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PROTON RADIOSURGERY



Teresa M. McCue "August Morning"

MASSACHUSETTS GENERAL HOSPITAL
CANCER CENTERSM

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U.S. News & World Report, Annual Guide to America's Best Hospitals consistently ranks Massachusetts General Hospital "among the elite of America's hospitals...an institution to seek when the highest and best standards of diagnosis and treatment are needed...a magnet for the best and brightest researchers and clinicians..." and places its Cancer Center services among the top 1% in the country.

The Massachusetts General Hospital Cancer Center is a founding member of the Dana-Farber/Partners CancerCare, (DF/PCC) a collaboration in adult oncology between Massachusetts General Hospital, the Brigham and Women's Hospital and the Dana-Farber Cancer Institute. Together these institutions form the largest system for cancer care and research in the United States. All three are affiliated with Harvard Medical School and are founding members of the Dana-Farber/Harvard Cancer Center (DF/HCC).

The DF/HCC, which is a designated Comprehensive Cancer Center by the National Cancer Institute, is the largest collaborative effort in the world against cancer. Hundreds of physicians and scientists, who are able to easily interact and exchange information, are working together to control and combat cancer through accelerating research in order to increase the speed with which new therapies become available to patients and those at risk.

*Cover Art from Illuminations:
August Morning — Teresa M. McCue
"My images are a celebration of the spirituality of nature.
They invite the viewer to step into my vision and
perhaps find the beauty in their own world."*

WELCOME

On behalf of the entire staff, we would like to welcome you to the Northeast Proton Therapy Center (NPTC) at Massachusetts General Hospital (MGH). The NPTC opened in 2001 and represents the forefront of technological advancement in radiation therapy. The construction of the facility was jointly funded by the MGH and the National Cancer Institute to meet the increasing medical demand for proton therapy. You have chosen one of the finest medical centers in the world to receive your care.

Our program builds on more than forty years of pioneering work and experience gained by MGH physicians, physicists and, clinical support personnel at Harvard University's Cyclotron Laboratory where more than 3,800 patients were treated with proton radiosurgery from 1961 to its closing in 2002.

We are proud to be able to offer this high precision, non-invasive treatment to patients whose tumors or vascular malformations cannot be safely treated by other methods including surgery. With several treatment rooms and specialized equipment for delivering proton radiosurgery, we have the flexibility to offer a variety of treatment options. Our experienced team of physicians and support personnel will use these resources to design a treatment program that is the most effective for your condition.

While our ability to deliver this state-of-the-art technology is extremely important, at the center of all we do is a person for whom we care and to whom we are committed to providing personalized, compassionate treatment and support. During your treatment you and your family will have access to all hospital support services.

This patient information guide describes in general what you can expect during your proton radiosurgery treatment. As your therapy is individualized and planned specifically for your needs, this information is meant as a guide and not all may apply to your treatment. Your treatment team will provide you with more specific information should it be required. We also encourage you to ask questions at any time during your treatment program.



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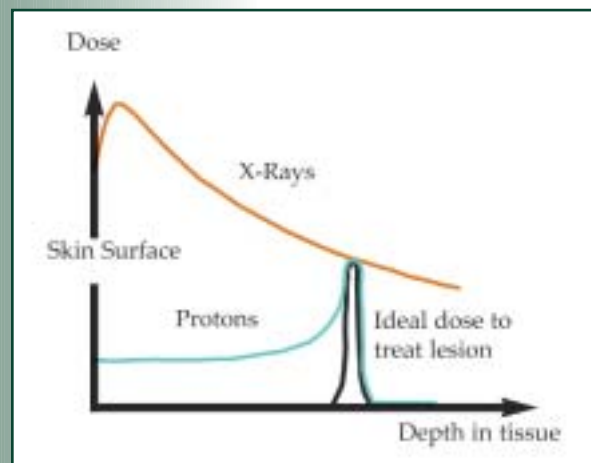
RADIOSURGERY

Radiosurgery is a procedure that uses a neurosurgical technology known as stereotaxis to precisely aim an intense dose of radiation into a targeted abnormality, such as a brain tumor or vascular malformation. With this technique, the radiation dose to the normal tissues surrounding the target is minimized. Radiosurgical treatments are typically performed in one or two sessions.

