Commissioning Roadmap: Standard LINAC

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Landauer Medical Physics

Disclosure

Landauer Medical Physics has a division that sells commissioning services.

I work in the clinical services division and do not personally do commissioning work with LMP.

Clarification

Much of what I say will be Varian-centric. That is a reflection of my experience and should not be construed as an endorsement or statement of preference. My clients have mostly owned Varian accelerators. I regret that I have not had the opportunity to become equally knowledgeable about details of other vendors' products.

Roadmap signposts:

- Manage expectations.
- Make a plan, rich with contingencies.
- Get the right tools. Know how to use them.
- Dress rehearsal may be a good idea.
- Get the right staffing at the right time.
- Do the job well.

Manage expectations

- There's a lot of money in play. At a certain moment the revenue spigot will be "waiting for" you. The bean-counting impatience will land square on you the moment the acceptance is signed.
- Make sure management knows well (years?) in advance how many weeks – yes <u>weeks</u> – it's going to take.
- Calibrate your own values.

Expectations - My values

- The quality of the commissioning work establishes the baseline quality of care for every patient who will be treated on that machine, possibly over its entire lifetime.
- 15 years, 300 patients per year = roughly 4500 people, some you may not be around to meet, who are directly personally touched by the work you are about to do.
- I will take the time I need to get it right.

The Plan

- Dataset is combination of treatment planning commissioning, TG-51, clinical data book, validation.
- Order of work matters.
- Validation starts in real time.
- Don’t allow first patient treatment without independent output check. RDS is very accommodating if lined up in advance.

The Plan – Order Matters

- Get mechanicals perfect.
- Get calibration close.
- Peak.
- Steer beam profile near perfect.
- Take PDDs, profiles, OFs, Sc
- Generate clinical data tables – Sp, TMR/TPR, OAR
- Make final output adjustments with full formal TG-51.
- Irradiate the OSLDs and send them overnight.

The Plan – Order Matters

Photons

1. Mini-phantom
   - Sc
2. Offset tank
   - Large field half-beam cross profiles with small chamber on-end.
3. Center tank
   - Intermediate size cross profiles, large and intermediate OFs with small ion chamber on-end.
   - Large and intermediate depth doses with PPC.
   - Small field depth doses and cross profiles, small field OFs with diode.

The Plan - Time

From Sherouse Systems spreadsheet for Pinnacle data collection:

- Scans
  - Open photon per energy – 8 hrs
  - Hard wedge per wedge, energy – 4 hrs
  - EDW per energy – 2 hours
- OFs
  - Open photon per energy – 1 hr
  - Hard wedge per wedge, energy – 1 hr
  - EDW per energy – 5 hr

The Plan - Time

- Total TPS data collection time roughly 40 hours for a typical general-purpose photon beam. (2 days for a team, 1 week FTE) Electrons: just say no.
- Eclipse requires half as many cross-beam profiles as Pinnacle but an extensive OF table for each open and wedged field. Overall time for Pinnacle vs Eclipse data collection is essentially the same.
- My understanding is that both Xio and RayStation require very similar datasets to Pinnacle.

The Plan

- The purpose of the Plan and the prep is to make sure you don't have to think while working.
- Things you wouldn't believe will go wrong.
- Bear in mind that things drift
  - Solid state detectors can change sensitivity with integral dose.
  - The water temperature will rise as you pump energy in. Evaporation can be significant.
  - The ambient pressure may change, especially if scanning during dramatic weather.
  - Sometimes mechanical supports sag, transports shift.

The Plan - Real Time Validation

- Have your checklists/spreadsheets ready.
  - Manifest of measurements, in the right order.
  - Benchmark dataset comparison with statistics and graphs.
- Have benchmark scan comparisons ready.
- Repeat some measurements periodically to evaluate constancy.
- May need to build in "moving reference" for certain applications.

The right tools…

- A properly-calibrated 3D scanner. Hardware and software support contracts.
- Calibrated and properly-functioning TG-51 gear.
- Detectors. Lots of detectors.
- Barometer, thermometer, lead.
- Water. Bucket. Towels. Sump pump.
- Filtered power, common ground. Lots of outlets.
- Network, network storage, flash drives.
- Levels, clamps, hoses, fixtures, holders, cables, connectors, adaptors, duct tape, bailing wire, chewing gum, phone numbers, espresso, fire extinguisher…

The right tools…

Know how to use the tools.

- Obvious – know which buttons to push and what to cable where.
- Procedure to level, align, validate tank motions.
- The right detector for each measurement.
- The right bias for each detector.
- Optimal scanning protocol for each detector and measurement.

