Proton Beam Radiation Therapy in the Treatment of Cancer

James D. Cox, MD
Professor and Head
Division of Radiation Oncology
University of Texas M. D. Anderson Cancer Center

How has therapeutic radiology evolved over the past several years?

Particularly over the last 10 years, a major shift has taken place in the planning of treatment incorporating radiation therapy (RT) for patients with cancer. Years ago, we had to assume the location of the tumor and employ very large fields to be sure we were covering the malignant area. Now, with improvements in diagnostic imaging, especially computed tomography, the fields of irradiation can be smaller and more carefully shaped. Radiation oncologists are able to conform the high-dose irradiated volume to whatever size and shape is most appropriate for the tumor inside the body. The need to make RT more conformal, that is, to exclude normal tissue and treat only the tumor, has placed an increasing burden on the accuracy of diagnostic imaging and the development of 3-dimensional representations.

The image-guided RT technologies available today include 3-dimensional conformal RT and its more sophisticated offspring intensity-modulated RT (IMRT), in which the dose is "painted" into the tumor from multiple tiny beams coming from various directions. With these technologies, it is possible to plan radiation treatment in 3 dimensions and to be precise and sharp with the margins. However, the best use of these methods depends upon knowing the exact size and shape of the tumor, and knowing the location of the tumor each day, since this may vary in some cases.

What is proton beam therapy?

Proton beam RT is a logical extension of the development that has taken place over the past decade. The peak dose delivered by the proton beam is deeper in the body than that of x-rays and electrons, and also not as close to the surface. The proton beam deposits all of its energy when the protons come to a stop at some point in the body, as determined by the energy of the proton beam. Then, once all the energy is deposited to some location in the body, which is, ideally, precisely where the tumor is, the radiation beam stops. There is no exit dose and there is no penetration into the normal tissues that lie beyond the tumor.

Why does the proton beam come to a stop?

Protons interact with matter in a different way than x-rays or photons, and this is one of the characteristics. The proton beam enters the body and, depending on its energy, goes to a certain depth and then stops. As the beam stops, it releases all of its energy. The tumor receives a high dose of radiation, with no further radiation beyond the tumor. This strategy enables much more precise, conformal RT than that of x-rays, providing a higher dose and better avoidance of normal tissues.

Can patients tolerate more proton beam radiation than other types of radiation in their lifetime?

Yes, but more importantly, patients can tolerate more of this type of radiation at the time of their first treatment because a higher dose can be administered in a more precise way.

Does the tumor being treated need to be at an early stage in order for proton beam RT to be maximally effective?

Tumors that are in early stages are always easier to treat and control with RT than advanced-stage tumors. However, proton beam RT enables treatment of advanced tumors without as many side effects as are associated with x-ray and photon beam RT. This aspect is especially pertinent for regimens in which RT and chemotherapy are given at the same time. Such regimens are often limited by reactions in the normal tissues. Because proton beam RT avoids normal tissues, it is safer and the chemotherapy can also be given more safely.

What is the current status of proton beam RT in terms of availability to patients?

Most patients who have received proton beam radiation around the world have been treated at high-energy physics research laboratories, not clinical facilities. There are very few hospital-based proton beam radiation facilities. The most well developed facility is at Loma Linda University, where patients have been treated with proton beam radiation since 1990. However, the patients treated there are a fairly select group. Most have cancer of the prostate; other cancer types treated include head and neck, lung, pediatric, and some others.

The possibility of using proton beam radiation for a wider variety of disease sites and a greater number of patients is now being explored by various manufacturers. Treatment strategies for patients with genitourinary tumors, gastrointestinal tumors, and several other cancer types including lung, head and neck, brain, breast, and others are being planned.

One of the advantages of proton beam RT is that the interaction with tumors and normal tissues is the same as with x-rays. There is no concern about different relative biological effectiveness, as is the case with some of the other heavy ions or neutrons.

Have there been studies comparing proton beam radiation with other types of RT?

There have been very few comparative studies of this kind. There have been many comparisons of dose distribution. When planning 3-dimension conformal RT or IMRT, the goal is to include the tumor to the greatest degree possible. Many comparisons of these 2 modalities have been done, as have comparisons between IMRT and protons, which have consistently shown proton beam therapy to be advantageous. It is difficult to rationalize studies comparing standard photons and protons since the dose distribution with protons is clearly superior. A prospective, randomized trial of IMRT versus proton beam RT for prostate cancer is currently being planned.

Does proton beam radiation seem to be most effective before, during, or after chemotherapy?

While a couple of studies have shown an advantage for giving chemotherapy first, followed by RT, the majority of comparative trials have shown an advantage for giving RT and chemotherapy at the same time. Proton beam RT may play a crucial role here because of the ability to avoid normal tissue. For example, it is often the reaction of chemotherapy and RT in the esophagus that leads to the most distressing symptoms for lung cancer patients undergoing treatment. With proton beam radiation, the esophagus can be avoided.

How have advances in radiation treatment changed the relationship between oncologists, radiation oncologists, and diagnostic imaging specialists?

These specialties diverged several decades ago, with diagnostic imaging specialists serving mainly as consultants to physicians and radiation oncologists being directly involved with patient care. Now, as the image-guided aspect of RT has become so prominent, these specialties are working more closely together than ever, and that relationship will continue to evolve as the field of radiology advances. At the M. D. Anderson Cancer Center, a diagnostic imaging suite will be included in the new proton center now being planned, and we anticipate working side by side with diagnostic radiologists in the treatment of patients.

When do you anticipate this technology becoming more widely available?

It is difficult to estimate these timings. The interest in proton therapy throughout the United States and internationally has continued to increase. However, the technology is very expensive, both the building that would house it and the equipment that produces and guides the proton beam. As more facilities are built, the costs will decrease, but how quickly that will happen is impossible to determine.

How are advances in physics related to advances in radiology?

There is of course an historical relationship between the physicists who originally helped to define the proton beam and radiologists. Likewise, today it would be impossible for radiation oncology to advance without the close involvement of physicists. Medical physicists are primarily involved in ensuring that the equipment is working properly and in characterizing the beams that are emitted. They are also involved in computer-based treatment planning that uses the proton beam to the greatest advantage, and to conduct the quality assurance checks to verify that the radiation being delivered to the patient is what we think it is. Medical physicists and radiation oncologists are also partnered in their understanding of the biology of tumors, how they spread, where they spread, being able to image the extensions of tumors, and ensuring subsequent coverage with the radiation.

Suggested Reading

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