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Cancer Center

## A Review of Managing Commonly Seen **Implanted Devices** for Radiotherapy Patients

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### Disclosure

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Grant #SKI-1069

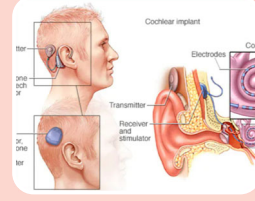
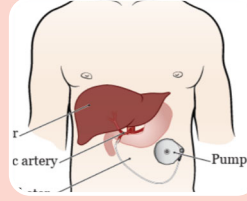
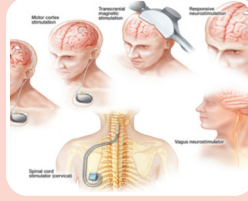
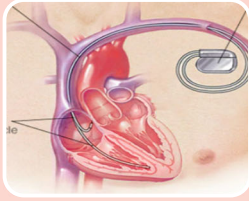
#### Relevant financial interests

- None



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## Categorizing Implanted Devices by Types



### CIEDs:

Pacemaker, Impalpable or Wearable Cardiac Defibrillator, CRT-P, CRT-D, Leadless Pacemaker, Loop Recorder, LVAD, Watchman Device

### Neurostimulators:

Deep Brain Stimulator, Spinal Cord Stimulator, Sacral Nerve Stimulator (Bladder, Gastric Stimulators), Inspire™ Sleep

### Infusion Pumps:

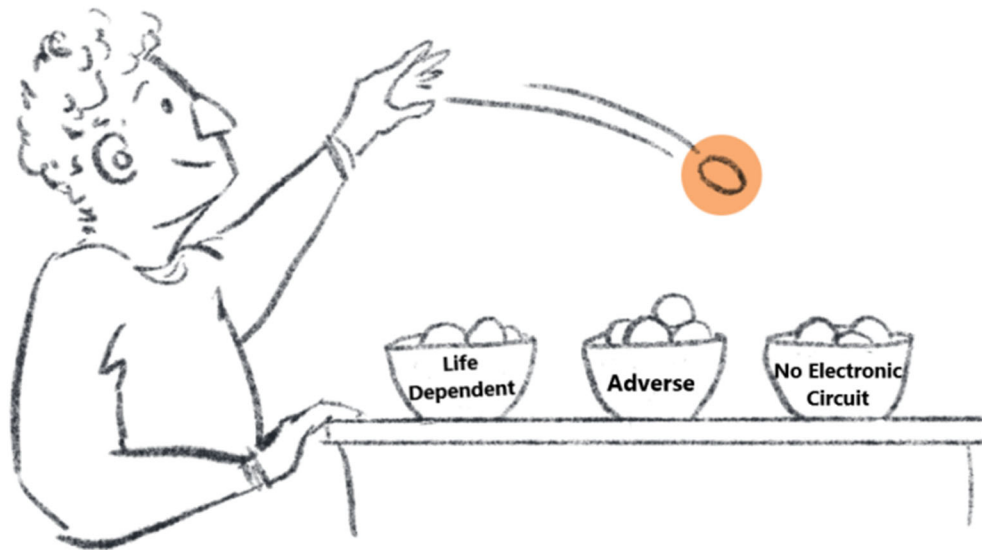
Programmable Hepatic Pump, Intrathecal Pump, Insulin Pump, Implantable Infusion Pump, CVAD, Vascular Port, Medi-port

### Other Implants:

Cochlear Implant, Glucose Monitor, Ankle Monitor Device, Cerebral Shunt, Aneurysm Pipeline, Patient-Specific Internal Fixation Systems

Picture credits: Mayo Clinic, MSKCC

## Categorizing Implanted Devices by Risks

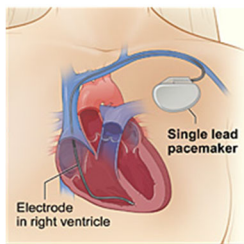


Picture credit: B. Zedan

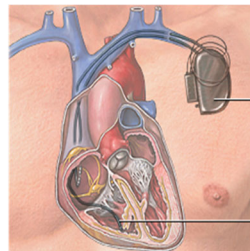
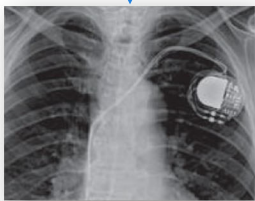