Tools - Scanning protocol.

- My philosophy is to do no data processing. I strive to ***collect*** the required dataset with high fidelity. The place for smoothing is in the detector.
- I typically use a "step and integrate" protocol and try to achieve jitter of less than 0.5%.
- Adaptive point spacing is very useful but also requires good understanding of underlying mechanisms.
- I typically start a session with "protocol searching."
- I shift the detector not the data.

Dress Rehearsal

- Set up the tank and take a test scan.
- Better yet: set up, measure, tear down, repeat until results are identical.

Staffing

"An expert is a man who has made all the mistakes which can be made, in a very narrow field."

- Niels Bohr

Staffing - My bias

- Assuming you are properly staffed for routine clinic support, you will need extra help to get the commissioning done well and timely.
- Historically, I advised that it's best to hire locum help for running the routine and free the incumbent to bond with the new machine.
- As I've learned from my naïve mistakes I have come to believe that commissioning is a deep "special procedure" best performed by (or with) contract experts.

Staffing – Hair on fire

- Dr. Fred Brooks, a highly-regarded elder computer scientist, writes in his book on the development of IBM's OS/360 in the 1960s, "Nine women cannot make a baby in one month."
- Data collection is very much like taking a cross-country drive. You have to click through every mile, shortcuts lead to dead ends, and stopping to pee delays your arrival. You need 60± hours of beam time.
- 3 people can work around the clock. One cannot.

Do the job well.

- Make the right measurements well.
- Document, document, document.
- Validate. Document the validation.
- DO NOT COMPROMISE.
- At the end, audit documentation as if you were the new guy on day 1.

Varian 2300iX #1201
Danville Regional Medical Center
January 2008

Notes:

The machine is calibrated using TG-51 to deliver 1 cGy/MU to the calibration point.

For electrons the calibration point is at the depth of maximum dose (as tabulated elsewhere in this book) for an open **15x15 field, SSD=100 cm**.

For photons the so-called "isocentric" protocol was used. The calibration point is at the nominal depth of maximum dose at a **distance of 100 cm**. For 6 MV photons, the calibration point is at **depth=1.5 cm, SSD=98.5 cm**. For 18 MV photons, the calibration point is at **depth=3.5 cm, SSD=96.5 cm**.

The data presented here were acquired in January of 2008 using a variety of detectors. Depth doses for photons and electrons were measured with a PPC05 plane-parallel chamber down to field size 5x5 and smaller photon fields were measured with a TN60008 diode. Profiles were measured primarily with the diode but supplemented and validated using a 0.125 cc ion chamber. Output factors were measured with the PPC05 for electrons and with a combination of detectors for photons.

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Michael P. Gnaster, MS

Justin D. Keener, MS

Job Well Done - Think Legacy

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ROCKS

Commissioning Roadmap: Treatment Planning

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- RTFM, then engage brain.
- Make a plan.
- Get the right staffing at the right time.
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Manage Expectations

- As long as you're measuring stuff it at least looks like you're working.
- Recall that the data collection Plan was meant to keep you from having to think while working. Software system commissioning is the big payback. **Every detail has to be right.**
- Prepare the bean counters that you are going to spend a week or longer in your office apparently watching the data stream from The Matrix and that you must not be disturbed.

The Manual

- Each vendor provides a "physics guide" and a "data collection guide."
- You really need to understand how the beam model works. What the heck is a "Gaussian height" or "dynamic leaf gap" and how does it affect calculations?
- The modeling procedure given by the manufacturer may not be necessary and is almost certainly not sufficient.

The Plan

- Configure machine parameters section. Should be done well in advance.
- Import measurements.
- Groom measurement data. GIGO. Big time.
- Perform modeling procedure. Get your best fit with your most reasonable compromises.
- Confirm correct answers out for input data.
- Validate answers for ancillary measurements.
- Document, document, document.

The Plan – Doesn't stop with TPS.

- Create data book.
- Configure second check software.
- Configure R&V.
- End-to-end test of entire IS chain.
  - Create and calculate one of every beam configuration in TPS.
  - Confirm with "hand calc" from data book.
  - Export to second check and confirm.
  - Export (as needed) to R&V.
  - Execute each beam, validate treatment parameters, perform array measurement and gamma analysis.

Staffing

- Do not, DO NOT, attempt to do this work "in your spare time." It's high-demand, high-intensity work and needs full attention.
- Don't be seduced by "dead time."
- You may have issues with sharing resources that are already heavily used in the clinic. May be necessary to work "second shift."
- Either hire a locum to take care of the clinic, or hire a contractor to help with the commissioning.

