia a seconda dell'azienda produttrice, mentre negli ICD un magnete rende le terapie anti-tachicardia inattive, ma non influenza la modalità di stimolazione. Va quindi verificato con attenzione quale sia la marca del device in oggetto, in modo da essere pronti in caso si dovesse applicare un magnete durante la Radioterapia.

APSS: casistica

70 CIEDs - Rx Terapia

- Magnete in PM-dipendenti e riprogrammazione degli ICD (OFF)
- Monitoraggio ECG telemetrico intraoperatorio
- Monitoraggio settimanale postoperatorio del funzionamento dei devices
- Non malfunzioni.

10 - Protonterapia (magnete per i CDIEs)

- Non malfunzioni.

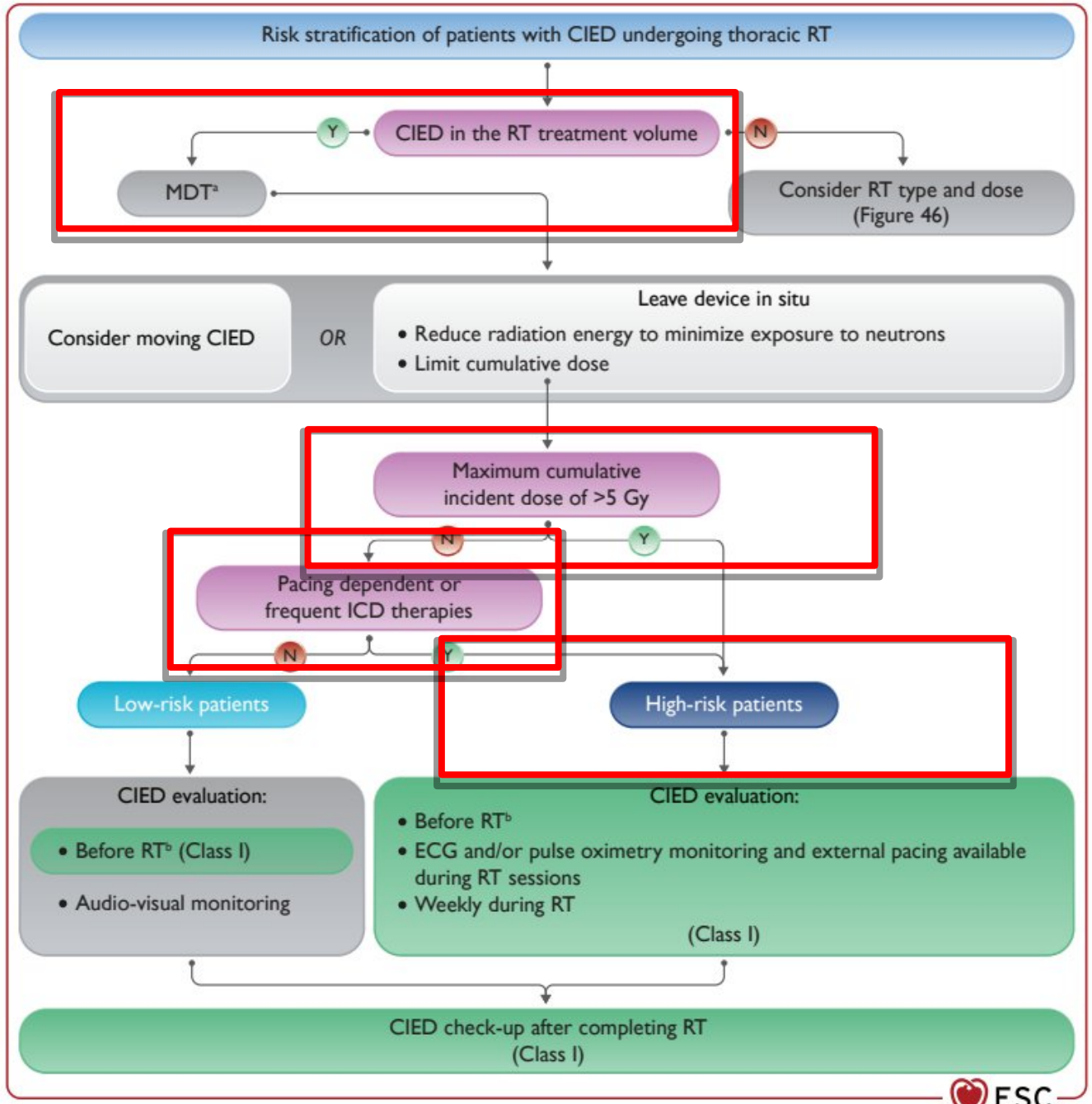
ESC European Society of Cardiology
European Heart Journal (2022) **00**, 1–133
https://doi.org/10.1093/eurheartj/ehac244