Radiosurgery may be performed as an alternative to conventional neurosurgery for certain types of medical conditions. In other circumstances it may be used in conjunction with fractionated radiotherapy and/or surgery. Some of the determining factors are the nature of the disease, its location, and extent. Brain tumors commonly treated by radiosurgery include benign lesions such as meningiomas, acoustic neuromas, pituitary adenomas, as well as a variety of malignant tumors including gliomas and metastases. Vascular abnormalities of the brain, especially arteriovenous malformations, are also frequently treated. Recent advancements allow for select lesions located throughout the body to be treated using radiosurgical techniques.

Radiosurgery can be performed with any type of beam of ionizing radiation. This includes photon beams such as gamma rays and x-rays, as well as particle beams, which include protons. When gamma or x-rays are directed at tissue, the radiation dose received by that tissue is most intense near the point of penetration. Progressively less radiation is delivered to the tissue as the beam passes more deeply into it. When protons are directed at tissue, the radiation dose gradually increases as the beam passes more deeply, then drops to near zero beyond the targeted depth.

In order to deliver a high dose of radiation to a target deep within the brain or other organ while sparing the surrounding tissues from the same radiation dose, it may be necessary to aim the beam at the target from multiple directions, thus focusing an intense spot of radiation on the target. This also allows the radiation dose to conform more closely to the margins of the target.



This diagram shows clinical dose profiles along the central path of x-ray and proton treatment beams. The black outline depicts a lesion at some arbitrary depth in the body. Ideally the dose is concentrated in this area and is near zero towards and away from the beam entrance into the body. Using beams from multiple directions further reduces the dose to normal tissue surrounding the lesion.

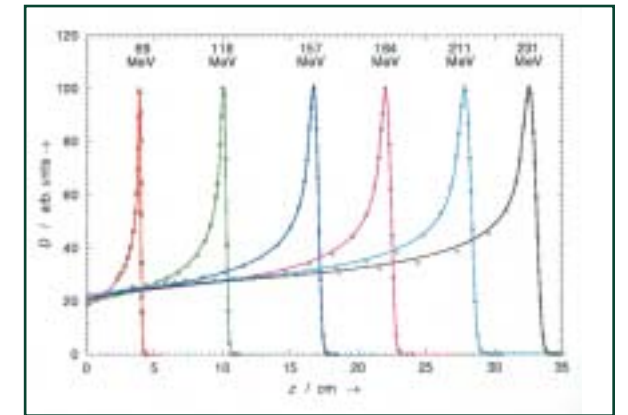
PROTON RADIOSURGERY

Small targets that tend to be spherical can be effectively treated using gamma or x-ray radiosurgery. However, with larger and more irregularly shaped targets, it becomes increasingly difficult to deliver a uniform dose of radiation within the target and spare surrounding normal tissues. In this circumstance, the unique characteristics of proton radiation are a significant advantage for performing radiosurgery.

Protons have a physical advantage over gamma and x-rays when it comes to sparing normal tissue. Protons deposit most of their radiation energy in what is known as the Bragg peak, which occurs at the point of greatest penetration of the protons in tissue. The exact depth to which protons penetrate and at which the Bragg peak occurs is dependent on the energy of the beam.

This energy can be very precisely controlled to cause the Bragg peak to fall within the tumor or other tissue that is targeted to receive the radiation dose. Because the protons are absorbed at this point, normal tissues beyond the target receive very little or no radiation.

