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The Utilization of Radiation Therapy for Benign Pathologies

Chloe Hanselman
Misericordia University

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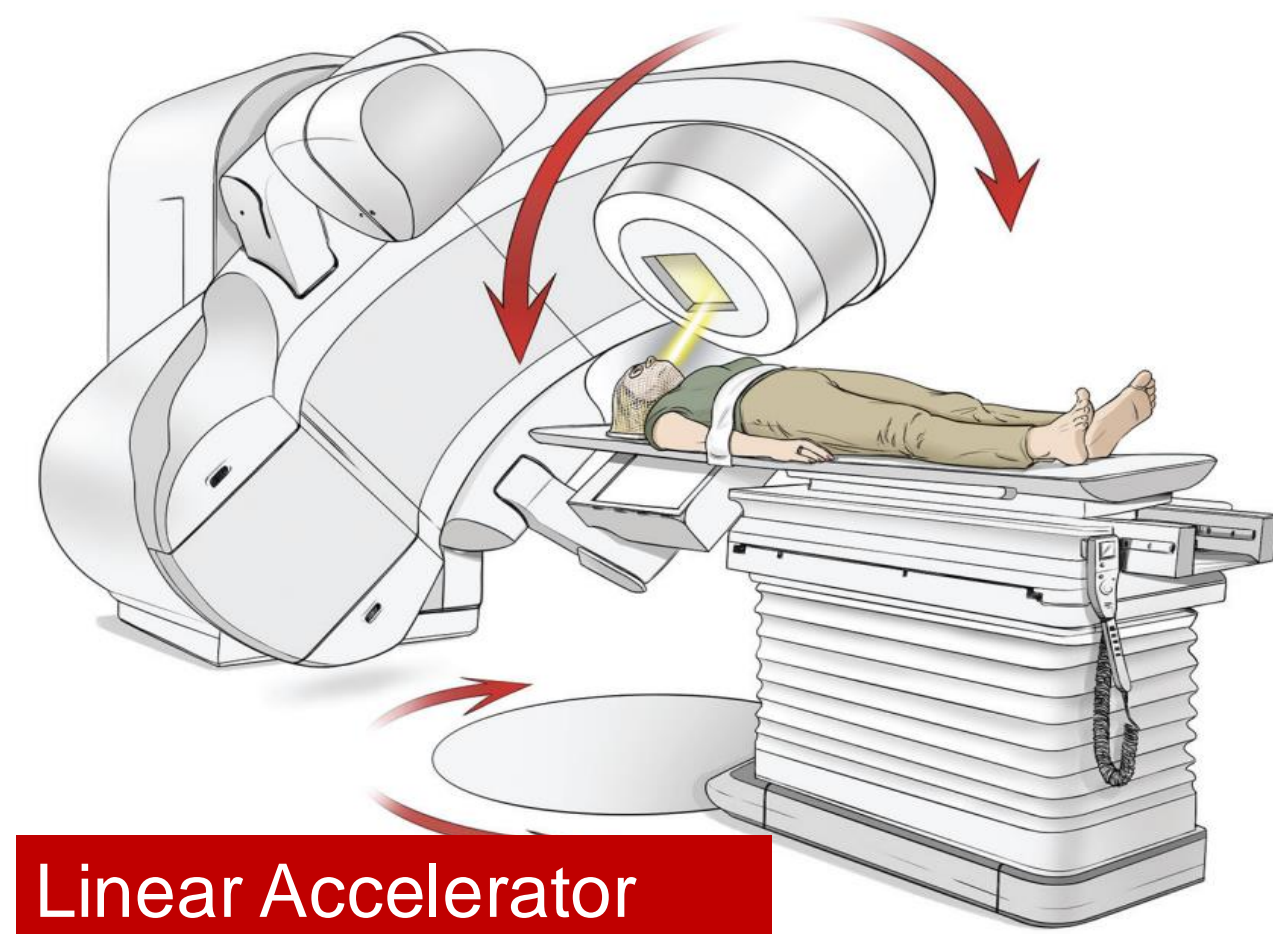
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Radiation Therapy

Radiation therapy is primarily utilized in the treatment of malignant neoplasms. When used for benign pathologies lower and more intermediate doses of ionizing radiation are used instead.

Radiation therapy uses specialized equipment known as a linear accelerator which produces high-energy particles to destroy cells.



(Carlson et al., 2019, p. 102)

Its role in treating benign pathologies has significantly increased as newer advancements are being made to equipment.