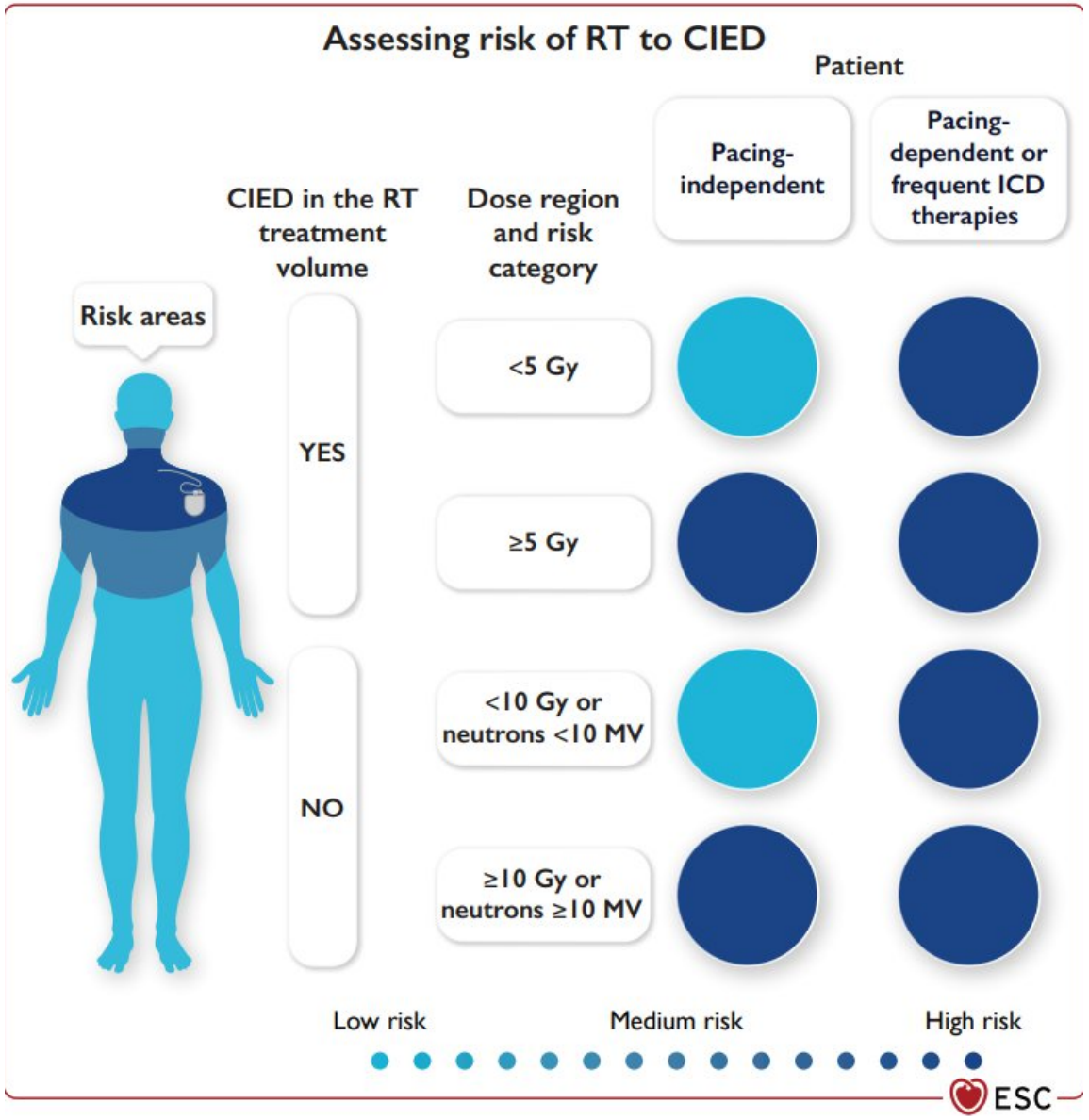
ESC GUIDELINES

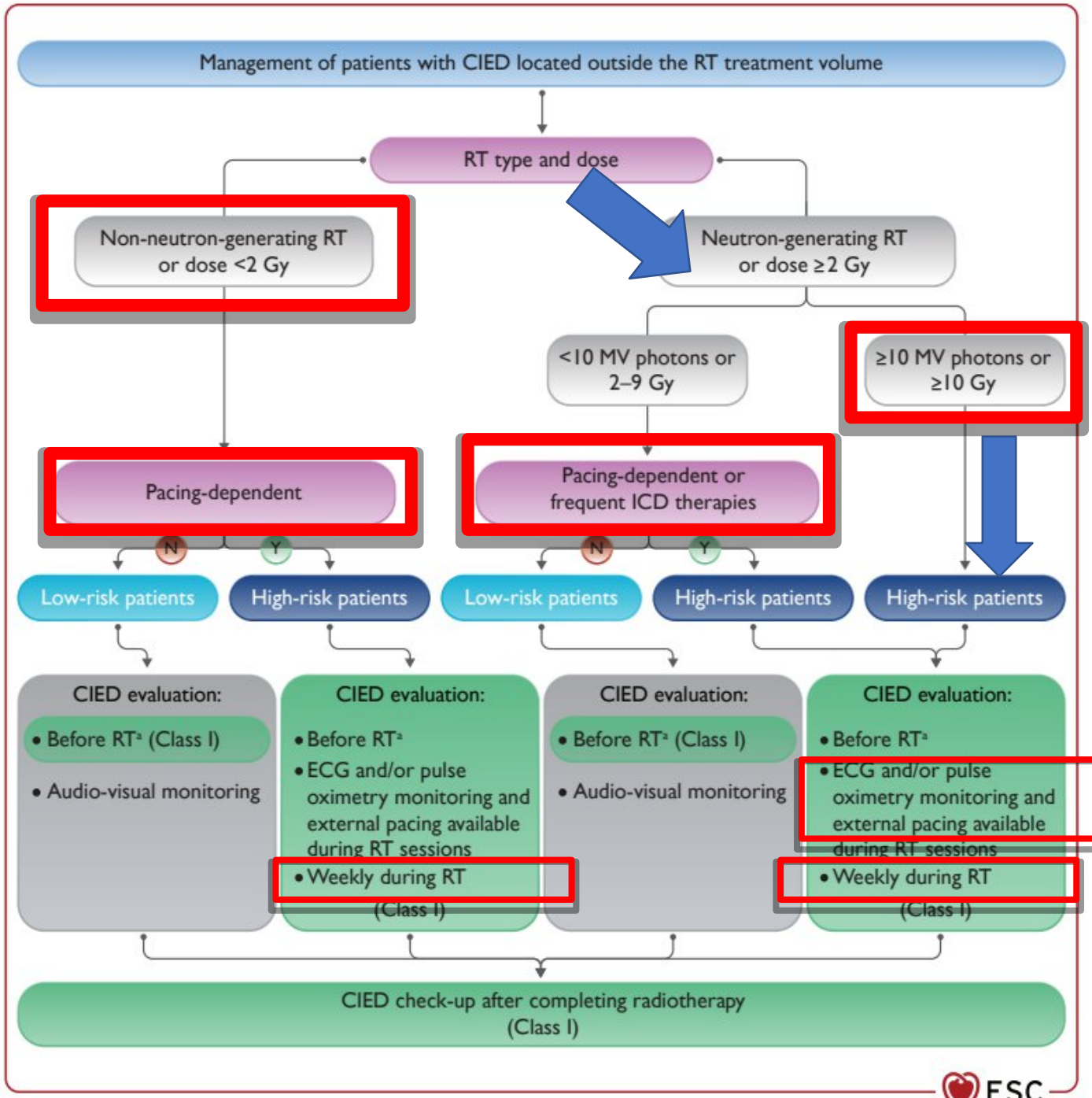
2022 ESC Guidelines on cardio-oncology developed in collaboration with the European Hematology Association (EHA), the European Society for Therapeutic Radiology and Oncology (ESTRO) and the International Cardio-Oncology Society (IC-OS)

Developed by the task force on cardio-oncology of the European Society of Cardiology (ESC)

Authors/Task Force Members: Alexander R. Lyon*† (Chairperson) (United Kingdom), Teresa López-Fernández*† (Chairperson) (Spain), Liam S. Couch (Task Force Coordinator) (United Kingdom), Riccardo Asteggiano (Italy), Marianne C. Aznar[1] (United Kingdom), Jutta Bergler-Klein (Austria),




Assessing risk of RT to CIED
Patient
Pacing-independent
Pacing-dependent or frequent ICD therapies
CIED in the RT treatment volume
Dose region and risk category
Risk areas
YES
NO
<5 Gy
≥5 Gy
<10 Gy or neutrons <10 MV
≥10 Gy or neutrons ≥10 MV
Low risk
Medium risk
High risk
ESC


Management of patients with CIED located outside the RT treatment volume
RT type and dose
Non-neutron-generating RT or dose <2 Gy
Neutron-generating RT or dose ≥2 Gy
<10 MV photons or 2–9 Gy
≥10 MV photons or ≥10 Gy
Pacing-dependent
Pacing-dependent or frequent ICD therapies
N
Y
Low-risk patients
High-risk patients
Low-risk patients
High-risk patients
High-risk patients
CIED evaluation:
• Before RT[a] (Class I)
• Audio-visual monitoring
CIED evaluation:
• Before RT[a]
• ECG and/or pulse oximetry monitoring and external pacing available during RT sessions
• Weekly during RT (Class I)
CIED evaluation:
• Before RT[a] (Class I)
• Audio-visual monitoring
CIED evaluation:
• Before RT[a]
• ECG and/or pulse oximetry monitoring and external pacing available during RT sessions
• Weekly during RT (Class I)
CIED check-up after completing radiotherapy (Class I)
ESC

Recommendation Table 50 — Recommendations for risk stratification and monitoring for patients with cardiac implantable electronic devices undergoing radiotherapy

Recommendations	Class[a]	Level[b]
Risk stratification including planned radiation type and energy, dose to CIED, the patient's device type, and pacing dependence is recommended prior to starting treatment.[824,825,827,828]	I	C
In patients undergoing RT, a CIED check is recommended in all patients before and after completing RT, and during RT according to individual risk.[824,826]	I	C
In patients with a CIED undergoing RT at high risk of arrhythmia and/or device dysfunction, ECG monitoring and/or pulse oximetry are recommended during every RT session.[827,829,831]	I	C

CIED, cardiac implantable electronic device; ECG, electrocardiogram; RT, radiotherapy.
[a]Class of recommendation.
[b]Level of evidence.

IL fisico medico dovrà considerare che

- Il CIED non deve essere posizionato in fascio diretto
- L’ energia del fascio X deve essere ≤ 6 MV e per gli elettroni ≤ 15 MV per evitare produzione di neutroni.

- Stimare la dose massima cumulativa ricevuta dal CIED; se prossima a 2 Gy, dovrà effettuare la dosimetria in vivo.
- Stimare la distanza del CIED in cm dal bordo del campo più vicino: se < 3 cm, bisogna comunque effettuare la dosimetria in vivo.
- Nelle più recenti indicazioni delle LG, le classi di rischio vengono ridotte a 2 anzichè 3. Il rischio intermedio è considerato insieme a quello Alto.