In order to further reduce the amount of radiation received by normal tissues in the path of the proton beam, beams are aimed at the target from multiple directions. For each of these directions special devices called apertures are fabricated to shape the radiation to the target profile. Other devices called compensators control the proton's penetration within tissue. These devices are custom designed for each patient to further help each beam conform to the unique shape of the targeted lesion.



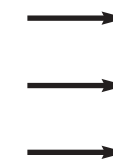
This graph shows how the energy of the proton beam can be controlled to adjust the position of the Bragg peak in order to treat lesions at most clinically relevant depths. The depth of the Bragg peak can be selected with sub-millimeter precision. Superimposing Bragg peaks with slightly different depths allows lesions of various sizes to be treated.



Beams may be aimed from multiple directions to treat a lesion. A Brass aperture is custom milled and shaped to the profile of the lesion for each beam used. The Brass stops the protons ensuring that only the intended lesion is irradiated minimizing the dose received by nearby normal tissue.



A Lucite compensator is custom milled and shaped to the depth profile of the lesion for each beam used. The compensator is attached to the front face of the aperture. The Lucite controls the penetration of the protons, which go through the aperture opening. At any point within the compensator the thickness of the Lucite will proportionally reduce the depth of the protons passing through the device. The diagram shows the direction of the protons incident on a compensator.



WHAT TO EXPECT DURING TREATMENT

Upon referral to our center, a senior neurosurgeon and radiation oncologist will review your case, assessing your medical and treatment history, medications and prior imaging studies to determine the best treatment course for your particular condition. Further diagnostic imaging studies such as MRI or angiography may be requested to complete your medical record. You will then have the opportunity to meet with the physicians to discuss their treatment recommendations.

Registration

Prior to receiving your treatment you must obtain a current blue hospital card. You may obtain one at Patient Registration in the Cox Building Lobby or on the first floor of the Wang Building next to the outpatient pharmacy or the Yawkey Center for outpatient care, Monday through Friday from 8:00 am to 4:30 pm. Please arrive 15-30 minutes prior to your scheduled appointment if you need to register for a blue card. Remember to bring all your insurance cards with you. You may also register in advance by phone by calling Patient Registration at (617) 726-9090 or toll free at (877) 726-9090.



Your Treatment Day

Please note that this brochure is meant to provide a general description of the procedures that will occur during a treatment day. As each patient case is different, your treatment plan may differ slightly from those described in this brochure.

For your support and comfort, we encourage you to bring someone with you to your treatment appointment. Upon arriving on the day of your treatment, please check in with the receptionist. You will then be greeted by a member of the proton radiosurgery team who will make you comfortable, provide you with an overview of your treatment day and answer any questions you may have.

For patients with lesions contained within the head, the treatment plan will require that several tiny beads, known as fiducials, be implanted in the surface of your skull. During proton therapy treatment, the fiducials help to insure that the proton beam is very precisely aimed at the target. Using a small needle, a neurosurgeon will put the fiducials in place. Performed with a local anesthetic, the procedure is very simple and you should feel only a slight pressure from the needle.



A patient is shown in two stereotactic immobilization device alternatives. Both of these devices can be used for the planning CT and proton radiosurgery treatment. The device on the left uses four bony fixation points, whereas the device on the right uses a customized bite mold and occipital cushion. The head frames attach to the CT and treatment beds to ensure a rigid fixation.