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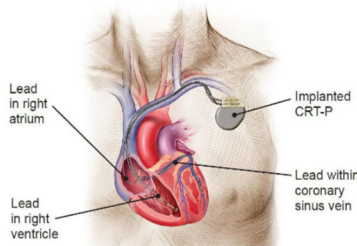
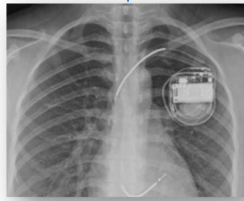
## Life-Dependent [1] - CIEDs



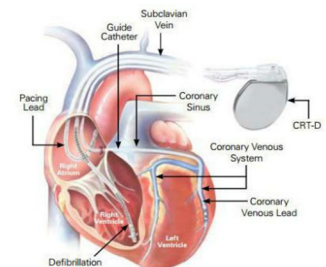
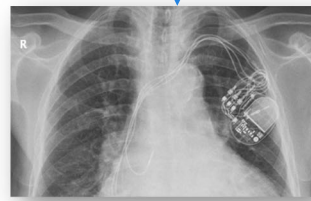
Cardiac Pacemaker



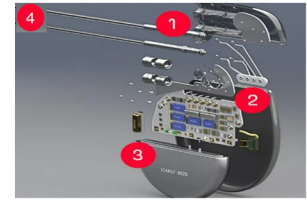
Implantable Cardiac Defibrillator



CRT-P



CRT-D



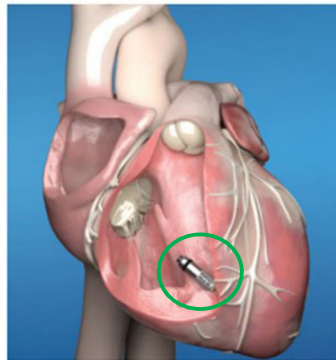
Picture credits: NHLBI, Mayo Clinic, Arizona Heart Arrhythmia Associate, Wikipedia.org

## Life-Dependent [2] - Leadless Pacemaker (Breast)

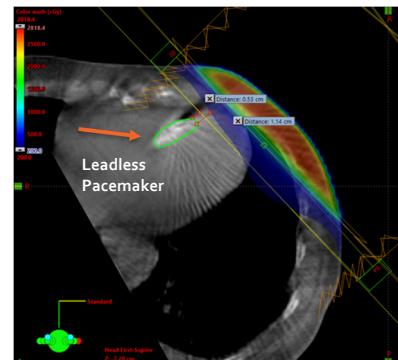
Dose Limit same as a regular pacemaker: **2-5 Gy**



Relative size  
to a penny



Implanted in the  
right ventricle



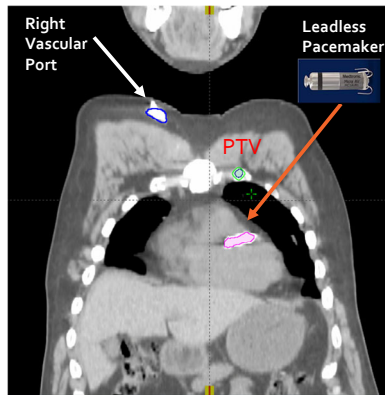
CBCT blended in TPS  
w/ 2Gy color-wash

Wang D, Chan MF, Zambri J, Lichtenwalner P, Oliver J, Gelblum D, Parikh D, *Advances in Radiation Oncology*, 2021

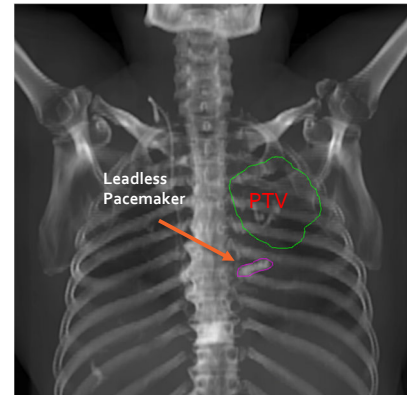
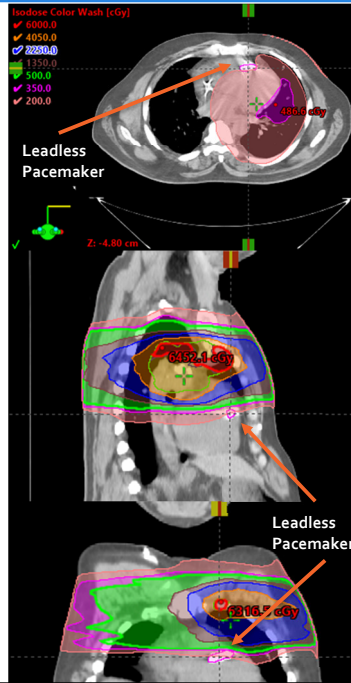