IL cardiologo elettrofisiologo dovrà considerare se

Prima della seduta di RT:

- Buon funzionamento e dipendenza dal CIED (pacing; frequenti terapie ICD);

Dopo la seduta di RT:

- Verificare se il device è entrato in modalità di reset (modalità asincrona reattiva al «rumore da EMI»)
- Riprogrammare il CIED come prima della RT, se modificato
- Verificare il buon funzionamento ed integrità del CIED

  a) Nell' altissimo rischio prima di scollegare il paziente subito dopo la seduta;

  b) Nell' alto rischio: dopo la prima seduta e poi settimanalmente

  b) Nel basso rischio: dopo la prima seduta e poi periodicamente
- Controllo per tutti i CIED a 1-(3)-6 mesi dopo la fine della RT.
- **Monitoraggio Remoto**

Conclusions: CIEDs and Radiotherapy

- The pooled prevalence of RT-related CIED malfunctions is variable, ranging from around **4% to 20%**;
- The use of **neutron-producing energies** is associated with a **higher risk** of CIED malfunctions as compared to non-neutron-producing energies;
- **ICD/CRT-D** showed a **higher risk** of malfunctions as compared to PM/CRTP.
- A higher radiation dose, that is, **Dmax >2 Gy** did not confer a significantly higher risk of CIED malfunctions.
- **Low- and High-Risk (55% and 45% of pts)** classes algorithm is a better classification in the management of CDIEs during RT.
- ECG monitoring during RT sessions; CIED clinician available within 10 min;
- Magnet/device reprogramming and weekly CIED interrogation are important parts of the multidisciplinary and safe management of **High-Risk** patients.

Elettrobisturi

Figura 1. Posizionamento della piastra bipartita

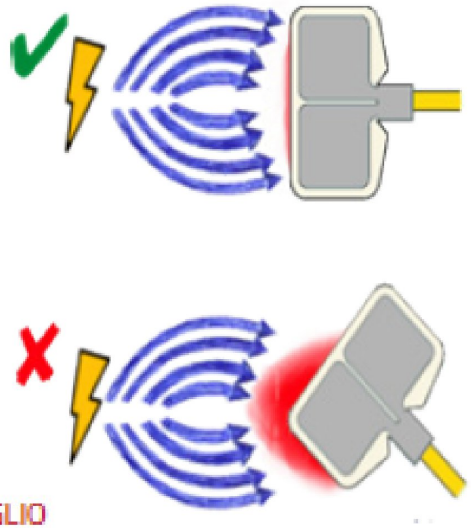


Figura A2. Forme d'onda relative alla modalità di taglio, taglio e coagulo contemporanei e coagulo (COVIDIEN, rev. 2008/03)[3]

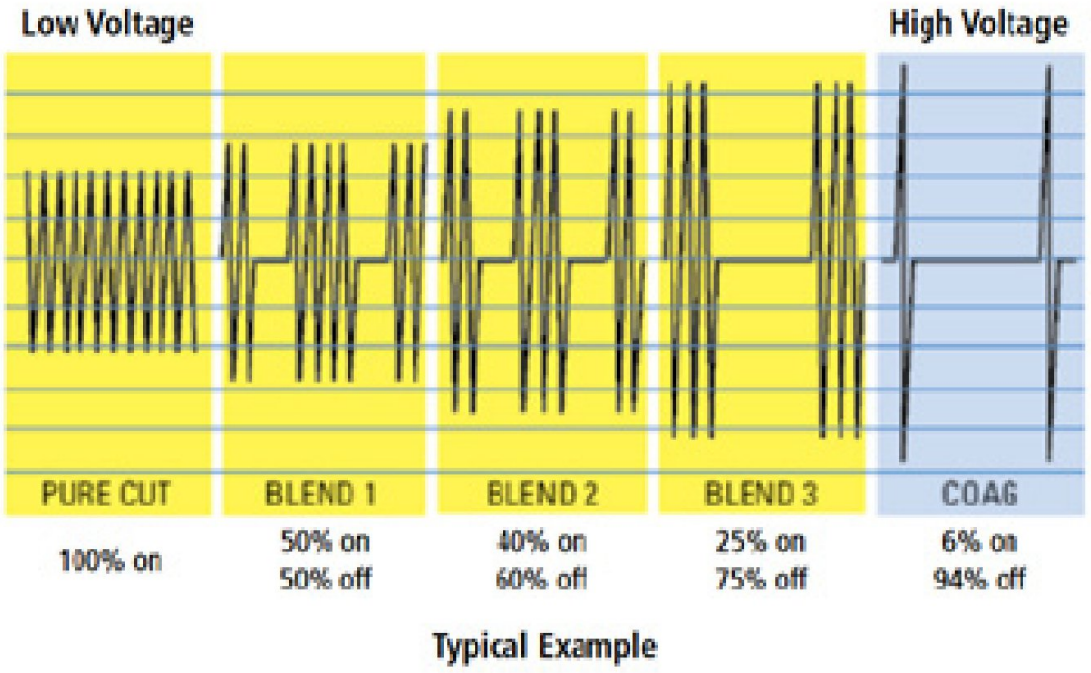
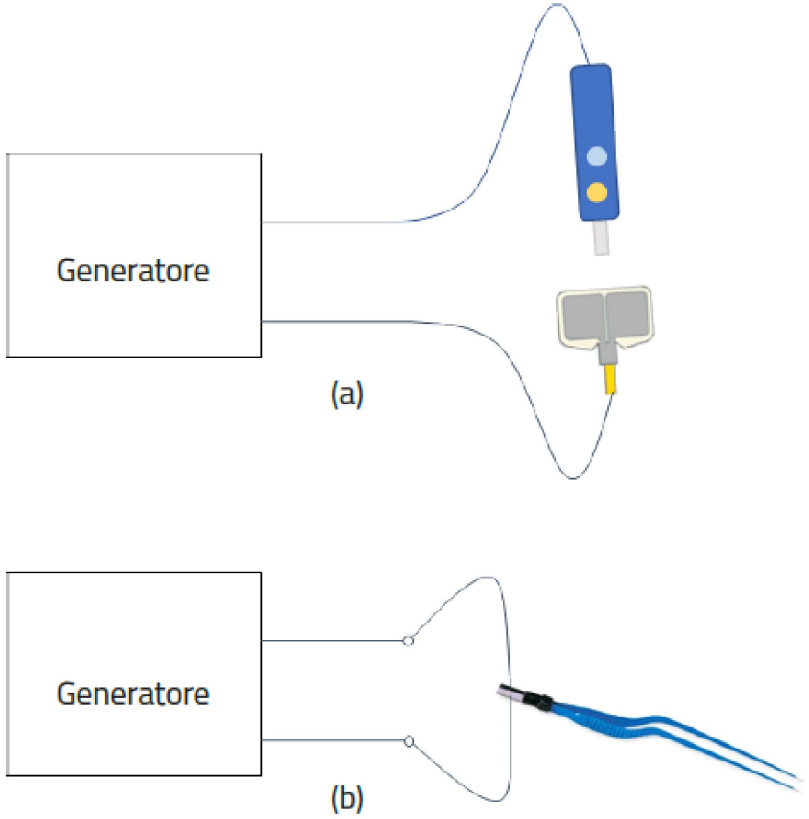


Figura A3. Tipologie di utilizzazione di un elettrobisturi: monopolare (a) e bipolare (b)



Classificazione degli elettrobisturi in relazione al circuito di uscita in alta frequenza

Elettrobisturi

- è utile ridurre l’applicazione ad intervalli di 5 secondi o meno, con pause di almeno 5 secondi
- è consigliabile minimizzare la durata e l’ energia delle applicazioni
- le interferenze si verificano più raramente quando l’elettrobisturi viene utilizzato al di sotto dell’ombelico, rispetto a quando viene utilizzato al di sopra,
- posizionando la piastra dell’elettrobisturi lontana dal device il rischio di interferenze diminuisce.

- **Le procedure gastrointestinali** con elettrobisturi possono causare interferenze.

The Heart Rhythm Society (HRS)/American Society of Anesthesiologists (ASA) Expert Consensus Statement on the Perioperative Management of Patients with Implantable Defibrillators, Pacemakers and Arrhythmia Monitors: Facilities and Patient Management

This document was developed as a joint project with the American Society of Anesthesiologists (ASA), and in collaboration with the American Heart Association (AHA), and the Society of Thoracic Surgeons (STS)

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[##]Representing the Society of Thora*

TABLE OF CONTENTS

ABBREVIATIONS **ICD** = Implantable
EMI = Electromagnetic interference; **CI**
electronic device; **RF** = Radio frequenc
apy; **TUNA** = Transurethral needle ablat
tion of the prostate; **TENS** = Transcutan
CRT-P = Cardiac resynchronization ther
resynchronization therapy defibrillator; **C**
and technicians who care for the
team = The anesthesiologist, surgeon, a
associated with the procedure and the pre
Rhythm 2011;8:1114–1152)

This document was endorsed by the H
30, 2010, and endorsed by the American H
2010, and by the American College of Ca
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ciety, 1400K Street, NW, suite 500,
solson@hrsonline.org.