Get it right.

- Every detail matters.
- Any stray detail can be like an abandoned landmine that will blow up years from now.
- Every detail matters.
- The possibility of errors canceling in test cases is strong.
- Every detail matters.

Get it right – Configuration

Configuration of machine description is tedious.

- Tempting to just copy "sample."
- TPS model may require physical dimensions that are hard to obtain or hard to parse from LINAC vendor documents.
- Names of things have to be compatible across all IS vendors. Details like special characters and trailing blanks are problematic.
- Conventions, directions, limits should be confirmed by physical observation of the LINAC.

Get it right – Parameters

Parameter names are misleading.

- Even in a strongly physics-based beam generation model, many parameters are more free variable than measurable physical parameter.
- It might be possible to measure a spot size or a DLG, but the right value in the model is the one that agrees best with measurement across the use domain.
- Best fit from an “automodel” may not be optimal.

Get it right – Beam features

Some features of the model are disproportionately important.

- Getting the field edge right is crucial and requires close scrutiny.
- It's easy to miss a significant modeling error in the corner of the largest field, behind the primary collimator.
- Fitting a continuous function to a few discreet points can lead to interstitial errors.
- Build-up is inherently unreliable and not worth fussing. This is an ongoing education issue with CMDs and MDs that can't be fixed in modeling.

Get it right – Edges

- Modern radiotherapy is all about edges.
- Modeling the edge properly is more important than is obvious.
- Exact modeling of a badly-measured edge is a common and serious systematic error.
- Automodeling won't get it right.
- Some beam models don't even allow tuning. In those cases it is still important to characterize the goodness of fit.

Edges

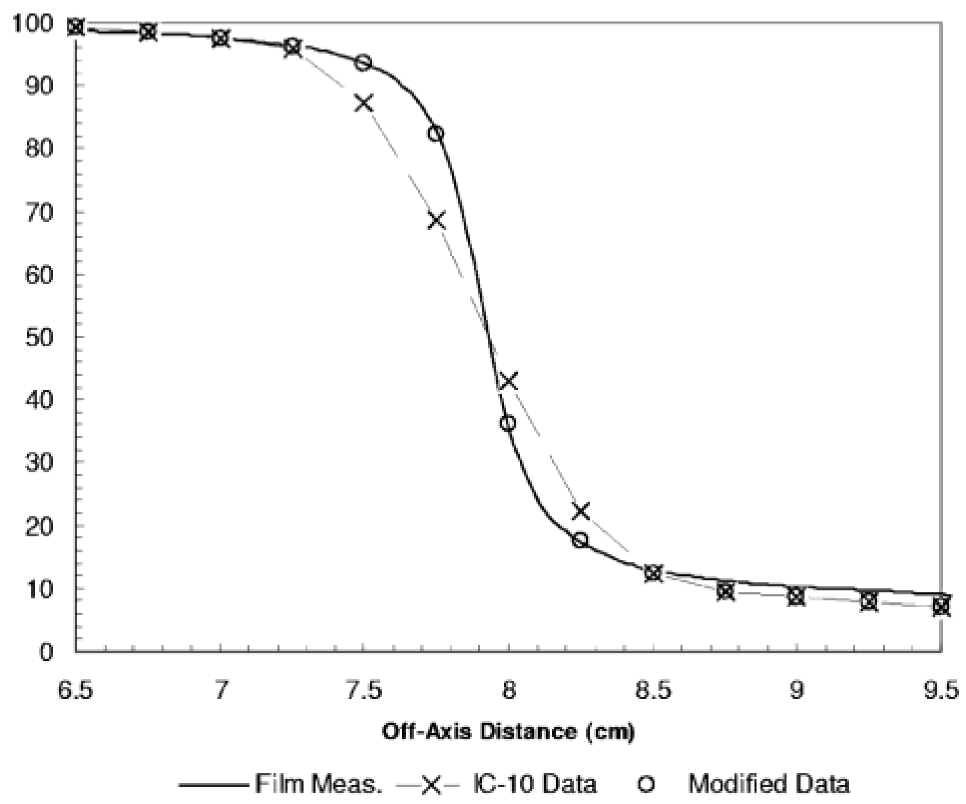
Two very useful papers:

- Arnfield et al., Med. Phys. 32 (1), January 2005
- García-Vicente et al., Radiotherapy and Oncology 74 (3), March 2005