Benign Pathologies

Benign Pathologies include localized growths with low potential for progression to metastasize. If treated late they can lead to voluminous sized tumors and be locally aggressive causing secondary secretory symptoms that can affect the patient's quality of life. Radiation Therapy used simultaneously with surgery provides the best outcome to the patient (Yang et al., 2019).

Examples of benign pathologies:

- Keloids
- Paragangliomas
- Vestibular Schwannoma
- Meningiomas
- Ledderhose Disease



Figure A demonstrates a keloid on the ear (Yang et al., 2019, p. 4)

Classifications

For benign indications in radiation therapy two classifications are used: anatomical, and functional.

The anatomical classification consists of the location of the pathology this includes areas like the eyes, head, skin, bones, heart, etc.

The functional classification includes four categories: degenerative, hyperproliferative, functional and focal (Fionda & Rembielak, 2023).

Treatment Options

Radiation Therapy offers different types of treatment options for benign pathologies. Various conditions including location and type will decide the plan for treatment. The most utilized types include photon treatments, electron radiation, and brachytherapy.

Brachytherapy is proven to be one of the best treatments for keloid scars. This type of radiation therapy is different as it requires tiny devices of radioactive material to be placed directly into the body near the pathology. Brachytherapy delivers high dose rates *only* to the area with the radioactive sources.

Electron therapy is another form of treatment that uses high energy electrons instead of photons. This is primarily used for tumors that are superficial and near the surface of the skin. Unlike photon therapies the beam is shaped to the target area using a metal cutout that protects the healthy tissue.

There are multiple treatment options when it comes to photon radiation. The two most commonly used treatments for benign pathologies are intensity modulated radiation therapy (IMRT) and modulated volumetric arc therapy (VMAT). IMRT uses images from a CT and the radiation is customized to match the tumors. VMAT varies the intensity of the beam as it rotates around the body in an arc pattern.

Innovations with Cyberknife



(Carlson et al., 2019, p. 118)

The cyberknife is a robotic linear accelerator system that features real-time image guidance and little immobilization.

This system has submillimeter accuracy that allows for fractionated treatments to moving parts while maintaining tight dosimetry.

Planning takes advantage of the robot's six-degree-of-freedom maneuverability that allows for an array of overlapping beams to be superimposed without an isocenter. A benefit of this frameless system is the ability to treat patients in multiple sessions, which is an advantage in treating lesions within the brain region (Carlson et al., 2019).

Cyberknife is unique as it uses a multi-leaf collimator that is able to block a broad beam while the treatment length is not dependent on the age of the source which minimizes the beam-on time (Nguyen et al., 2021).

Advantages of Radiation Therapy

Radiation therapy is a non-invasive alternative to surgery. Some surgeries are very aggressive or contraindicated due to the location and size of the pathology. The reoccurrence of the pathology after surgery is unacceptable at a rate of 45-100% (Hernandez et al., 2022).

Radiation therapy is used because it provides a better quality of life with its anti-inflammatory and anti-proliferative effects.

Anti-inflammatory effects:

- Inflammatory responses are regulated by a sequential process that depends on mediators, cell adhesion expression, and leukocyte interaction.
 - This results in the slowing of blood flow and stimulating immunocompetent cells to migrate to surrounding tissue leading to edema, erythema, and pain.
 - When LD-RT (<1 Gy) is applied it inhibits the expression of Inducible Nitric Oxide Synthase (iNOS) which reduces leukocyte interactions along with vasodilation (Royo et al., 2020).
 - Other anti-inflammatory cytokines are produced including Transforming Growth Factor- β 1 that increase apoptosis.
- Anti-proliferative effects:
- With doses between 8-10 Gy, it produces a delay in the cells mitotic cycle which prevents cell growth (Royo et al., 2020).

Disadvantages of Radiation Therapy

Ionizing radiation induces double-strand breaks in DNA that can lead to cell death. A consequence of this is the potential to produce mutations that may result in tumorigenesis and malignancy (Carlson et al., 2019).

The exposure to radiation therapy is associated to an increased risk of basal cell carcinoma. This is more common for those who are younger at the time of treatment.

A secondary neoplasia formation can occur and it is described as a tumor that was not present during the time of irradiation and arises within that region. This tumor does not necessarily have to be malignant, but it is a new formation (Carlson et al., 2019).

These associated risks have become some of the most feared adverse effects of radiation therapy and could result in the decline of using it to treat benign conditions.

Effectiveness

The clinical effectiveness of radiation therapy in the treatment of benign conditions has been proven through various studies.

It is more effective for small lesions that are situated at a safe distance from vital organs.