Table 3 Preoperative recommendations

- The Procedure team must advise the CIED team about the nature of the planned procedure.
- The CIED team will provide guidance in the form of a prescription to the procedure team for the management of the CIED.
- General principles guiding this prescription include the acknowledgement that:
  - Inactivation of ICD detection is *not* a universal requirement for all procedures.
  - Rendering PMs asynchronous in pacemaker-dependent patients is *not* a universal requirement of all procedures.
  - Pacemakers that need to be protected from inhibition may be made asynchronous by programming or by placement of a magnet applied over the pulse generator, provided the pulse generator is accessible.
  - ICD arrhythmia detection can be suspended by placement of a magnet over the pulse generator, provided the pulse generator is accessible.
  - A magnet placed over an ICD generator will not render pacemaker function in an ICD asynchronous.
  - Inactivation of ICD detection is recommended for all procedures using monopolar electrosurgery or RF ablation above the umbilicus.
  - Rendering a PM asynchronous in a PM-dependent patient is preferable for most procedures above the umbilicus.
  - In pacemaker patients, no reprogramming is usually needed if the electrosurgery is applied below the level of the umbilicus.
- All patients with pacemakers undergoing elective surgery should have had a device check as part of routine care within the past 12 months that identifies the required elements specified below.
- All patients with ICDs undergoing elective surgery should have had a device check as part of routine care within the past 6 months that identifies the required elements specified in Table 4.

1547-5271/$ -see front matter doi:10.1016/j.hrthm.2010.12.023

Table 6 Approach to emergent/urgent procedures

Identify the type of device
- ICD, pacemaker, CRT-ICD, or CRT-pacemaker. Options for help in identification are:
  - Evaluate the medical record
  - Examine the patient registration card
  - Telephone the company to clarify device type
  - Examine the chest radiograph

Determine if the patient is pacing
- Obtain a 12-lead electrocardiogram or rhythm strip documentation
- If there are pacemaker spikes in front of all or most P wave and/or QRS complexes, assume pacemaker dependency
  - **Pacemaker dependent**?#
    - — **Yes:** pacemaker (not ICD) → Use short electrosurgical bursts, place magnet over device for procedures above umbilicus or extensive electrosurgery, have magnet immediately available for procedures below umbilicus
      - --- Monitor patient with plethysmography or arterial line
      - --- Transcutaneous pacing and defibrillation pads placed anterior/posterior
      - --- Evaluate the pacemaker before leaving a cardiac-monitored environment
    - — **Yes:** ICD or CRT-D* → Place magnet over device to suspend tachyarrhythmia detection, use short electrosurgical bursts†
      - --- Monitor patient with plethysmography or arterial line
      - --- Transcutaneous pacing and defibrillation pads placed anterior/posterior
      - --- Evaluate the ICD before leaving a cardiac-monitored environment
    - — **No:** pacemaker (not ICD) → Have magnet immediately available
      - --- Monitor patient with plethysmography or arterial line
      - --- Transcutaneous pacing and defibrillation pads placed anterior/posterior
      - --- Evaluate the pacemaker before leaving a cardiac-monitored environment
    - — **No:** ICD or CRT-D → Place magnet over device to suspend tachyarrhythmia detection, use short electrosurgery bursts†
      - --- Monitor patient with plethysmography or arterial line
      - --- Transcutaneous pacing and defibrillation pads placed anterior/posterior
      - --- Evaluate the ICD before leaving a cardiac-monitored environment

Contact CIED team
- A member of the CIED team should be contacted as soon as feasible
  - Provide preoperative recommendations for CIED management if time allows
  - Contact manufacturer representative to assist in interrogation of device pre- and/or post-operative (under the direction of a physician knowledgeable in CIED function and programming)
  - Perform or review postoperative interrogation

*A magnet placed over an ICD (or CRT-ICD) will not result in asynchronous pacemaker function. This can only be accomplished by reprogramming of ICDs (or CRT-ICDs) capable of this feature (majority of newer devices implanted).
†Long electrosurgery application (>5 seconds and/or frequent close spaced bursts) may result in pacemaker inhibition, causing hemodynamic risk in a pacemaker-dependent patient. Long electrosurgery application in close proximity to the device generator may rarely result in power on reset or Safety Core™ programming (Appendix 4 for the pacemaker and ICD parameters associated with these features).
#Pacemaker dependency is defined as absence of a life-sustaining rhythm without the pacing system.

Table 9 Indications for the interrogation of CIEDs prior to patient discharge or transfer from a cardiac telemetry environment

- Patients with CIEDs reprogrammed prior to the procedure that left the device nonfunctional such as disabling tachycardia detection in an ICD.
- Patients with CIEDs who underwent hemodynamically challenging surgeries such as cardiac surgery or significant vascular surgery (e.g., abdominal aortic aneurysmal repair).*
- Patients with CIEDs who experienced significant intraoperative events including cardiac arrest requiring temporary pacing or cardiopulmonary resuscitation and those who required external electrical cardioversion.*
- Emergent surgery where the site of EMI exposure was above the umbilicus
- Cardio-thoracic surgery
- Patients with CIEDs who underwent certain types of procedures (Table 8) that emit EMI with a greater probability of affecting device function.
- Patients with CIEDs who have logistical limitations that would prevent reliable device evaluation within one month from their procedure.*

CIED = Cardiac implantable electrical device.
*The general purpose of this interrogation is to assure that reset did not occur. In these cases a full evaluation including threshold evaluations is suggested.

Table 7 Recommendations for the intraoperative monitoring of patients with CIEDs

- External defibrillation equipment is required in the OR and immediately available for all patients with pacemakers or ICDs having surgical and sedation procedures or procedures where EMI may occur
- All patients with ICDs deactivated should be on a cardiac monitor and during surgery should have immediate availability of defibrillation
- Some patients may need to have pads placed prophylactically during surgery (e.g. high-risk patients and patients in whom pad placement will be difficult due to surgical site
- All patients with pacemakers or ICDs require plethysmographic or arterial pressure monitoring for all surgical and sedation procedures
- Use an ECG monitor with a pacing mode set to recognize pacing stimuli
- PMs may be made asynchronous as needed with either a magnet application or reprogramming, provided that the pulse generator is accessible
- ICD detection may be suspended by either magnet application as needed or reprogramming, provided that the pulse generator is accessible
- During the placement of central lines using the Seldinger technique from the upper body, caution should be exercised to avoid causing false detections and/or shorting the RV coil to the SVC coil
- Because of interactions with monitoring, ventilation, and other impedance monitoring operative devices, inactivating minute ventilation sensors can be considered
- Keep a magnet immediately available for all patients with a CIED who are undergoing a procedure that may involve EMI

SERVIZIO OSPEDALIERO PROVINCIALE

PROCEDURA OPERATIVA PER LA GESTIONE DI PAZIENTI PORTATORI DI PACE-MAKER O DEFIBRILLATORE IMPIANTABILE DA SOTTOPORRE AD INTERVENTO CHIRURGICO/DIAGNOSTICO CHE PREVEDA L'USO DI CORRENTE/

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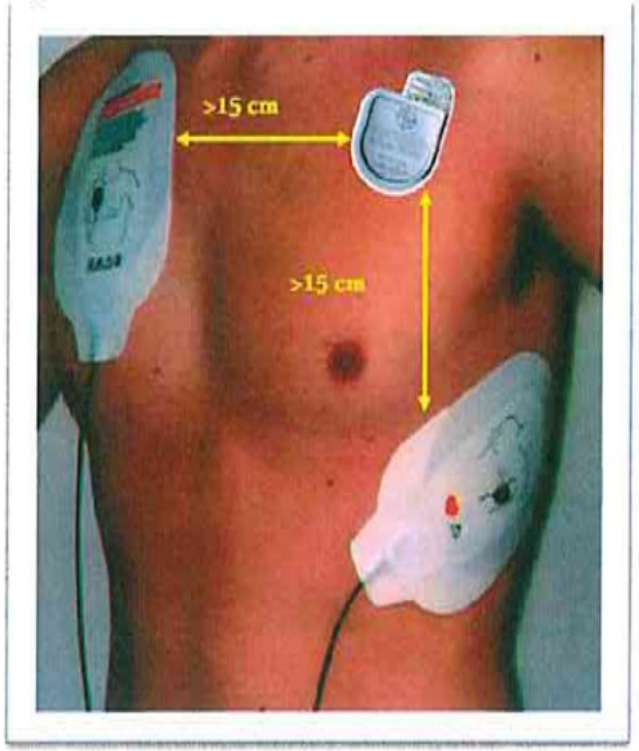