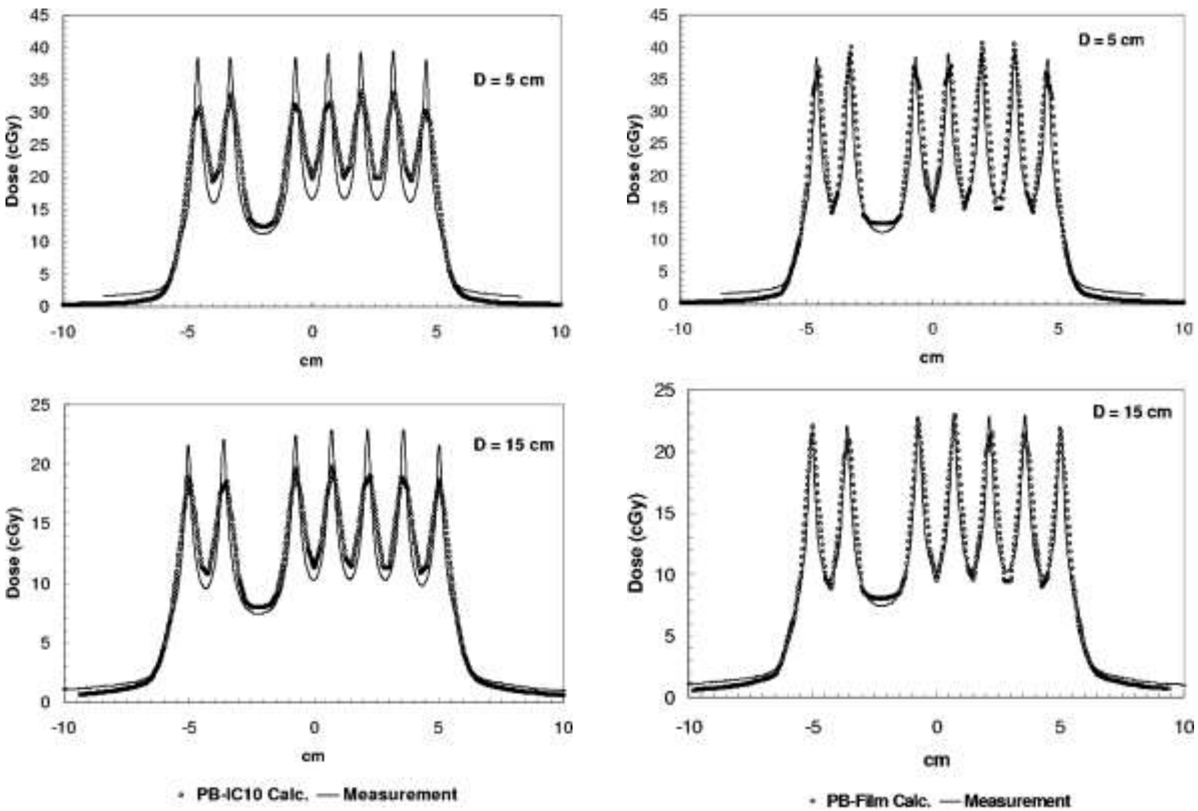
Arnfield et al.

- “The use of film dosimetry of the penumbra region to improve the accuracy of intensity modulated radiotherapy”
- Measured 2 datasets for single 2100EX, one with conventional scanning chambers, one with film.
- Modeled each with high fidelity.
- Compared calculations to measurement.

Arnfield et al.



Arnfield et al.