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## Life-Dependent [2] - Leadless Pacemaker (Lung)



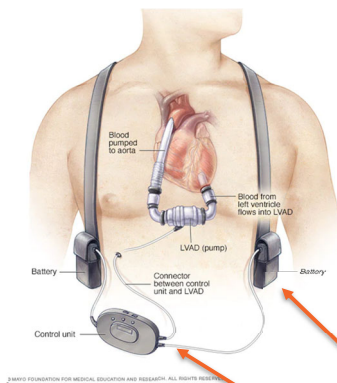
It should be programmed into asynchronous pacing mode and the dose limit is **5 Gy**



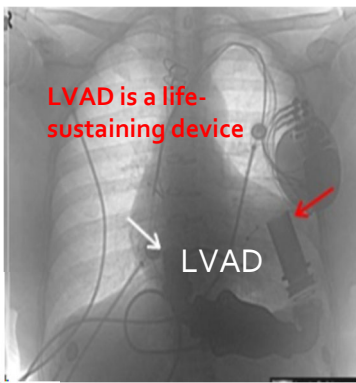
Rx to Lt Lung PTV:  
 $3/4\text{Gy} \times 15 = 45/60\text{ Gy}$



## Life-Dependent [3] – Wearable Cardiac Electronic Devices



Left Ventricular Assist Device (LVAD)



Spare battery away from machine  
Control unit as far as possible



In some situations,  
can be temporarily  
turned off and  
removed during  
radiation.

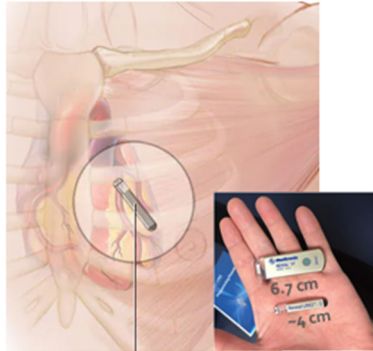
LifeVest® wearable  
cardioverter defibrillator (WCD)

Picture credits: Mayo Clinic, Learningradiology.com, Lifevest.zoll.com





## Adverse Effects [1] – Cardiac Loop Recorder (3F Breast)

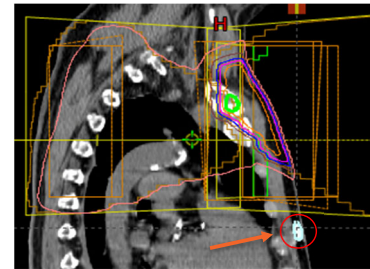
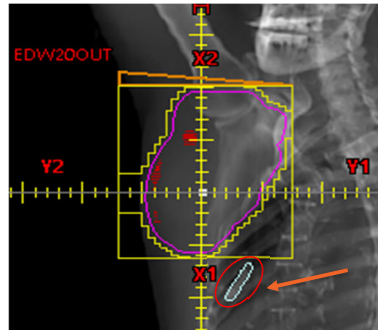
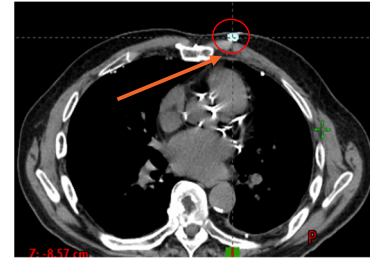
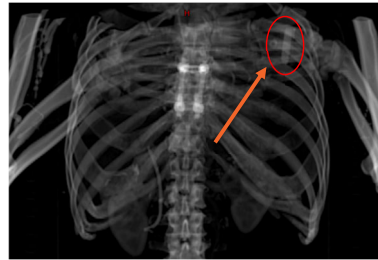


