RTS 11

The Use of Protons in Radiation Oncology

WHAT ARE PROTONS?

A proton is a heavy and positively charged particle in the nucleus of an atom. The use of protons in radiation therapy is relatively new. Protons are considered a densely ionizing radiation and are classified as high linear energy transfer (LET) radiation.[1] These are important characteristics when pertaining to radiation therapy. Having a high linear energy transfer means that the radiation will distribute its dose within a small and predictable distance. This is very beneficial because it allows the radiation to be distributed conformally and confidently within the target.

RANGES WITHIN TISSUE

To understand benefits of proton therapy it is important to know other particles that are used within radiation therapy. These particles include: protons, electrons, and photons. Both protons and electrons, the negatively charged particle in the atom, have the same amount of electrical charge at 1.6×10^{-18} coulomb (C), however the electron has much less mass than the proton.[1] Photons are massless and uncharged particles that are used extensively for radiation therapy. Mass is a key contributor to the LET of the radiation. Having a greater mass causes the particle to lose its energy over a much smaller distance. This is what makes proton therapy much more beneficial than photon or electron therapy. Due to photons being massless they lose their energy over a long distance causing more damage to surrounding tissues. Electrons deposit their energy more quickly due to having mass. They distribute their energy over a shorter distance than photons. However, protons have the greatest mass out of the different types of radiation, therefore, they have the shortest length that they deposit their energy.[2] Figure 4 displays the relative ranges of different particles and energies in tissue.

DOSE DISTRIBUTION

Figure 1. Photon treatment plan

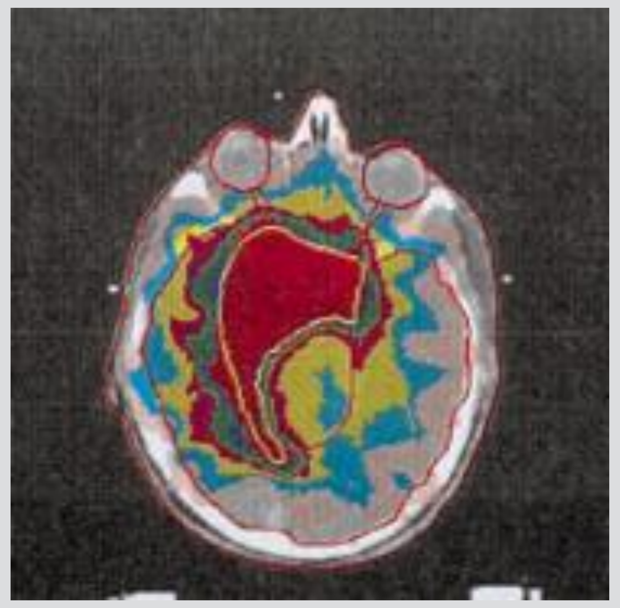

Figure 2. IMRT photon treatment plan

Figure 3. 2 proton treatment plan

Intensity modulated radiation therapy (IMRT) treatment plans using photons utilize a range of 5 to 9 different treatment beams[3]. Typically a greater amount of treatment beams will result in greater beam conformity and ability to spare surrounding critical structures from the effects of entrance and exit doses of the radiation. The advantage of protons, in comparison to photons, is due to the dose distribution. As protons transverse through matter, they deposit dose along their track and slow down until essentially stopping. Because of this, protons have essentially no contributing exit dose and have potential for complete sparing of critical structures distal to the treatment target[3]. Figure 1 displays a typical photon treatment plan with the use of 3 beam angles, figure 2 displays a typical IMRT photon treatment plan with the use of 9 beam angles, and figure 3 shows a proton treatment plan with the use of only 2 beam angles. The images show a much higher field conformity and lower doses to surrounding critical structures achieved by photon treatment plans while using a much smaller amount of beam angles.