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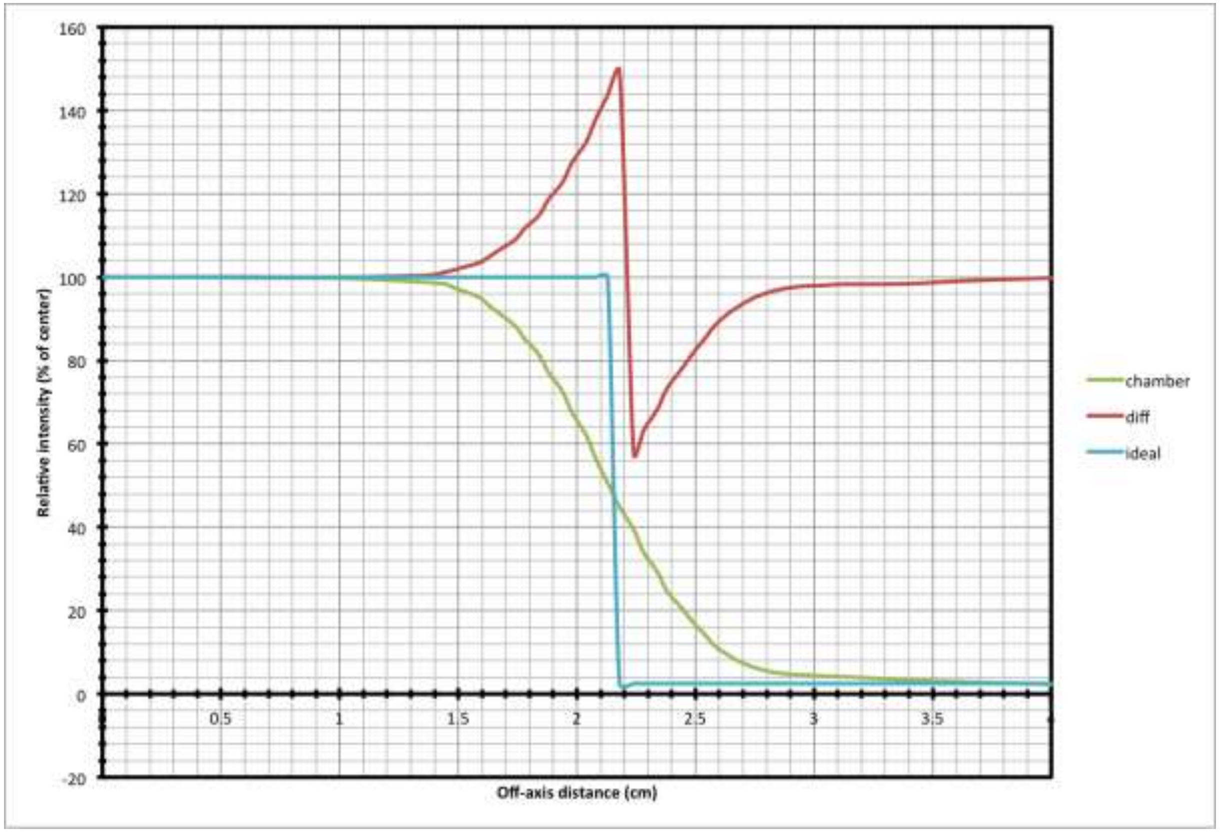