**Dose Limit:**

**5 Gy\***

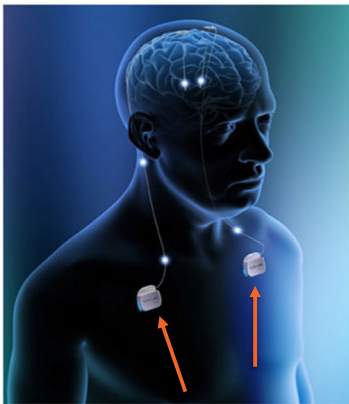
*\*For protecting the device.  
No risk to the patient even if  
damaged by RT as needed.*

Picture credits: Mayo Clinic



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## Adverse Effects [2] - Neurostimulators

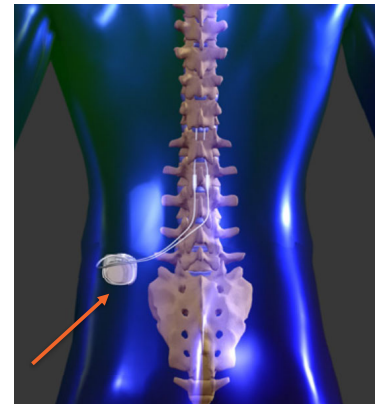


Deep Brain Stimulator (DBS)



Similar design to pacemakers

**Dose Limit: 5 Gy\***

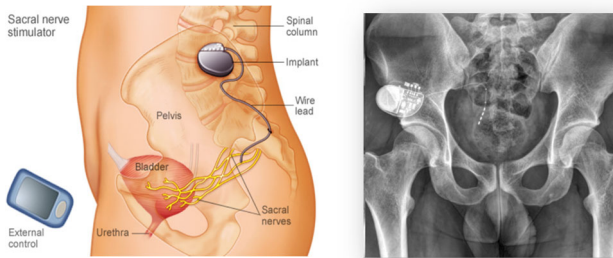


Spinal Cord Stimulator (SCS)

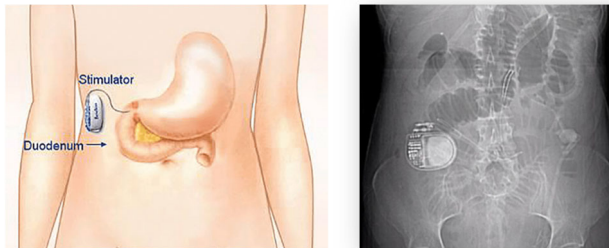
*\*Dose tolerances depending on the device/model*

Picture credits: St. Jude Medical, Medtronic, Commonwealth Spine

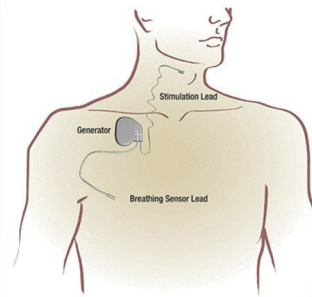
## Adverse Effects [2] - Neurostimulators



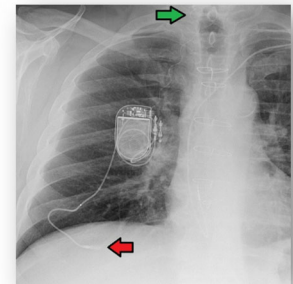
**Bladder Stimulator**



**Gastric Stimulator**



**Inspire™ Sleep**

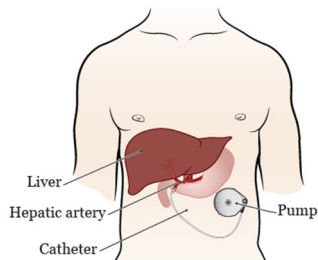


**Dose Limit: 5 Gy\***

*\*Dose tolerances depending on the device/model*

Picture credits: MD Edge, gcurology.com.au, Radiopaedia.org

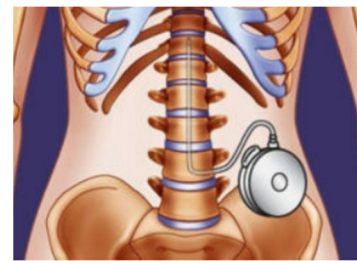
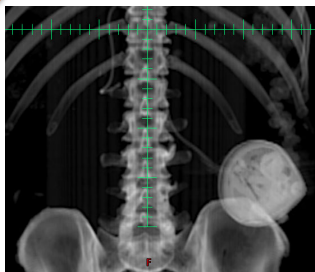
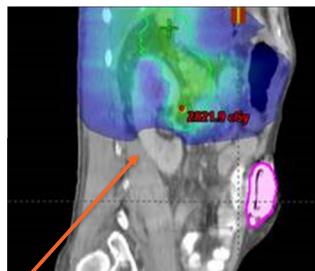
## Adverse Effects [3] – Implantable Pumps