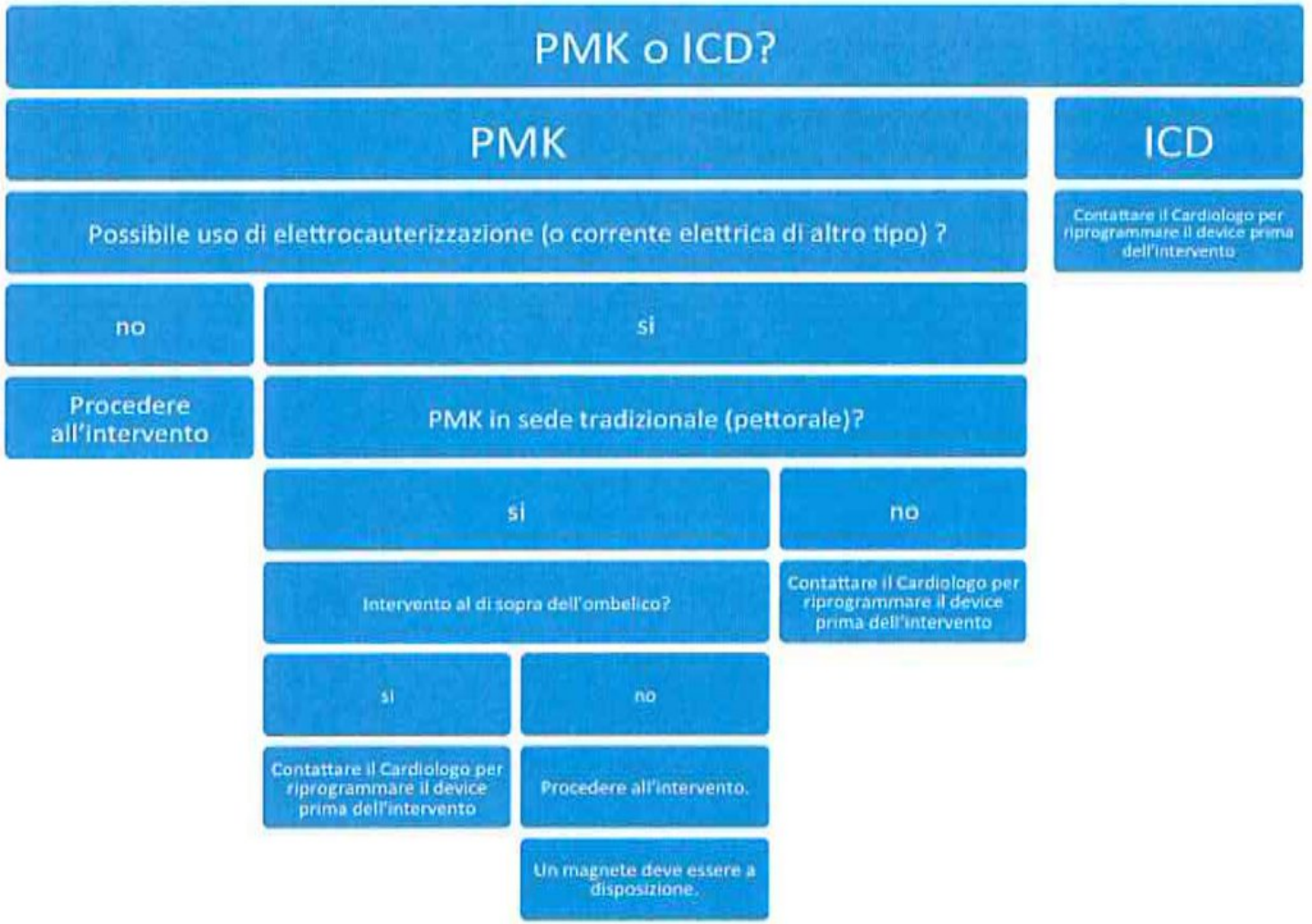

Figura 1 Algoritmo decisionale riassuntivo del percorso del paziente portatore di device cardiaco.

Paziente portatore di PMK o ICD che deve essere sottoposto a procedura che prevede l'uso di corrente, radiofrequenza, elettrocauterizzazione durante procedure endoscopiche gastroenterologiche (EGDS/colonscopia)

Practice Advisory for the Perioperative Management of Patients with Cardiac Implantable Electronic Devices: Pacemakers and Implantable Cardioverter–Defibrillators 2020

*An Updated Report by the American Society of Anesthesiologists Task Force on Perioperative Management of Patients with Cardiac Implantable Electronic Devices**

Practice advisories are systematically developed reports that are intended to assist decision-making in areas of patient care. Advisories provide a synthesis of scientific literature and analysis of expert opinion, clinical feasibility data, open forum commentary, and consensus surveys. Practice advisories developed by the American Society of Anesthesiologists (ASA) are not intended as standards, guidelines, or absolute requirements, and their use cannot guarantee any specific outcome. They may be adopted, modified, or rejected according to clinical needs and constraints, and they are not intended to replace local institutional policies.

Practice advisories summarize the state of the literature and report opinions obtained from expert consultants and ASA members. They are not supported by scientific literature to the same degree as standards or guidelines because of the lack of sufficient numbers of adequately controlled studies. Practice advisories are subject to periodic revision as warranted by the evolution of medical knowledge, technology, and practice.

This document updates the Practice Advisory for the Perioperative Management of Patients with Cardiac Implantable Electronic Devices: Pacemakers and Implantable Cardioverter–Defibrillators: An Updated Report by the American Society of Anesthesiologists Task Force on Perioperative Management of Patients with Cardiac Implantable Electronic Devices, adopted by the ASA in 2010 and published in 2011.[1]

Methodology

Definition of Cardiac Implantable Electronic Devices

For this advisory, a cardiac implantable electronic device refers to any permanently implantable cardiac pacemaker or any implantable cardioverter–defibrillator. The term cardiac implantable electronic device also refers to any cardiac resynchronization therapy device.†

Purposes of the Advisory

The purposes of this advisory update are to: (1) facilitate safe and effective perioperative management of the patient with a cardiac implantable electronic device and (2) reduce the incidence of adverse outcomes. Perioperative management refers to the preoperative, intraoperative, postoperative, or recovery period in any setting where an anesthesia provider will be delivering anesthesia care. Adverse outcomes associated with cardiac implantable electronic device function include, but are not limited to, damage to the device, inability of the device to deliver pacing or shocks, lead-tissue interface damage, changes in pacing behavior, electrical reset to the backup pacing mode, and inappropriate implantable cardioverter–defibrillator therapies.[2]

Adverse clinical outcomes include, but are not limited to, hypotension, tachyarrhythmia and bradyarrhythmia,

This article is featured in "This Month in Anesthesiology," page 1A. Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site (www.anesthesiology.org).

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A complete bibliography used to develop this updated Advisory, arranged alphabetically by author, is available as Supplemental Digital Content 1 (http://links.lww.com/ALN/B979).

*Updated by the Committee on Standards and Practice Parameters: Jeffrey L. Apfelbaum, M.D. (Committee Chair), Chicago, Illinois; Peter M. Schulman, M.D. (Task Force Co-Chair), Portland, Oregon; Aman Mahajan, M.D., Ph.D. (Task Force Co-Chair), Pittsburgh, Pennsylvania; Richard T. Connis, Ph.D. (Chief Methodologist), Woodinville, Washington; and Madhulika Agarkar, M.P.H. (Methodologist), Schaumburg, Illinois.

†Generic pacemaker and defibrillator codes are provided in tables 1 and 2. Note that every transvenous implantable cardioverter–defibrillator includes both pacing and shock therapy capabilities for the management of bradyarrhythmias and tachyarrhythmias.