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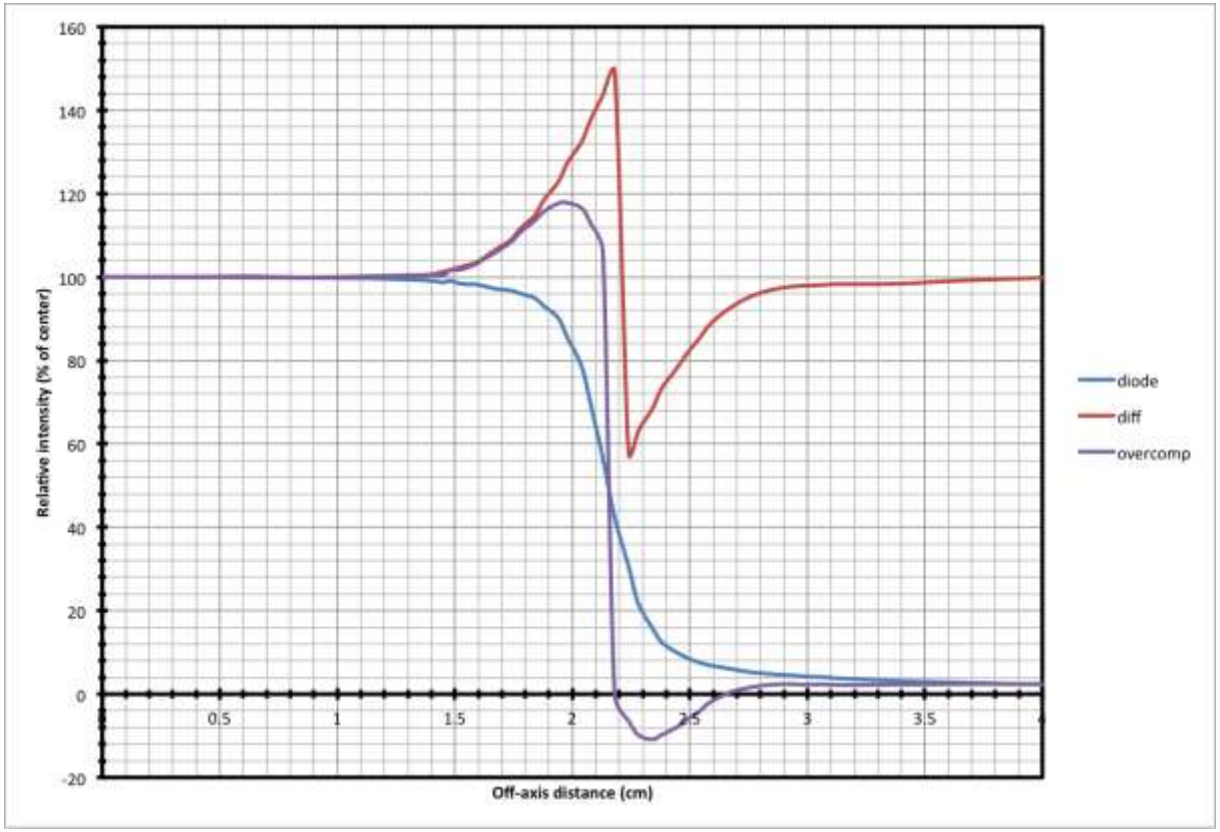
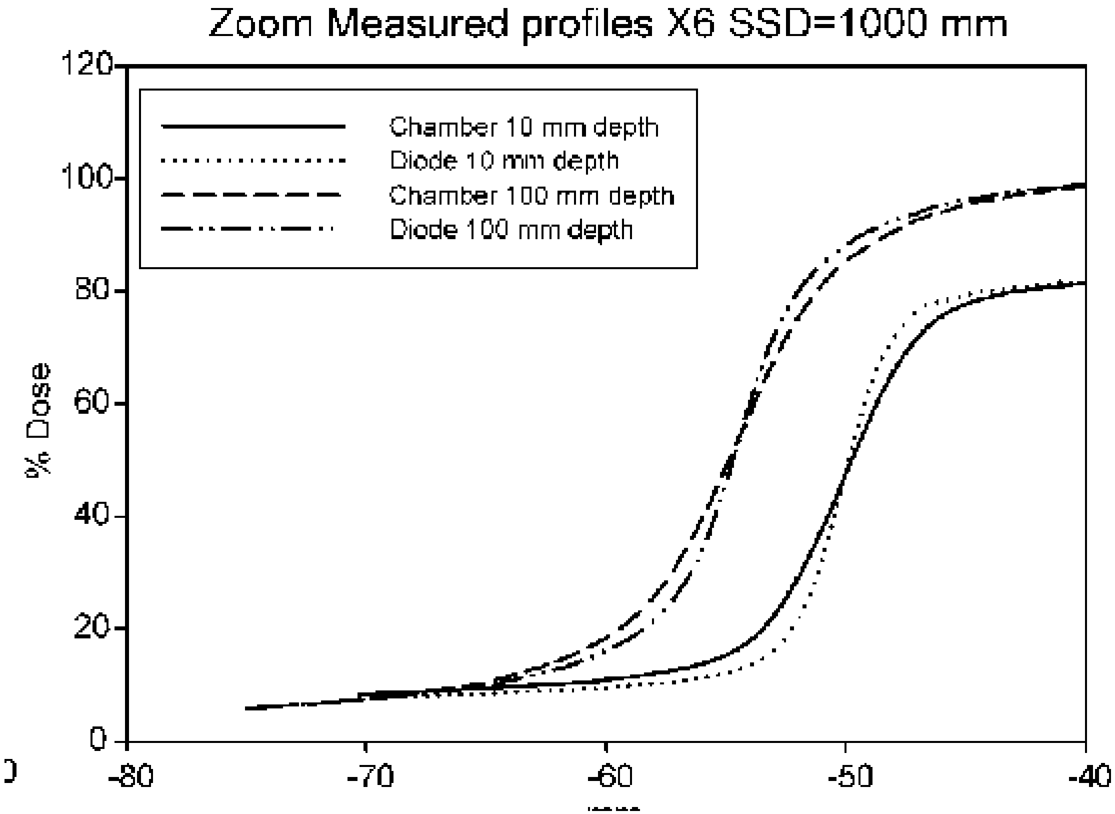


García-Vicente et al.

- "Clinical impact of the detector size effect in 3D-CRT"
- Measured 2 datasets for single LINAC, one with conventional scanning chambers, one with a dosimetry diode.
- Modeled each with high fidelity.
- Compared 3D CRT DVHs for plans of same delivery parameters for two common treatment sites.

García-Vicente et al.