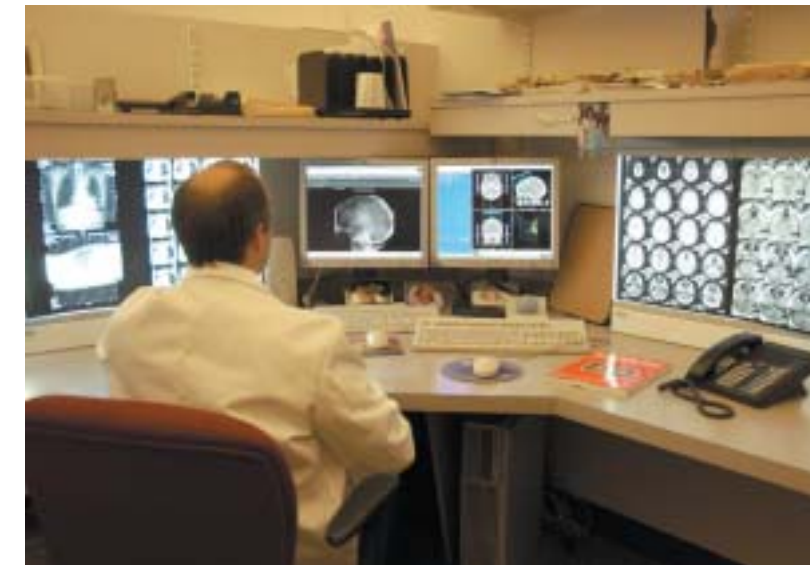
For both a CT scan and later during your actual proton therapy treatment, it is crucial that you remain absolutely still. To insure this, we will need to fit you with an immobilization device. Some circumstances require a stereotactic head frame to remain in place from the time of the CT to the end of the treatment. If this is the type of immobilization which is indicated for you a physician will secure the frame to your head. While the head frame is a bit awkward, wearing it is not painful. You should feel only a slight pressure as the frame is attached. If at any time you are feeling concerned or uncomfortable please let your physician or nurse know.

When the frame is securely in place, an IV contrast will be injected in preparation for a CT scan. The CT scan will create a precise three-dimensional picture of the area to be treated. This becomes the framework for calculating the radiation dose and designing your treatment. For the CT scan, you will be laid on a treatment bed and your immobilization device secured to insure that you do not move.

Once the CT scan is completed your treatment plan will be finalized. This process takes several hours during which time you are free to move around the hospital or relax in a semi-private patient lounge, located in the Cox building. The lounge is equipped with small televisions and a refrigerator with beverages. Also a Healing Garden located in the Yawkey Center for Outpatient Care, provides a comforting, meditative and inspirational retreat. We encourage you to eat and drink plenty of fluids during this period. Members of the radiation oncology team will be available throughout the day to answer questions and provide any assistance you may need.

Treatment Planning

The physicians will use the CT scan, in addition to other studies you have had, to outline the target and to note important normal structures. The size of the target, as well as its relationship to these structures, is critical in calculating the prescribed radiation dose. It also determines the directions from which the proton beam will be aimed through the body to the target. Once the treatment plan has been finalized, customized equipment is fabricated to shape the proton beam so that the radiation dose matches as closely as possible the shape of the target. This equipment is designed for each direction from which the beam will be aimed.



Treatment planning involves many steps from the review of the imaging studies to the actual implementation of the treatment. Following the planning CT the physicians define the lesion to be treated along with other normal structures to be avoided. The 3D outlines and dose prescription are reviewed with a medical physicist who will determine the optimal delivery plan. The resulting dose distribution is reviewed with the physicians prior to treatment.

