Using Scientific Thought to Avoid Mistakes

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ACR

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One of the most important contributing factors to errors in radiotherapy dose delivery is

Human Error

The WHO report on "Radiotherapy Risk Profile" states that 60% of all radiotherapy incidents are attributable to human error

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As Human Medical Physicists

- Must have appropriate education and training
- Have a commitment to be better than average
- Know the difference between
  - Prescriptive actions vs. Understanding before implementation
- Be a critical thinker, not a robot!
  (don't take things for granted)
- In your busy clinic, take the time to investigate and understand

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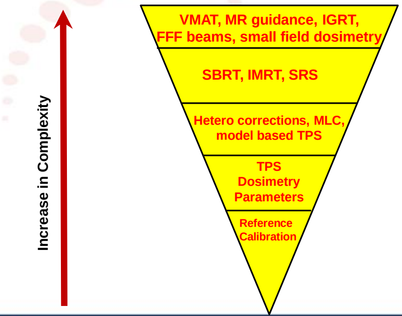

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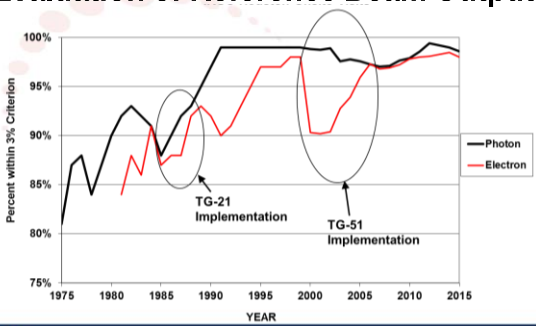
Evaluation of Reference Beam Output



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Implementation of TG-51

- TG-21 was very detailed
  - Each factor listed so you understood what went into calibrating a beam
- TG-51 was developed to be very prescriptive
  - A lot of the detail is behind the scenes
- Did we lose that understanding and ability to investigate reasons for errors?
- Do we know what to look for?

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Charge Measurements

- Electron beam gradient (P_{gr}) correction factor
  - No correction for photon beams since correction included in k_Q
  - Only for cylindrical ion chambers
  - Ratio of readings at two depths

$$P_{gr} = \frac{M(d_{ref} + 0.5 r_{cav})}{M_{raw}(d_{ref})}$$

  - The reading at d_{ref}+0.5r_{cav} should have the same precision as the reading at d_{ref} since:

$$\text{Dose} = \cancel{M(d_{ref})} \bullet (\text{many factors}) \bullet \frac{M(d_{ref}+0.5r_{cav})}{\cancel{M(d_{ref})}}$$

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Charge Measurements

- Electron beam gradient (P_{gr}) correction factor
  - E < 12 MeV; P_{gr} >1.000
  - E ≥ 12 MeV; $P_{gr} \leq$ 1.000
  - Why? Because for low electron energies d_{ref} = d_{max} and this places the eff. pt. of measurement in the buildup region thus a ratio of readings greater than 1.000.
  - At higher electron energies d_{ref} is greater than d_{max} and as such the eff. Pt. of measurement is on the descending portion of the depth dose curve thus a ratio of readings less than 1.000.

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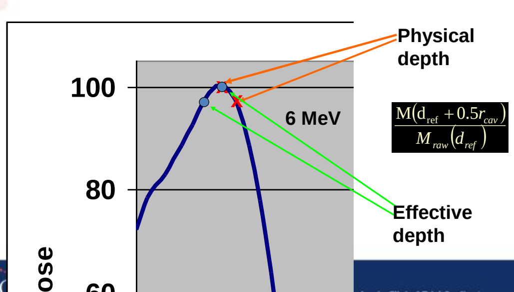
Charge Measurements



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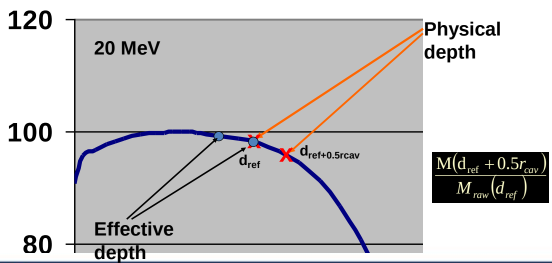
Charge Measurements