**Programmable Hepatic Pump**

10 Gy isodose  
color-wash display  
in Eclipse TPS

**Dose Limit: 10 Gy\***



**Programmable Intrathecal Pump**



**Battery life  
4-7 years**

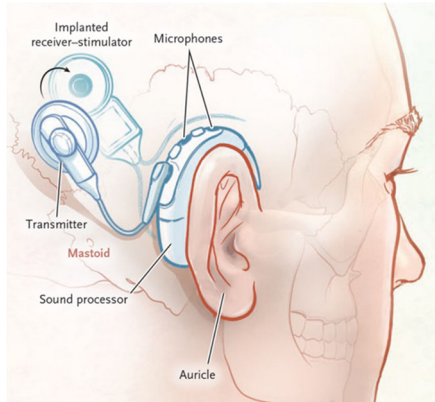
**New models  
have longer  
battery life.**

**Dose Limit:  
28.5 Gy\* SEU**

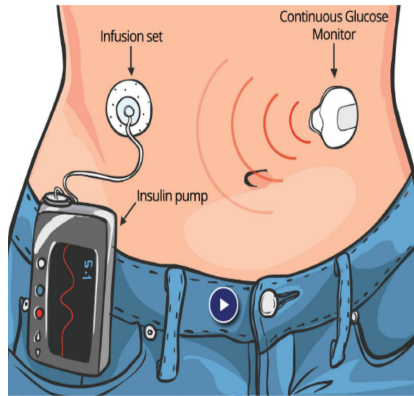
*\*Dose tolerances depending on the device/model*

Picture credits: MSKCC, Infusion Solutions, Dove Medical Press

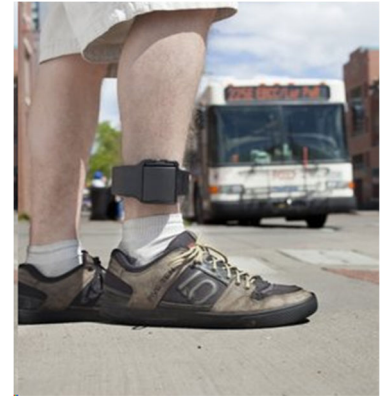
## Adverse Effects [4] – Other Implantable Devices



**Cochlear Implant**



**CGM & Insulin Pump**

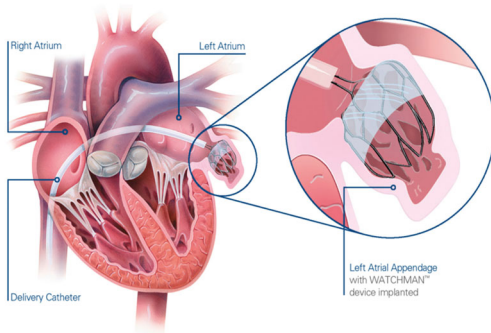


**GPS Ankle Tracker**

**(1) Disconnect; (2) Avoid neutron-producing radiation; (3) Not under direct radiation beam**

Picture credits: NEJM Resident 360, UMASSMED, Reliantmonitoring.com

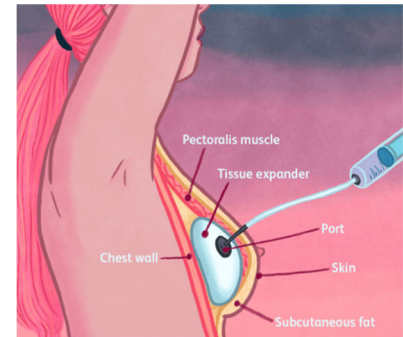
## No Electronic Circuitry (No Dose Limit) [1]



