

CLINICAL PROFILE

P⁺O SITIVE change

Proton Therapy at the University of Florida

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Location, Location, Location

If you were to travel back in time 200 years and visit the far northeast corner of Florida, you would find a major settlement at a very planned and precise location on the St. Johns River. The settlement? Cowford. The precise location? An especially narrow point along the river. As it happened, this easy passage provided cattlemen the perfect spot to drive their cattle across the river (called “fording”, thus the name “Cow-ford”...if only all nomenclature was so clear). By 1822, this growing settlement was renamed to honor a popular military man named Andrew Jackson, who would go on to become the 7th President of the United States. Cowford became Jacksonville.

I do suppose that despite the fancy new name, there were still plenty of cows and plenty of fording, right there at that precise spot once known as Cowford.

Well, precision must be “something in the water” in Jacksonville. Today, however, the precision is not so much about fording cows through

a special spot on the St. Johns River. No, today it’s something altogether different. Today, the precision has to do with herding a beam of flying protons, and fording them into cancerous tumors.

Why Protons?

When people talk about radiation therapy, they usually speak of high energy beams of light (photons). Photon beams can be delivered to the human body in intensity-modulated patterns and from many different directions. The light interacts with tissue and rustles up energy as it courses through the anatomy. This energy gets scattered and deposited along the way, and with enough beams it can be smeared around clumps of dangerous cells. Enough energy, delivered in small fractions, can kill the dangerous cells but give the healthy cells time to recover or replenish. That’s radiation therapy in a nutshell.

But photons are not the only radiation useful in cancer therapy. There is also “particulate” radiation such as electrons, which can deposit their energy closer to the skin sur-

face if this is necessary. Even more intriguing is proton radiation. Protons, those building blocks of the atomic nucleus that we’ve known since elementary school science class, carry around about 1,836 times the mass of an electron and hold one positive charge (to the electron’s one negative charge). Given that relative mass, you might assume the proton is a clumsy radiation, but this is decidedly not so.

As it turns out, the flying proton has a unique energy deposition pattern that can be very useful. While light (photon) radiation traverses all the way through tissue and attenuates along the way, the proton actually moves along, depositing a little energy at first, then dumping a huge amount of energy at the end of its track. And then it stops, engulfed. This “energy dump” is called a Bragg peak, and it can be used to shape radiation very precisely to tumor masses while doing essentially no damage downstream of the beam. Since tumors often grow next to very sensitive and critical normal organs, the proton beam’s precision, high-gradient dose characteristics can be very useful in controlling



Image courtesy of UFPTI

The University of Florida Proton Therapy Institute, Jacksonville, Florida, opened in August 2006. It is the only proton therapy facility in the Southeast and treats an average of 80 patients per day.

collateral damage.

The promise of proton therapy is balanced, however, by the challenges and costs to build a proton facility. They are rare. They are expensive. They are big. But, they do exist.

Welcome to Jacksonville: The University of Florida Proton Therapy Institute

January 2003 marked the groundbreaking for the University of Florida Proton Therapy Institute (UFPTI). About three and a half years later, in August 2006, the facility treated its first patient. One of only five clinical proton therapy centers in the United States, UFPTI has four proton treatment rooms – three on rotating gantries and one of which is dedicated to a special form of eye treatment. The proton therapy machines are complemented by two top-of-the-line linear accelera-

tors (conventional radiation therapy) with image-guidance capability.

Currently, over 90 different patients might be treated at any given day at UFPTI, with that number changing as this new facility continues to move forward. Many things about proton therapy are similar to conventional radiation therapy. Dose fractionation is about the same, with about a 10% adjustment for increased radiobiological effectiveness (RBE) of protons compared to photons. The treatment time per fraction, about 20 minutes, is on par with today's IMRT/IGRT modalities, even though the number of beams in proton plans is comparatively smaller than photon plans: ~2 for prostate cases, and anywhere from 3-6 for other more complex targets.

Given the size and scope of the facility, the staffing requirements at the UFPTI are, as might be ex-

pected, significant. Today, UFPTI employs the full-time equivalence (FTE) of 7.4 medical physicists, 8 dosimetrists, and over 20 therapists. Over 100 people altogether work at UFPTI, and that doesn't even include the roughly 8 FTE radiation oncologists. It's an impressive operation, especially given its relative "youth" of less than two years since going clinical.

Physics

The responsibilities of a medical physicist at a new proton facility are challenging, varied, and perhaps more than a little daunting. Zuofeng Li leads the physics team at UFPTI. Says Dr. Li of what drew him to proton therapy, "It holds potential to provide better radiotherapy treatment. And it's a rare modality that has yet to see wider use of its physical advantages for more clinical sites."



Images courtesy of UFPTI

Left: The cyclotron, where protons are accelerated to nearly the speed of light.
Right: One of three UFPTI gantry treatment rooms.

Below right: Dr. Zuofeng Li

“It’s also a challenge for a clinical physicist to confront something new and try to make it work on a large scale.”

The technical challenges, however, are matched by general challenges of something “new” to many clinicians. Communication, training, process – these are just as essential to keep finely tuned as the proton beam-lines themselves.