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Performing required QA tests

- One performs the required annual QA tests.
- Check that off the list as **DONE**

- No effort was made to compare to clinical values or
- Comparison done but no action taken

Main explanation – it is on my TODO list or do we just not know how to critically resolve the error

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Other Examples of Errors

- Use of wrong chambers for small field dosimetry
- Incorporation of FS and depth dependence for WFs (especially for Elekta machines)
- Following, explicitly, manufacturer’s procedures for acceptance testing
- Use of standard dosimetry data for TPS not knowing its limitations

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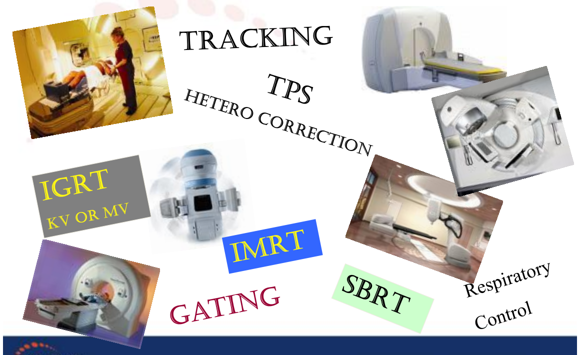
What about Advanced Technologies in Radiotherapy



Imaging, Planning and Delivery - QA required at each step

Positioning and Immobilization → Image Acquisition (CT, MR) → Structure Segmentation → treatment planning →

File transfer and management → Plan validation → Position verification → treatment delivery →

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Imaging, Planning and Delivery
Can we troubleshoot the process or do I believe the manufacturer that all is fine?

Black Box

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Understanding Complex treatments

- The best way to fully understand where things can go wrong is to perform an FMEA analysis

A la TG-100

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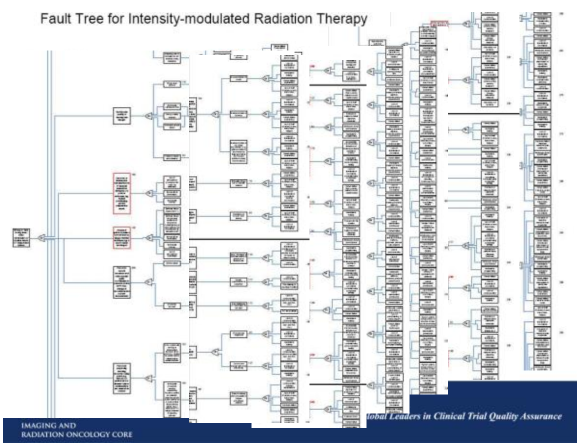

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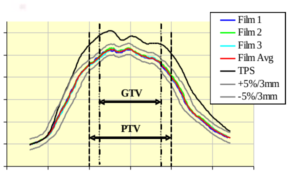
CyberKnife Findings

- Pencil Beam Algorithm in lung showed a **13-15% error** (overestimation) compared to phantom TLD in target
  - Profiles were correct shape, but wrong absolute dose.



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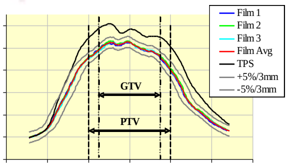
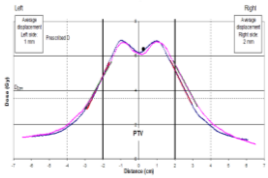
CyberKnife Findings

- Implementation of Monte Carlo algorithm in lung resulted in results that were **±2%**.





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Thus the need for an end-to-end QA audit tool to verify the intended treatment goal.

Deliver the correct dose to correct location as planned

Even with this QA tool, it can be very difficult to determine the exact cause of an error

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Summary

- **Radiotherapy is a continually evolving complex and highly technical treatment modality that, unlike other therapies, deliver doses to the tumor that can be quantified precisely.**
- **Critical thinking and investigation are needed to ensure that errors are not introduced.**
- **Medical physicists must understand the process otherwise errors will not be resolved.**
- **We are scientists who must continually evaluate and improve, not just button pushing technicians.**

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Thank you
Questions?

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