The effectiveness is determined based on the response of the pathology or if the patient received pain relief.

It was found that many non-malignant diseases have a greater response to low dose radiation therapy as compared to osteoarthritic disorders.

One study indicated that recurrence happened for some patients, but in 99.5% of patients a disease response was noted (Hernandez et al., 2022).

Figure A. shows an MRI of a benign intercranial meningioma on a 70-year-old male patient prior to being treated using radiation therapy from the Gamma Knife

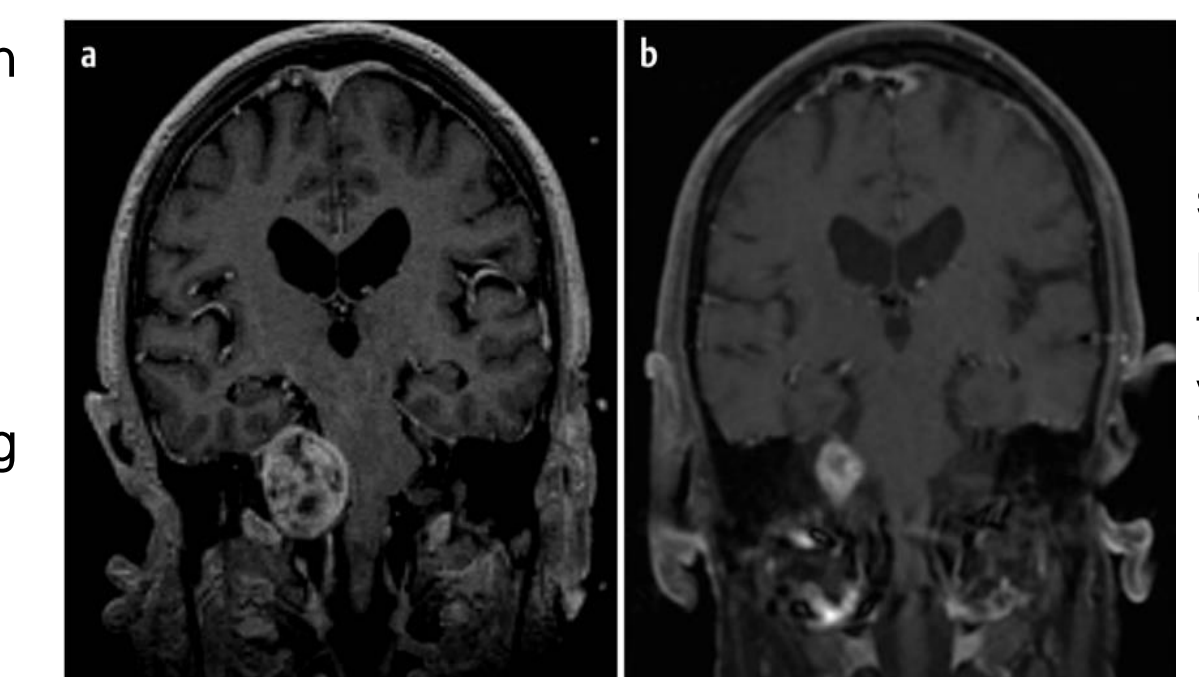


Figure B. is an MRI of the same patient post treatment following up 4 years later

(Carlson et al., 2019, p. 134)

Toxicity

Acute toxicity is the short-term effects of radiation and primarily occurs within the first few weeks following the completion of treatment.

Chronic Toxicity is also referred to as long-term toxicity and occurs at a much later time after treatment. These effects may not appear for months to even years.

Toxicity is categorized into five different grades between I and V. Grade I consists of mild adverse effects whereas grade IV and V lead to life threatening effects or death.

Many studies have been conducted to evaluate the acute and chronic toxicity of treatment using various radiation techniques. Toxicity rates are low for treatments on benign pathologies since low doses are utilized.

Patients that experienced acute toxicity were graded III or lower. Those with chronic toxicity fell within grade I with very small percentages being in grade II and III.

Higher toxicity was found in larger tumor volumes, greater than 9.6 cc compared to smaller lesions (Nguyen et al., 2021).

Conclusion

The popularity of radiation therapy for benign treatments is fading as new therapeutic drugs are coming into perspective. These drugs have no radiation related toxicity while offering the same anti-inflammatory effects as therapy.

Radiation therapy for benign pathologies has been proven to be effective with acceptable toxicity making treatment generally low risk. It has provided patient with a better quality of life due to the anti-inflammatory effects, and even with reoccurrence disease response was achieved.