Proton Radiation Treatment

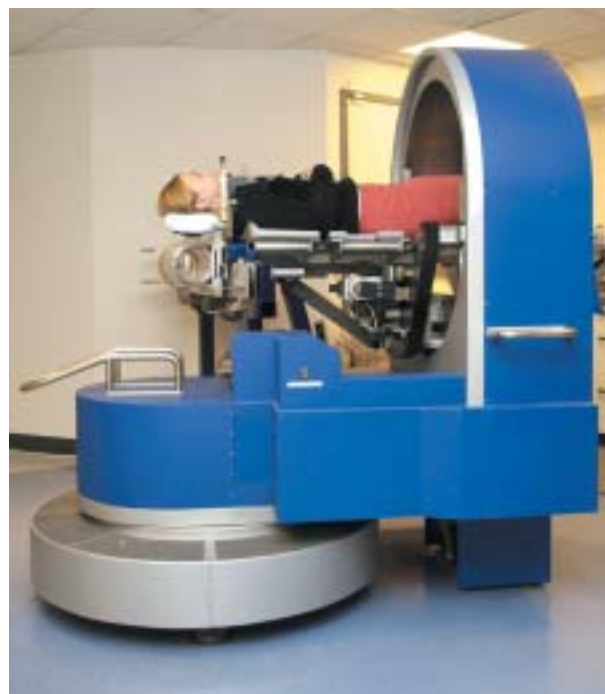
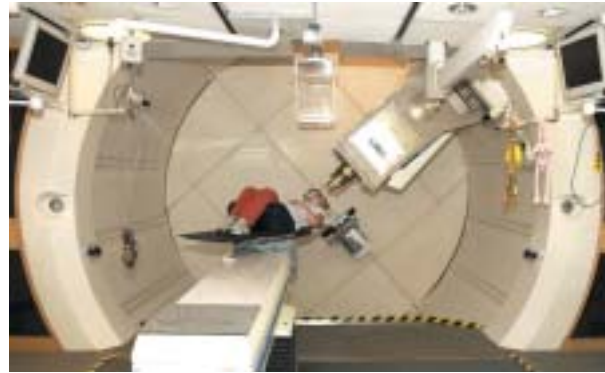
Once your plan is finalized, treatment will begin. You will be asked to lie on a treatment bed with the immobilization device secured. X-rays will be taken and adjustments in your position may be made based on comparison to the CT scan and the orientation of each treatment direction. The beam will then be turned on to deliver the precise radiation dose. This process may be repeated several times in order to aim the beam at the target from different directions.

During the treatment, you will not feel, see or hear the radiation beam. In general the total time required for a typical treatment is one hour. As soon as your treatment is over, the immobilization will be removed. After a brief observation period you will be free to go home.

Follow-Up

After treatment, your physician will discuss further care with you, including any immediate precautions, follow-up recommendations and instructions in the event of further symptoms related to your illness and/or treatment.

Patients may undergo proton radiosurgery using one of two different delivery systems available to us. Despite which system is used the protons are generated from the same proton accelerator machine known as a cyclotron. MGH physicians have used the first system known as the STAR device since 1991 (bottom image). It's proven technology uses a fixed horizontal beam, which requires rotating the patient to aim the protons from various directions relative to the lesion. The second system uses a 150-ton gantry to rotate the radiation rather than the patient to aim the protons (top image). The middle image shows a brass aperture as it approaches the patient in order to deliver the radiation treatment.



GLOSSARY OF COMMONLY USED TERMS

Angiogram: An X-ray exam performed by an interventional radiologist to study blood vessels and organs by injecting a contrast material into the blood vessel.

Aperture: A metal block containing a hole through which the radiation (photon or proton) beam passes. The shape of the hole is the approximate shape of the target being treated by the beam. Each patient requires his or her own set of custom-made apertures.

Arteriovenous Malformations (AVM): Masses of arteries and arterialized veins interspaced with brain tissue, which is usually abnormal and often scarred from previous tiny hemorrhages. In AVMs, blood flow is high and the pressure is elevated within the veins. This elevated pressure may well contribute to hemorrhages or seizures.

Benign tumor: A non-cancerous tumor, which does not invade nearby tissue or spread to other parts of the body. However, a benign tumor can continue to grow and put pressure on surrounding structures.

Compensator: A custom-made block positioned beyond the aperture. The contours and thickness of the block conform the beam to the shape of the far edge of the target.

Bragg peak: The depth at which protons deposit most of their energy when penetrating a material such as tissue. This point occurs at the ends of the particle's paths. By varying the beam's energy, this peak can be adjusted to match the depth of a target.

CT or CAT Scan: Computerized tomography scan. An imaging study, which is done with a doughnut-shaped machine that uses advanced x-ray technology to take pictures of cross-sections of the body. The cross-sections are superimposed to create a 3-dimensional model of the body. A CT scan is required to model proton radiation doses within the body. A CT scanner is much less confining than an MRI scanner.