**Watchman™ Device**



**Fixation Devices**

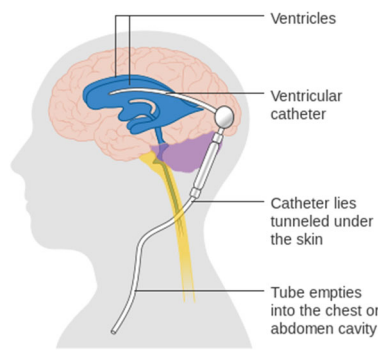


**Tissue Expander**

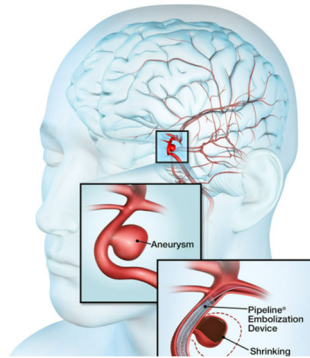
Picture credits: Boston Scientific, Medtronic, Verywell Health



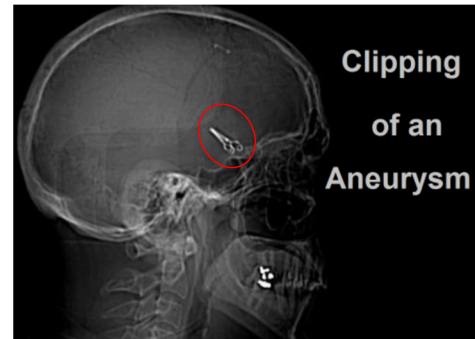
## No Electronic Circuitry (No Dose Limit) [2]



**Brain Shunt**



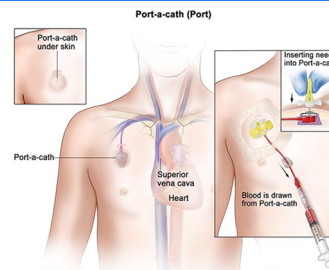
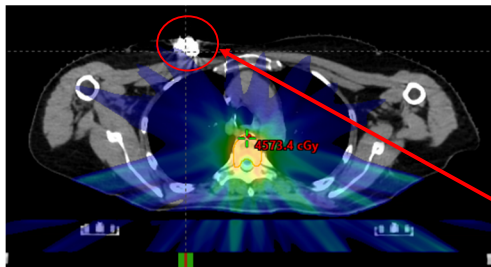
**Aneurysm Pipeline Flex**



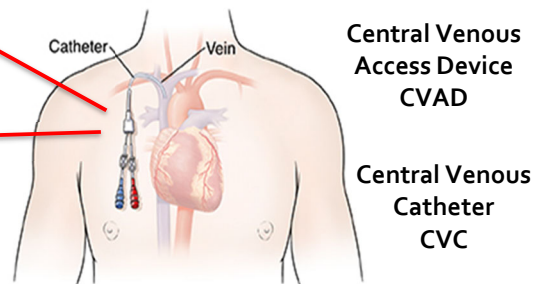
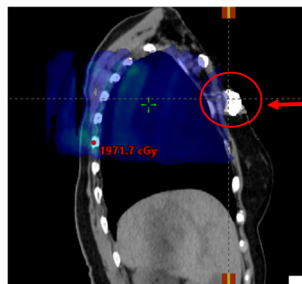
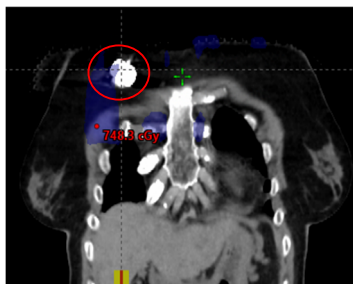
**Aneurysm Clips**