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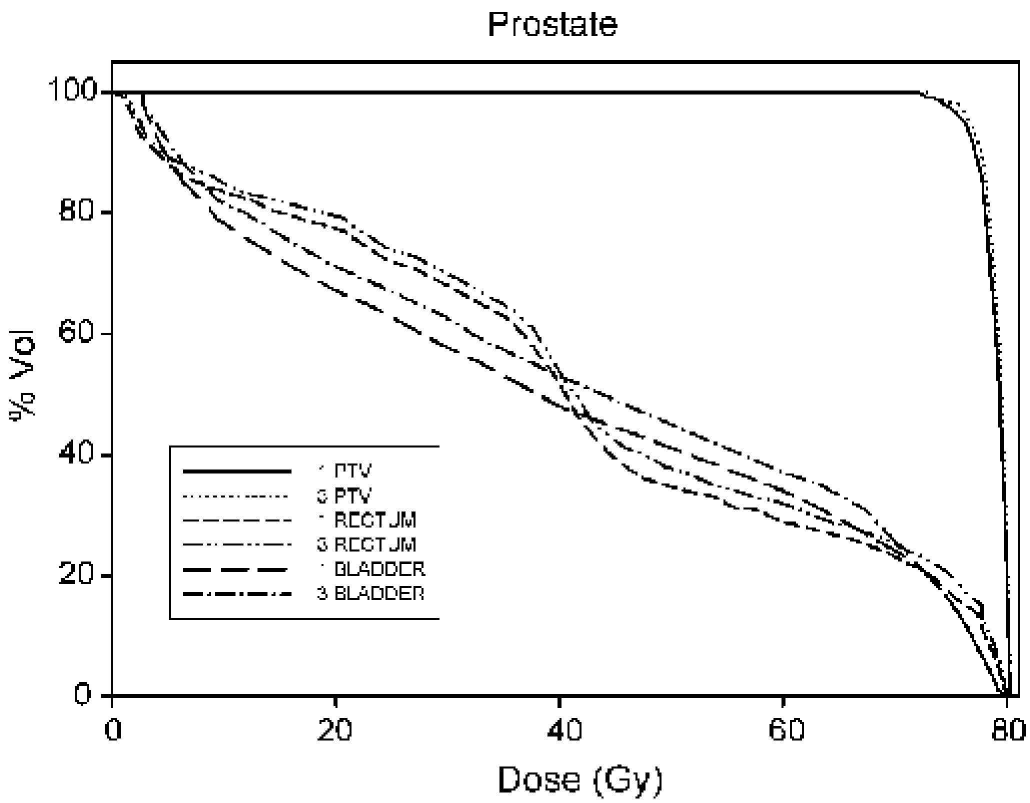

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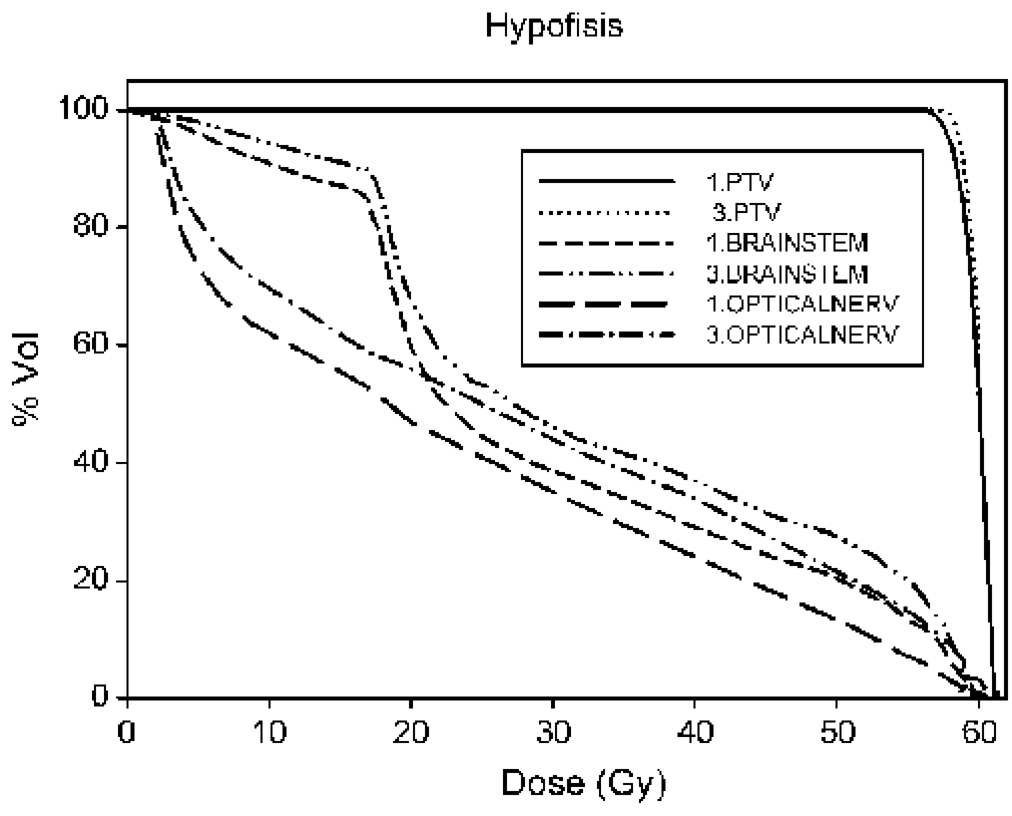