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Journal of *Clinical Medicine*

MDPI

Review

Perioperative Management of Patients with Cardiac Implantable Electronic Devices and Utility of Magnet Application

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Abstract: With the demographic evolution of the population, patients undergoing surgery today are older and have an increasing number of sometimes complex comorbidities. Cardiac implantable electronic devices (CIED) are also getting more and more complex with very sophisticated programming algorithms. It may be generally assumed that magnet application reverts pacing to an asynchronous mode in pacemakers and disables tachycardia detection/therapy in internal cardioverter-defibrillators. However, depending on device type, manufacturer and model, the response to magnet application may differ substantially. For these reasons, perioperative management of CIED patients is getting more and more challenging. With this review article we provide an overview of optimal perioperative management of CIED patients with a detailed description of CIED response to magnet application depending on manufacturer and device-type, which may help in providing a safe perioperative management plan for the CIED patient.

Keywords: cardiac implantable electronic device; perioperative management; magnet application; pacemaker; implantable cardioverter defibrillator; cardiac resynchronization therapy

check for updates

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1. Introduction

The clinical adoption of novel therapies which were developed over the last two decades, including cardiac implantable electronic devices (CIEDs) for patients with cardiovascular diseases, resulted in a substantially improved quality of life and survival of these patients. As a result, more CIED patients are possibly exposed to diseases in need of surgery during their lifetime [1–3]. Given the increasing complexity of CIED programming, peri- and intra-operative management of CIED patients by surgeons, anesthesiologists, internal specialists and cardiologists require a good understanding of the device function and behavior in case a CIED is exposed to electromagnetic interference (EMI) during surgery. Placing a magnet over the device may be sufficient for some devices, whereas for others it may cause unexpected CIED behavior or even harm the patient [4,5].

Anesthesiologists refer to clinical practice recommendations by the American Society of Anesthesiologists for the management of CIED patients [6]. These guidelines, however, do not specifically focus on CIED behavior and possible issues occurring during magnet application. On the other hand, cardiologists and clinical electrophysiologists refer to recommendations which were issued by the Heart Rhythm Society [7] more than 10 years ago. This document does not consider more recent device technologies such as subcutaneous implantable cardioverter defibrillators (ICD) or leadless cardiac pacemakers (LCP). Notably, to date, there are no European guidelines regarding the perioperative management of CIED patients. In contrast, national recommendations such as those issued jointly by

Medtronic

Microport

Biotronik

St. Jude Medical#

Boston Scientific*

Abbott

Table 1. Magnet application on Pacemakers.

Manufacturer	Magnet Mode, Rate at BOL/ERI (ppm)	Magnet Response Programmable	AV-Delay (if DDD)	Remarks
Abbott (former SJMI)	DOO/SOO, 100 [§]/85 [$]	*Battery test* [n], *Off*	120 ms	• Asynchronous pacing starts after EGM storage (may take up to 5 s) • *AutoCapture* enabled: high-output mode
Biotronik	DOO/SOO, 90/80 *	*Auto*[n], *Asynchronous*, *Synchronous*	100 ms	• *Auto*: asynchronous pacing only for 10 cycles • *Trigger function* enabled: magnet mode automatically set to *synchronous* • Device in mode switch: DOO (only for 10 cycles if magnet mode is *Auto* [n]) • Dual-chamber pacemaker programmed to VVI: VOO (only for 10 cycles if magnet mode is *Auto* [n])
Boston Scientific	DOO/SOO, 100 [%]/85	*Pace Async* [n], *Store EGM*, *Off* (In older models: *Async* [n], *EGM* or *Off*)	100 ms	• *Pace Async*: pulse width of 3rd impulse reduced by 50% to evaluate sufficient pacing safety margin
Medtronic	DOO/SOO, 85/65	No	minimum pro-grammed pAV delay or 180 ms	• Azure, Astra: 100 ppm for 5 cycles followed by magnet rate • Adapta, Versa, Sensia, Relia, Attesta: *threshold margin test:* 100 ppm with 100 ms AV delay and amplitude reduction by 20% at 3rd impulse, afterwards conversion to magnet rate • Leadless cardiac pacemaker (MICRA VR and MICRA AV): magnet has no effect
Microport (former Sorin)	DOO/SOO, 96/80	No	resting AV delay	• Pacing with 5 V @ 0.5 ms in each paced chamber (if not programmed higher) • Exiting magnet mode: 6 cycles at magnet rate with 95 ms AV delay, followed by 2 asynchronous cycles with permanently programmed parameters, followed by permanent programming

Medtronic

Microport

Biotronik

St. Jude Medical#

Boston Scientific*

Abbott

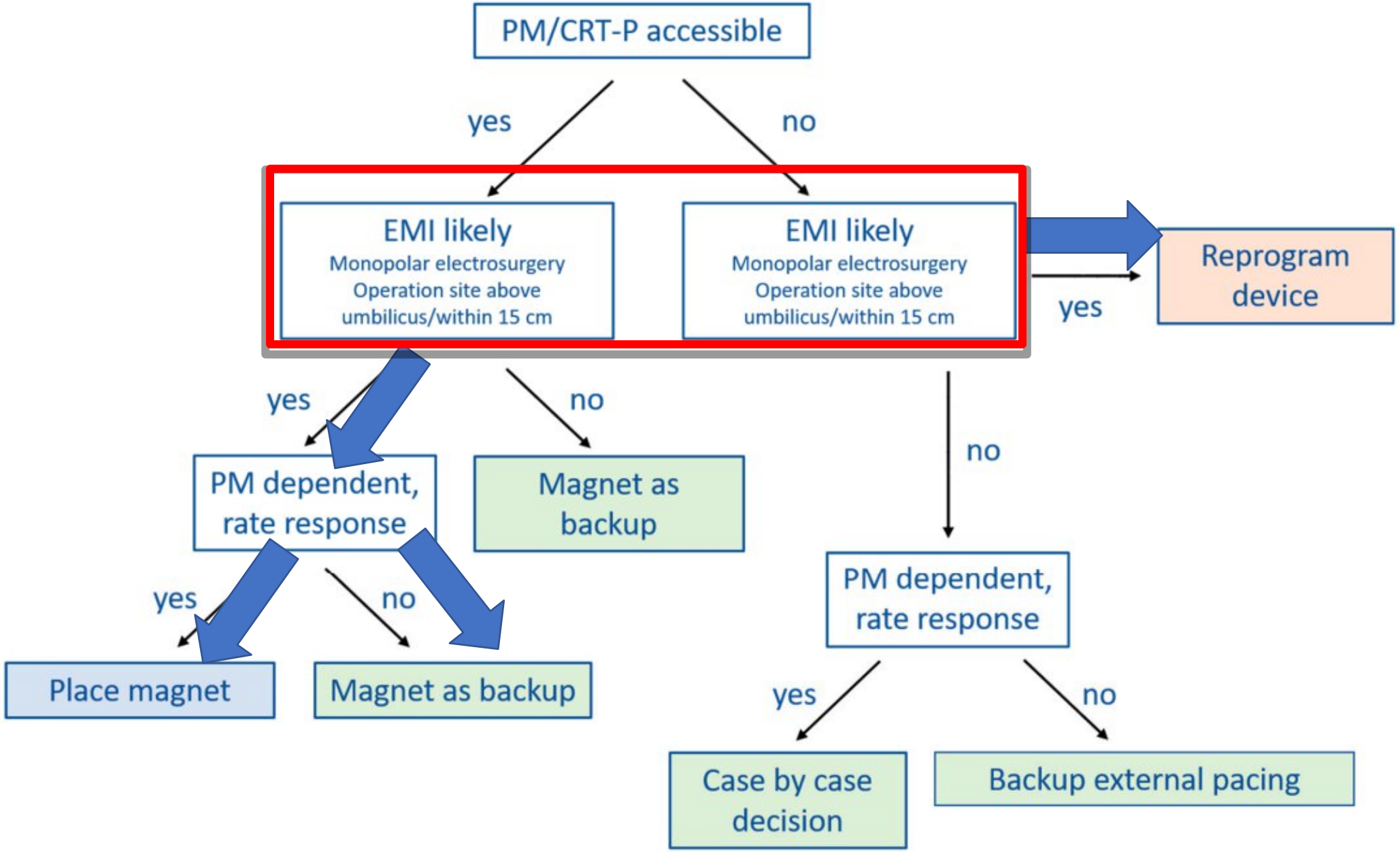
Table 3. Magnet application on an implantable cardioverter defibrillator.

