**AN ANALYSIS OF PROTON THERAPY: A METHOD TO REDUCE LATERAL PENUMBRA**

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**PURPOSE**

To ensure proper treatment of a target in X-ray therapy, large amounts of healthy tissue are put at risk to harmful radiation levels. In proton therapy, radiation treatments can be delivered in a conformal distribution sparing healthy tissue. However, at low energies the lateral dose spread, called lateral penumbra, can compromise the advantage of protons. A dynamic collimation system (DCS) was computationally modeled to investigate the benefit of the DCS in reducing lateral penumbra of proton therapy dose distributions delivered in a spot-scanned (SS) technique.

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**INTRODUCTION & BACKGROUND**

**Delivery Techniques of Radiation Therapy:**

- **Passive Scattering**
  - Broad beam delivery
  - Delivered with high-energy X-rays, protons, or electrons
  - Large irradiation area
  - Multifield collimator or aperture outlines target

- **Active Scanning**
  - Spot scanning
  - Mono-energetic beam of protons
  - Rapid delivery by energy layer
  - Lorentz force sweeps protons from a time-varying magnetic field
  - Aperture and DCS collimation available

- **Bragg Peak and Dose Fall-Off**

Figure 3 shows the behavior of photons as they interact with a water phantom. The maximum energy disposition of X-rays appears proximally in the phantom where as the maximum energy disposition for protons, known as the Bragg peak, is distal<sup>3</sup>. Since X-rays are composed of high-energy photons, they will continue to interact with matter at any depth. Due to the proton’s charge and mass, they will not interact with matter past the Bragg peak thus sparing distally compared to that of the gradual decay of photon therapies<sup>3</sup>.

- **Isotrim Prototype**

Proposed by Hyer et al<sup>3</sup>, the DCS is a new technology that can improve the lateral penumbra for low energy SS proton therapy. The lateral dose distribution is defined by rapidly traveling trimmer blades which track the edge of the target as a narrow proton beam scans across the target. The main components of the DCS are shown in Figure 4 and include:

  - Two pairs of rectangular, orthogonal nickel rods
  - Four high-precision, independently driven linear motors
  - Insertable range shifter
  - Maximum acceleration of a trimmer: 19.6 m/s²
  - Maximum velocity of a trimmer: 2.5 m/s

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**TRIMMED BEAMLET MODEL**

Spot scanned proton therapy is delivered by a series of beams where a beamlet is a finite exposure to a proton beam. Each beamlet is defined by a depth dose and a lateral dose distribution at a particular range within the beam. By taking a 2D slice of the beamlet at any point, one can view the lateral distribution as shown below.

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**TREATMENT DELIVERY ALGORITHMS AND TECHNIQUES**

**DCS Raster-Style Scanning Delivery**

To treat targets in both an effective and timely manner, a technique known as raster-scanning was adopted. It was found that the method detailed below gave the best compromise between healthy tissue sparing and the time penalty associated during direct treatment.

**Dose Delivery**

- A full treatment of a target is done in discrete energy layers
- The highest (deepest reaching) energy is delivered first
- Subsequent lower energies are then delivered
- There can be thousands of individual beamlets that must be delivered rapidly in a single treatment
- A single orientation of trimmer blades allow for raster scanning in a double-half row beamlet group pattern
- Beam scans from the middle of row n to middle of row n + 1
- Trimmers move into position for next double-half row and the process repeats

**Collimation Method**

- Spacing: (mm) | Time Penalty (+)
  - Beamlet-Unique: Trimming | 5 | 47.98
  - Raster Scanning | 5 | 58.27

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**CLINICAL DATA SET INVESTIGATION: RESULTS AND ANALYSIS**

**Analysis of Figure 3**

- Reduction in dose to normal tissue from the DCS shown in the bottom right
- Critical structures such as the brainstem, the optic nerves, and cochlea are spared with the DCS
- Due to the reduced dose to healthy tissue, patient tolerance of the treatment increases
- Reduction in excess dose greatly reduces secondary cancer rate induced by treatment

**Conclusion**

The DCS’s ability to collimate every energy layer yields better conformity and reduces the dose delivered to normal tissue adjacent to the target region. Furthermore, the device can be integrated with current or future proton therapy equipment and may serve as a useful tool to further improve the next generation of proton therapy<sup>3</sup>.

**REFERENCES**


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