A Review of Managing Commonly Seen Implanted Devices for Radiotherapy Patients

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- None
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

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Categorizing Implanted Devices by **Risks**

Picture credit: B. Zedan

Life Dependent
Adverse
No Electronic Circuit

Memorial Sloan Kettering Cancer Center
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

Memorial Sloan Kettering Cancer Center
Life-Dependent [2] - Leadless Pacemaker (Lung)

It should be programmed into asynchronous pacing mode and the dose limit is $5\text{ Gy}$.

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

Life-Dependent [3] – Wearable Cardiac Electronic Devices

LVAD is a life-sustaining device.

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

LifeVest® wearable cardioverter defibrillator (WCD)

Left Ventricle Assist Device (LVAD)

Spare battery away from machine Control unit as far as possible

Picture credits: Mayo Clinic, Learningradiology.com, Lifevest.zoll.com
**Adverse Effects [1] – Cardiac Loop Recorder (3F Breast)**

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

**Dose Limit:** 5 Gy*

Picture credits: Mayo Clinic

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**Adverse Effects [2] - Neurostimulators**

*Similar design to pacemakers*

**Dose Limit:** 5 Gy*

Deep Brain Stimulator (DBS)  
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

Inspire™ Sleep

Dose Limit: 5 Gy*

Gastric Stimulator

*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

(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  Central Venous Access Device CVAD  Central Venous Catheter CVC

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

Commonly Seen Implanted Devices Dose Limits

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

\(^a\)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.
\(^b\)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**
  - Energy dependency
  - Overresponse if calibrated in-field
  - Nonlinearity
  - Low dose level
  - High dose level
  - Overresponse to <200cGy
  - Neutrons

- **TLD**
  - Energy dependency
  - Overresponse if calibrated in-field
  - Nonlinearity
  - Neutrons
  - Overresponse
  - Readout time

- **Diode**
  - Energy dependency
  - Instantaneous dose-rate dependency
  - Angular dependence
  - Temperature dependence

- **MOSFET**
  - Energy dependency
  - Overresponse
  - Angular dependence
  - Asymmetric design
  - Limited lifetime
  - Sensitivity

- **Film**
  - Energy dependency
  - Underresponse
  - < 50 kV
  - Dose level
  - > 1 cGy
  - Calibration curve
  - Extend low dose

- **IC**
  - Energy dependency
  - Low energy
  - High-Z materials
  - Low readings
  - High voltage
  - Use of biased electronics & cables

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

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

Thank You!