Dr. Li explains: “Proton therapy, while being one of the radiation delivery modalities, presents its own challenges. Technically, it involves working with physicians, dosimetrists, and therapists who may not have prior experience in proton therapy. Many nuances in patient immobilization, setup, imaging, treatment planning, and localization must be well understood for the safe, accurate, and efficient delivery of proton therapy.”

And this is where the experienced medical physicist can bring attention to the details. Dr. Li continues: “Physics can take an active role in the developing of protocols for each part of proton therapy process, and continues to provide in service training to all groups.”

Like any job well-done in medicine, the hard work can be rewarding. There are many anecdotes of patients who receive treatment with protons that could not have been matched by any other modality, such as patients who received prior conventional radiation therapy that brought their healthy tissues close to tolerance levels. These patients could not be treated again with photons without exceeding these crucial dose limits; but often they can be treated to full therapeutic dose with protons, as the dose can be so carefully “sculpted” as to avoid those critical regions.

Dr. Li described one illustrative example: “We had a patient with a sarcoma on the back, posterior to spinal cord. A single proton field was able to deliver a high dose to the PTV with minimal cord and lung doses. The comparative 7-field IMRT plan would have delivered a cord dose well beyond its tolerance.”

Solid Solutions

I suppose the cattlemen of early 1800s in Cowford, Florida worked hard to perfect their methods of fording cows across the St. Johns River.



I’m sure they used horses, dogs, and maybe lots of optimized hollerin’. One might ask, then, how those protons are carefully “fording” to match unique 3-dimensional tumor shapes so well. How are the beams customized for each patient’s specific size, shape, and internal anatomy?

The answer lies in multiple, customized devices for each and every beam. The last elements of the beam-line that the stampede of pro-

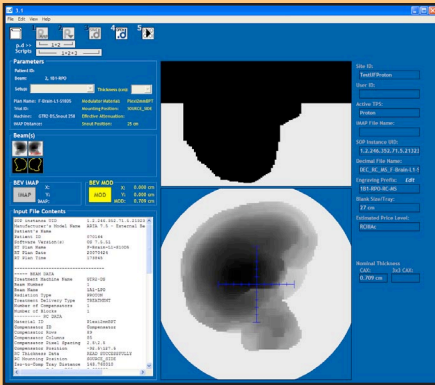


Figure 1. A screenshot from p.d

tions encounters are the range compensator and the aperture. Range compensators, optimized and designed by the treatment planning system (TPS), are physical devices accurately crafted to conform the dose to the distal edge of the tumor. Range compensators can be made of materials similar in density to tissue (such as acrylic, or wax) and milled with great care for each beam. Apertures, on the other hand, are dense (e.g. brass), precisely-shaped “cut-outs” that mold to the tumor in the beam’s eye view (BEV) to block proton radiation from reaching outside the edges of the tumor. The combination of range compensators and apertures shape the depth dose topography (range compensators) and the edges of the beam (aperture) to create a highly conformal dose distribution.

Hmmm, a need for accurate milling of materials into highly customized shapes needed (pronto!) by radiation therapy centers...sound familiar? Yes, this is where .decimal comes in.

With the same precision milling machines that are used for IMRT compensators, but optimized for the fabrication of proton parts, the .decimal facility is very well-equipped to make state-of-the-art proton range compensators and apertures. UFPTI was, in fact, the validation test site for the .decimal proton solution, a solution which includes software

(“p.d”), online ordering and transfer of data, milling, and next day shipping of the devices. Today, .decimal can make range compensators and apertures for any proton TPS that outputs in the DICOM RT (ION) Plan format. The information is processed, visualized, and reformatted by the p.d software (see Figure 1), uploaded to .decimal for fabrication and labeling (See Figure 2), then shipped.

UFPTI delivers all their proton beams using this solid range compensator, “scattered beam” approach. This modality ensures that every fraction is identical and simplifies the QA protocols, while still providing the dose conformality that is the calling card of proton therapy. Another strategy, called “scanning beam”, raster scans a narrow proton beam across an area while modulating the energy and intensity. Scanning beam allows more control over dose proximal to the tumor, but the level of complexity of scanning delivery introduces more risk and therefore burdens the QA protocols.

To accommodate its patient load, UFPTI built its own dedicated machine shop. The shop was designed and planned long before

.decimal got into the proton game. But while it’s always nice to have a dedicated machine shop in house, having .decimal as an additional commercial solution has allowed UFPTI unlimited capacity.

What do Zuofeng Li and his colleagues do with all the leftover customized devices when treatments are concluded? Concerning the thick apertures, that brass is stored for a time for safety reasons, then recycled. As for the acrylic range compensators, well they are a different story – “They make nice gifts for patients!” says Dr. Li.

Protons: Positive Charge, Positive Change

And so the uniqueness of Jacksonville continues to lead to positive changes, drawing interest from beyond the city limits. Like the legendary cattlemen of Cowford, Florida, UFPTI has found a special spot to do special things.

Jacksonville is lucky to have UFPTI and people like Zuofeng Li leading the charge in exploring new treatments of cancer. For more information on proton therapy and UFPTI, you can visit their website, www.floridaproton.org.

Figure 2. A custom .decimal Proton Aperture (Left) and Range Compensator (right)