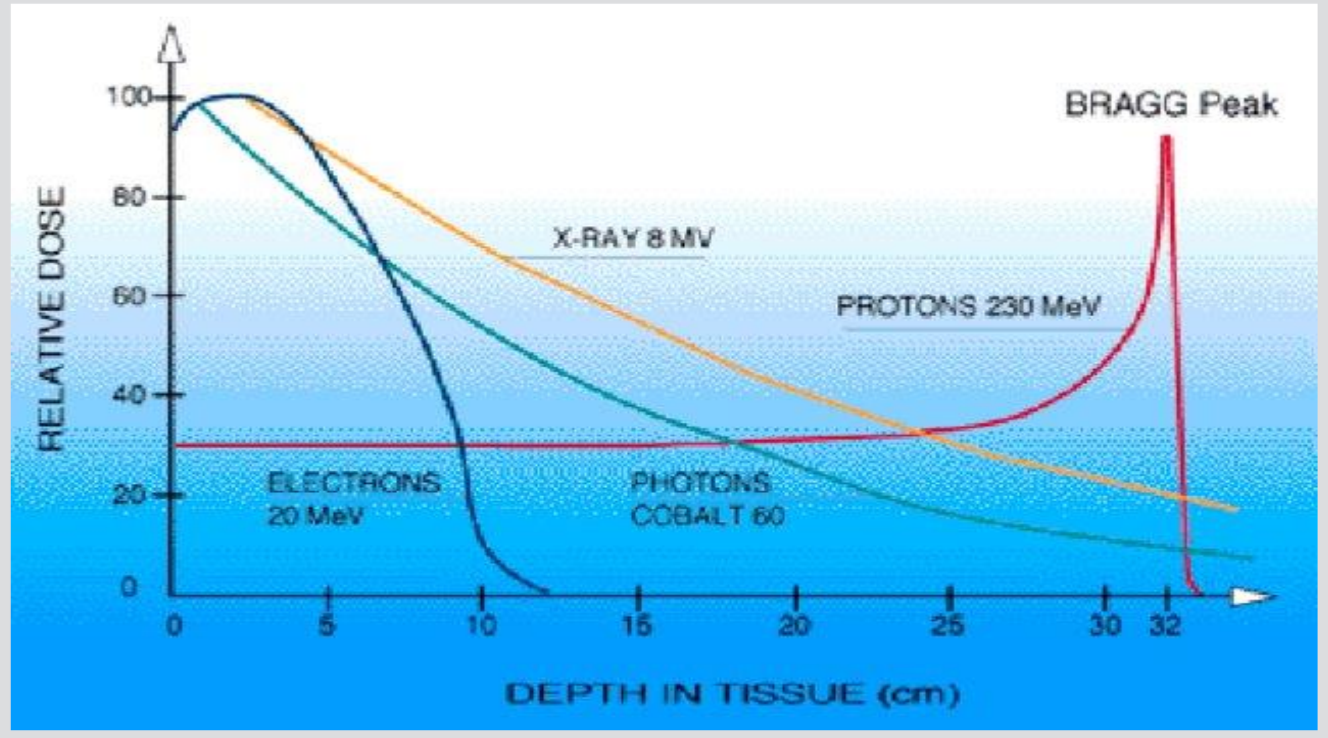

Figure 4. Graph representation of the therapeutic particles previously discussed. This graph compares the relative ranges in tissue for differing particles and energies used in radiation therapy[4].

References

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ADVANTAGES

There are many advantages when using protons for treating cancer. The Bragg Peak results in low entrance dose, narrow margin for dose deposition at the tumor, and a steep falloff leading to low exit dose[3]. Due to the Bragg Peak, the dose of radiation can be targeted directly at the tumor. Less healthy tissue is irradiated which reduces the risk of both acute and chronic side effects[5]. Increasing the dose to the tumor is another advantage of proton therapy. The localized dose distribution allows higher doses to be administered enhancing the therapeutic abilities[5]. Currently, proton therapy is recommended for pediatric tumors, brain and spine, and head and neck cancers[3]. Due to the increased risk of secondary malignancies when treating with radiation, pediatric patients could benefit greatly from protons. Head and neck cancer patients could also benefit greatly from the use of protons. Photon treatment can be very difficult on these patients and decrease quality of life. Protons could reduce the long term side effects and increase quality of life for patients and their families.

FUTURE OF PROTON THERAPY

Due to the lack of prospective studies for proton therapy, many radiation oncologists are skeptical. The future is going to focus on more research to increase the certainty of the advantages of protons. This will help to improve the reliability and increase physician confidence in recommending this therapy[5]. Currently, there are 25 proton centers actively treating and 11 more under construction[6]. The majority of these centers are located in the east and northeast United States[6]. Protons may be very useful in the future to reduce negative side effects of photon therapy. One disadvantage of proton therapy is the cost. Proton therapy can be up to twice as much as standard radiation therapy and may not be covered by some insurance companies[5].

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