Fractionated Radiotherapy: Radiation therapy usually delivered over the course of one to eight weeks. Only a small fraction of the total dose is delivered during each of the many treatments. Typical daily treatment doses are in the 2 to 4 Gy range.

Gantry: In radiation therapy, this a device used for rotating the radiation delivery apparatus around the patient so as to treat from different angles. At the NPTC each gantry weighs approximately 150 tons.

Gray: A measure of absorbed radiation dose, abbreviated "Gy" (energy per unit mass). Typical radiosurgery doses are in the 8 to 20 Gy range.

Ionizing Radiation: Radiation of sufficient energy to displace electrons from the atoms of cells and produce ions. Ionized cells are damaged and must repair themselves otherwise they will die. Generally, normal cells are better able to repair themselves than cancer cells.

Immobilization Device: A device that minimizes patient motion during procedures such as a CT scan and radiation treatment.

GLOSSARY TERMS (CONTINUED)

Malignant Tumor: A cancerous tumor in which abnormal cells divide without control. Malignant cells can invade nearby tissues and can spread through the blood-stream and lymphatic system to other parts of the body.

MRI Scan (Magnetic Resonance Imaging scan): A diagnostic imaging technique that uses a magnetic field and radio waves to produce highly detailed 3-dimensional images of the body. MRI scans sometimes provide additional information to that obtained from a CT scan.

Neurosurgeon: A physician who specializes in the treatment and diagnosis of various neurological disorders.

Photon: A general term for electromagnetic radiation. In radiation therapy it refers to x-rays or gamma rays.

Proton: A positively charged particle that can be accelerated for the purpose of radiation therapy.

Radiation Oncologist: A physician who specializes in the use of ionizing radiation to treat various types of cancers and malformations.

Radiation Nurse: A nurse specializing in the care of patients who receive radiation therapy.

Radiation Physicist: A physicist who specializes in the technical and clinical aspects of radiation therapy.

Radiation Dosimetrist: A member of the treatment team who is skilled in calculating and planning doses in radiation therapy.

Radiation Therapist: A technologist certified to deliver therapeutic radiation to patients in accordance to a medical prescription.

Radiation therapy: A medical specialty that uses high-energy photons or particles to kill abnormal cells while trying to avoid normal cells.

STAR (Stereotactic Alignment Radiosurgery): A technique developed at MGH using x-ray imaging technology to ensure very high precision targeting for proton radiosurgery.

Tumor: An abnormal mass of tissue that results from excessive cell division. Tumors perform no useful body function. They may be benign (not cancerous) or malignant (cancerous).

X-Ray or Gamma Rays: High-energy photon radiation. It is used in low doses to diagnose diseases and in larger doses and higher energy to treat abnormalities such as tumors or malformations.

GENERAL INFORMATION

Neurosurgery

Office of Paul Chapman, MD (617) 726-3887
Clinical Coordinator: Sylvia Weld
<http://neurosurgery.mgh.harvard.edu>

Radiation Oncology

Office of Jay Loeffler, MD (617) 724-1548
Nurses: Patricia McManus (617) 726-0922
Ena Chang (617) 726-0923
http://cancer.mgh.harvard.edu/cancer_home.htm



Support and Education

The Massachusetts General Hospital Cancer Center offers numerous educational and support services for patients and their families, plus many amenities to make your treatment visits as comfortable as possible. For a complete list, please ask your radiation oncology nurse for a copy of "A Patient's Guide to the Cancer Center", a booklet filled with information and resources including outpatient pharmacy hours, child care, interpreter services, financial counseling and much more.

Healing Garden

The Howard Ulfelder, MD Healing Garden, located on the 8th floor of the Yawkey Center for Outpatient Care provides a comforting, meditative and inspirational retreat for our patients, their families and friends.