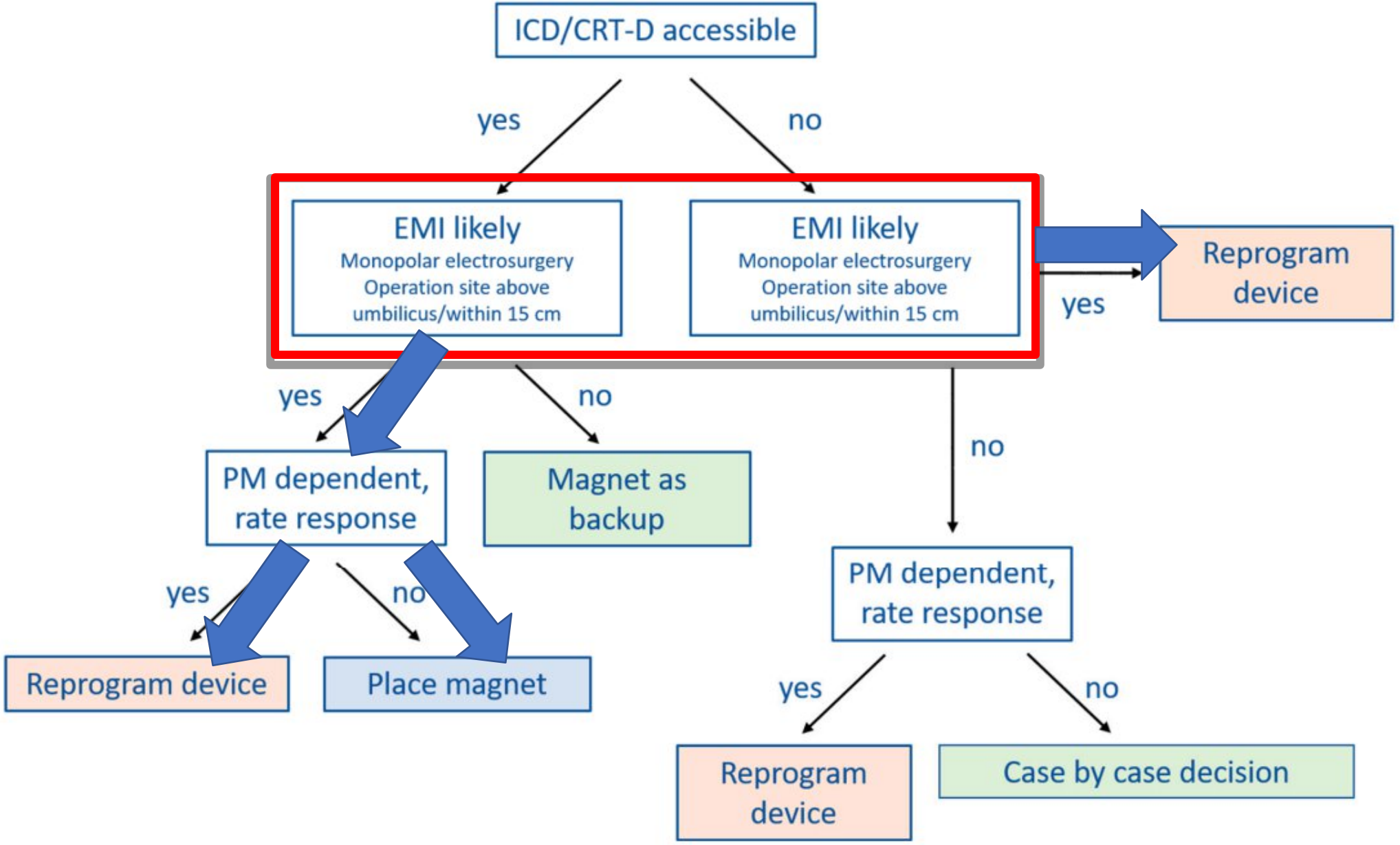
Manufacturer	Tachycardia Function	Brady Function and Sensor	Magnet Response	Acoustic Signal	Remarks
Abbott (former SJM)	Detection and therapy inhibited	Not altered	*Normal* [n], *Ignore*	• Magnet mode initiation: 4 s tone * • Magnet mode termination: 6 s higher tone *	• Acoustic signal only in newer models (Avant, Gallant, Entrant, Neutrino)
Biotronik	Detection and therapy inhibited	Not altered	Not programmable	None	• 8 h of continuous magnet application: tachy detection and therapy automatically re-enabled
Boston Scientific	Therapy inhibited, detection active	Not altered	*Inhibit Therapy* [n], *Off*, *Store EGM*	• *Off*, *Monitor Only*, *Electrocautery Mode*: constant tone • *Monitor + Therapy*: beeping tone • S-ICD: 60 s beeping confirms deactivation of tachy detection and therapy • PRIZM, PRIZM 2, VITALITY change from beep to continuous—therapies deactivated; change from continuous to beep—therapies re-activated;	• *Inhibit Therapy*: detection remains active • *Store EGM*: after 60 d or EGM storage via magnet: conversion to *Inhibit Therapy* • Correct magnet positioning for S-ICD: centrally in SQ-RX 1010, over header or lower edge in Emblem. • Older models (PRIZM, PRIZM 2, VITALITY): magnet toggles mode between *Monitor + Therapy* and *Off*; magnet repositioning required to change between modes
Medtronic	Detection and therapy inhibited	Not altered	Not programmable	• 10 s continuous: normal function • 30 s intermittent on-off ("truck backing up"): low-urgency alert • 30 s alternating high-low frequency ("French police car"): high-urgency alert	

Table 5. Electrical Reset in CIED.

Manufacturer	Pacing Mode Brady/ Tachy	Pacing Rate Brady/Tachy	Pacing Polarity Brady/Tachy	Pacing Output Brady/Tachy	Remarks
Abbott (former SJM)	VVI/VVI	67 ppm/67 ppm	unipolar/ bipolar	5 V @ 0.6 ms/ 5 V @ 0.6 ms	• CRT-D: LV pacing from tip to RV Ring (anodal capture possible) • CRT-P: unipolar LV pacing • Victory, Zephyr, Identity, Verity PM: pacing at 67.5 ppm, 4 V @ 0.6 ms
Biotronik	VVI/VVI	70 ppm/70 ppm	unipolar/ bipolar	7.5 V @ 1.5 ms/ 5 V @ 0.5 ms	In CRT-D: LV-output 4.8 V @ 0.5 ms
Boston Scientific	VVI/VVI	72.5 ppm/ 72.5 ppm	unipolar/ unipolar	5 V @ 1.0 ms/ 5 V @ 1.0 ms	In CRT: LV offset 0 ms, unipolar LV pacing
Medtronic	VVI/VVI	65 ppm/65 ppm	uniolar/ bipolar	6 V @ 1.5 ms/ 6 V @ 1.5 ms	Older models (Adapta/Versa/Sensia/Relia): bipolar pacing with 5 V @ 0.4 ms
Microport (former Sorin)	VVI/VVI	70 ppm/60 ppm	unipolar/ bipolar	5 V @ 0.5 ms/ 5 V @ 0.35 ms	-

Brady—pacemaker or CRT-P, SJM – St. Jude Medical, tachy—ICD or CRT-D.