Picture credits: Wikipedia.org, Texas Winslow, Pinterest.com, Radiopaedia.com

## No Electronic Circuitry (No Dose Limit) [3]



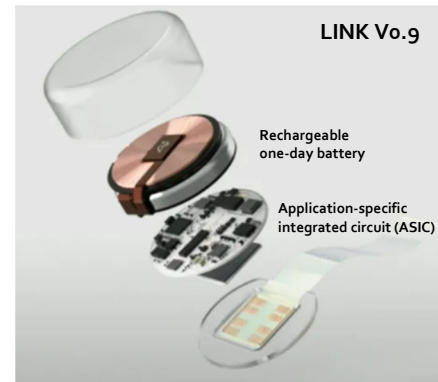
**Medi-port**



Picture credit: NCI



## What to do when you encounter a new device?



Call Manufacturer  
Literature Search



Find out what  
Components are



Apply the Principle  
Classify the Device



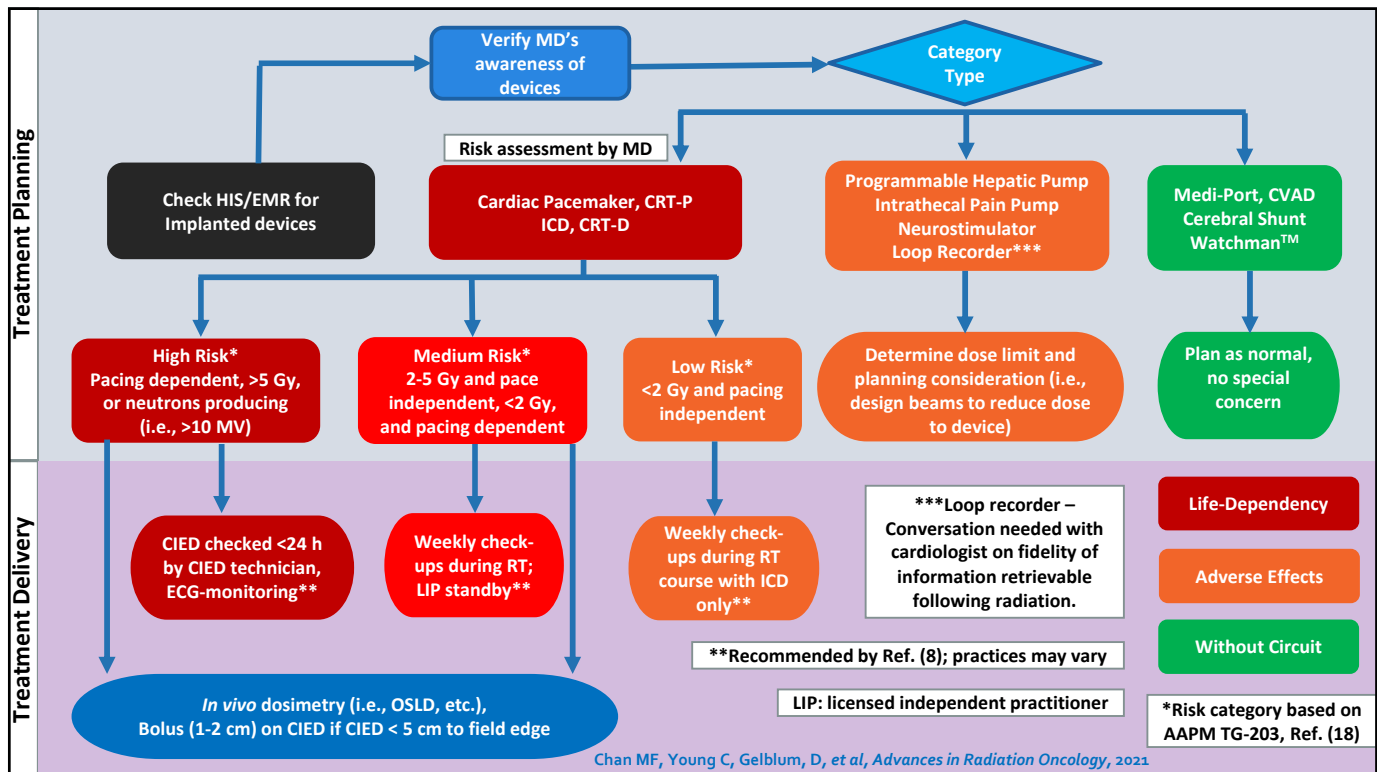
Picture credits: Medialist Innovation, CNET

## Commonly Seen Implanted Devices Dose Limits

Implanted Device	Clinical Use	Category	Dose Limit
Pacemaker	Control heartbeat	Life-dependent	2-5 Gy
ICD	Sends electrical signals to heart	Life-dependent	0.5-2 Gy
Neurostimulators	Send electrical signals to brain, spine, sacral nerve, stomach, etc.	Adverse	5 Gy
Programmable hepatic pump	Gives continual chemotherapy to liver	Adverse	10 Gy
Intrathecal pain pump	Gives continual pain medication to spine	Adverse	28.5 Gy (SE)
Cardiac Loop Recorder	Monitors heart rhythm	Adverse <sup>α</sup>	5 Gy <sup>α</sup>
Glucose Monitor/Insulin Pump	Measures glucose/deliver insulin in body	Adverse <sup>β</sup>	NA
Cerebral shunt	Drains excess CSF from brain	Without circuits	NA
Mediport, CVAD	Vein access point for chemo, IV	Without circuits	NA

<sup>α</sup>5 Gy is a soft limit for protecting the device itself. No risk to the patient even if the device is damaged by radiation as needed.