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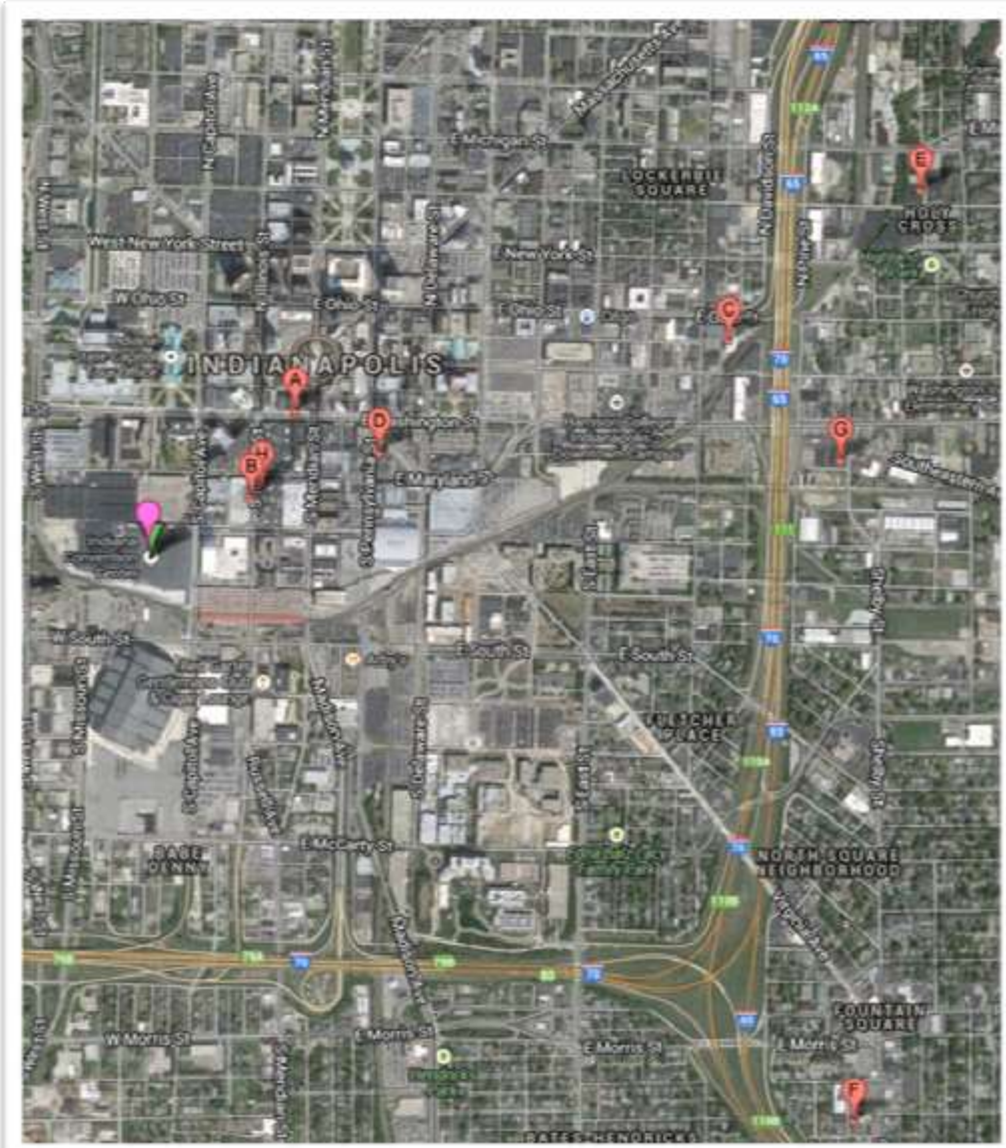
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