PM/CRT-P accessible
yes
no
EMI likely
Monopolar electrosurgery
Operation site above
umbilicus/within 15 cm
EMI likely
Monopolar electrosurgery
Operation site above
umbilicus/within 15 cm
yes
Reprogram
device
yes
no
PM dependent,
rate response
Magnet as
backup
no
yes
no
Place magnet
Magnet as backup
PM dependent,
rate response
yes
no
Case by case
decision
Backup external pacing


ICD/CRT-D accessible
yes
no
EMI likely
Monopolar electrosurgery
Operation site above
umbilicus/within 15 cm
EMI likely
Monopolar electrosurgery
Operation site above
umbilicus/within 15 cm
yes
Reprogram
device
yes
no
no
PM dependent,
rate response
Magnet as
backup
yes
no
Reprogram device
Place magnet
PM dependent,
rate response
yes
no
Reprogram
device
Case by case decision

ESC European Society of Cardiology

European Heart Journal (2022) **00**, 1–99
https://doi.org/10.1093/eurheartj/ehac270

ESC GUIDELINES

2022 ESC Guidelines on cardiovascular assessment and management of patients undergoing non-cardiac surgery

Developed by the task force for cardiovascular assessment and management of patients undergoing non-cardiac surgery of the European Society of Cardiology (ESC)

Endorsed by the European Society of Anaesthesiology and Intensive Care (ESAIC)

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Recommendation Table 23 — Recommendations for management of bradyarrhythmia and patients carrying cardiac implantable devices

Recommendations	Class[a]	Level[b]
If indications for pacing exist according to the 2021 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy,[481] NCS surgery should be deferred and implantation of a permanent pacemaker should be considered.	IIa	C
It is recommended that patients with temporarily deactivated ICDs have continuous ECG monitoring, and during the peri-operative period are accompanied by personnel skilled in early detection and treatment of arrhythmias. In high-risk patients (e.g. pacemaker-dependant or ICD patients), or if access to the torso will be difficult during the procedure, it is recommended to place transcutaneous pacing/defibrillation pads prior to NCS.	I	C
It is recommended that all patients with CIEDs that are reprogrammed before surgery have a re-check and necessary reprogramming as soon as possible after the procedure.	I	C
In high-risk CIED patients (e.g. with ICD or being pacing-dependant) undergoing NCS carrying a high probability of electromagnetic interference (e.g. involving unipolar electrosurgery above the umbilical area), CIED check-up and necessary reprogramming immediately before the procedure should be considered.	IIa	C

CIED, cardiac implantable electronic device; ECG, electrocardiogram; ICD, implantable cardioverter–defibrillator; NCS, non-cardiac surgery.
[a]Class of recommendation.
[b]Level of evidence.

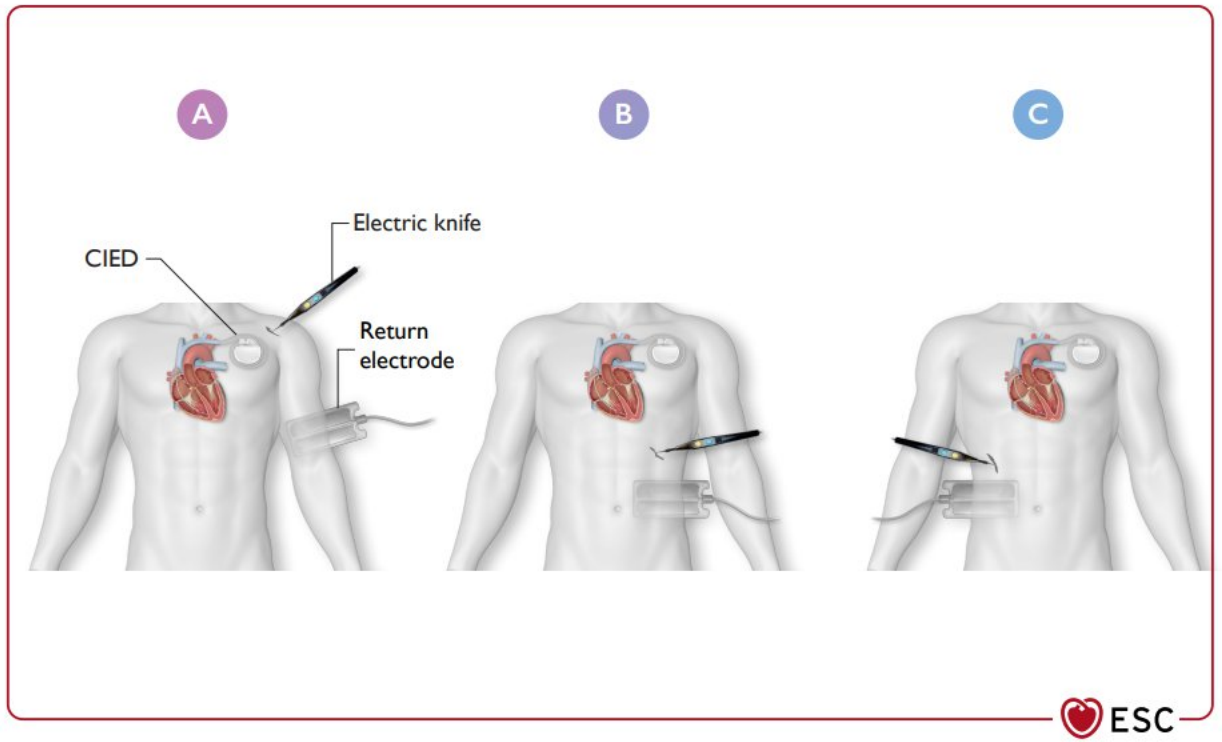

Figure 15 Optimal location of return electrode during unipolar electrosurgery in patients with cardiac implantable electronic devices, depending on the surgery site. CIED, cardiac implantable electronic device. Use of bipolar electrocautery, short (<5 s) bursts of impulses, with the lowest effective energy, operating with pen or stylus away (>15 cm) from the device can minimize the risk of interference with the device. (*A*) Surgery site on ipsilateral site above CIED. (*B*) Surgery on ipsilateral site below CIED. (*C*) Surgery on contralateral site.[494]

Gestione perioperatoria dei CIEDs

- programmare il pace-maker (PM) in asincrono nei pazienti PM dipendenti **non è indispensabile** per tutte le procedure; è preferibile per molte procedure da eseguire al di sopra dell'ombelico utilizzare l'elettrobisturi a brevi intervalli, posizionare un magnete sul PM per le procedure al di sopra dell'ombelico o per utilizzo duraturo dell'elettrobisturi, avere il magnete a portata di mano per le procedure al di sotto dell'ombelico;

- i PM che necessitano di protezione dalle inibizioni possono essere programmati in asincrono mediante il programmatore o ponendovi al di sopra un magnete;

- in genere **non è necessaria** una riprogrammazione del PM quando l'elettrobisturi viene utilizzato **al di sotto dell'ombelico.**

- nei defibrillatori (ICD) l'inattivazione degli algoritmi di identificazione delle aritmie **non è indispensabile** in tutte le procedure; è raccomandata in tutte quelle che prevedono l'utilizzo di elettrobisturi **in monopolare** o nelle procedure con radiofrequenza da eseguire in zone **al di sopra dell'ombelico**;

- il rilevamento di aritmie da parte dell'ICD **può essere momentaneamente interrotto** dalla sovrapposizione di un magnete sul device;

- il magnete posizionato sull'ICD **non modifica** in asincrono le funzioni di pacing;

– posizionare le placche per stimolazione e defibrillazione in senso antero-posteriore;

Monitorare con ECG il pz con ICD disattivato o PM-dipendente e posto in asincrono (con magnete o riprogrammazione).

Ricontrollare il device a fine procedura se riprogrammato (PMK in asincrono e ICD disattivando le terapie antitachi), in corso di chirurgia d' emergenza, chirurgia cardiotoracica e vascolare, dopo intervento complicato da arresto cardiorespiratorio con defibrillazione, stimolazione temporanea o cardioversione elettrica.

Conclusions: Perioperative management

- Electromagnetic interference (EMI) may induce oversensing (more likely with unipolar leads), activation of rate-responsive sensors, device resetting, or other damage.
- The most common source of EMI is electrocautery, although it is **rare** during **bipolar electrocautery >5 cm from the CIED and monopolar electrocautery below the umbilicus.**
- To reduce the risk of EMI, monopolar electrocautery should be applied in short (<5 sec) pulses, with the skin patches away from the area of the device.
- Other sources of EMI include radiofrequency procedures, nerve stimulators, and other electronic devices.
- The peri-operative strategy should be **tailored** based on the individual needs and values of patients, procedure, and device.
- **Most procedures will not require any intervention.**
- In **pacemaker-dependent** patients, a **magnet** should be applied during delivery of diathermy pulses, or, if EMI is likely to occur or magnet stability cannot be guaranteed, the device should be **reprogrammed** to an asynchronous mode (VOO/ DOO). The response to magnet application may differ between device manufactures.
- CIEDs with a rate-responsive function using an active sensor may also require magnet application or disabling of this function to prevent inappropriate rapid pacing.
- Post-operative CIED interrogation is recommended **if malfunction is suspected or if the device has been exposed to strong EMI.**