<sup>β</sup>The devices should be disconnected and removed for radiation treatments. This is applied to many other similar implanted devices.



## In Vivo Dosimetry (Out-of-Field)

OSLD	TLD	Diode	MOSFET	Film	IC
<ul style="list-style-type: none"> <li>• Energy dependency               <ul style="list-style-type: none"> <li>❖ Overresponse if calibrated in-field</li> </ul> </li> <li>• Nonlinearities               <ul style="list-style-type: none"> <li>❖ Low dose level</li> <li>❖ High dose level &gt; 200cGy</li> </ul> </li> <li>• Neutrons</li> </ul>	<ul style="list-style-type: none"> <li>• Energy dependency               <ul style="list-style-type: none"> <li>❖ Overresponse if calibrated in-field</li> </ul> </li> <li>• Nonlinearities</li> <li>• Neutrons</li> <li>• Overresponse</li> <li>• Readout time</li> <li>❖ 1-24 hrs</li> </ul>	<ul style="list-style-type: none"> <li>• Energy dependency</li> <li>• Instantaneous dose-rate dependency</li> <li>• Angular dependence</li> <li>• Temperature dependence</li> </ul>	<ul style="list-style-type: none"> <li>• Energy dependency               <ul style="list-style-type: none"> <li>❖ Overresponse</li> </ul> </li> <li>• Angular dependence</li> <li>• Asymmetric design</li> <li>• Limited lifetime</li> <li>• Sensitivity</li> </ul>	<ul style="list-style-type: none"> <li>• Energy dependency               <ul style="list-style-type: none"> <li>❖ Underresponse &lt; 50 kV</li> </ul> </li> <li>• Dose level</li> <li>❖ &gt; 1cGy</li> <li>• Calibration curve</li> <li>❖ Extend low dose</li> </ul>	<ul style="list-style-type: none"> <li>• Energy dependency               <ul style="list-style-type: none"> <li>❖ Low energy</li> <li>❖ High-Z materials</li> </ul> </li> <li>• Low readings</li> <li>• High voltage</li> <li>❖ Use of biased electronics &amp; cables</li> </ul>

Kry SF et al., AAPM TG-158, Kry SF et al., AAPM TG-191, Yorke E et al., AAPM TG-62, Niroomand-Rad A et al., AAPM TG-235

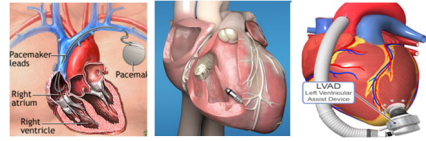
- ❑ Use of bolus with proper thickness (i.e., ~dmax of the photon energy) on the top of the implanted device would reduce lower energy head scatter/leakage radiation to a lower level
- ❑ Dosimeters should be calibrated out-of-field and preferably with buildup equal in thickness to the depth of interest

Chan MF et al., 2012. Estimating dose to implantable cardiac defibrillator outside the treatment fields using a skin QED diode, optically stimulated luminescent dosimeters, and Lif thermoluminescent dosimeters. *Med Dosim.* 37(3): 334-8.2012.

In summary, managing implanted devices can be based on **three classifications**

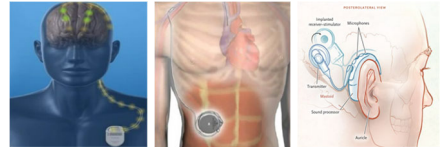
❑ Life-dependent

Pacemaker, leadless pacemaker, implantable cardiac defibrillator, CRT-P, CRT-D, LVAD



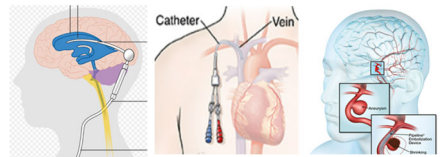
❑ Adverse

Loop recorders, neurostimulators, programmable hepatic pumps, intrathecal pumps, insulin pumps, cochlear implants, glucose monitors, ankle monitors



❑ No Electronic Circuitry

Brain shunts, CVAD, medi-port, Watchman™ device, tissue expanders, peripheral artery stents, spine fixation systems, aneurysm pipeline, vascular ports



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**Thank You!**