



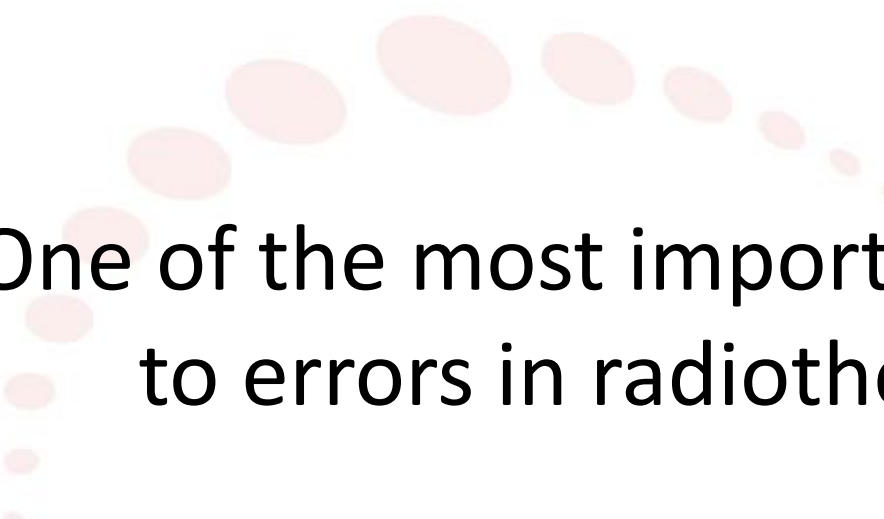
# Using Scientific Thought to Avoid Mistakes



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AMERICAN COLLEGE OF  
RADIOLOGY

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

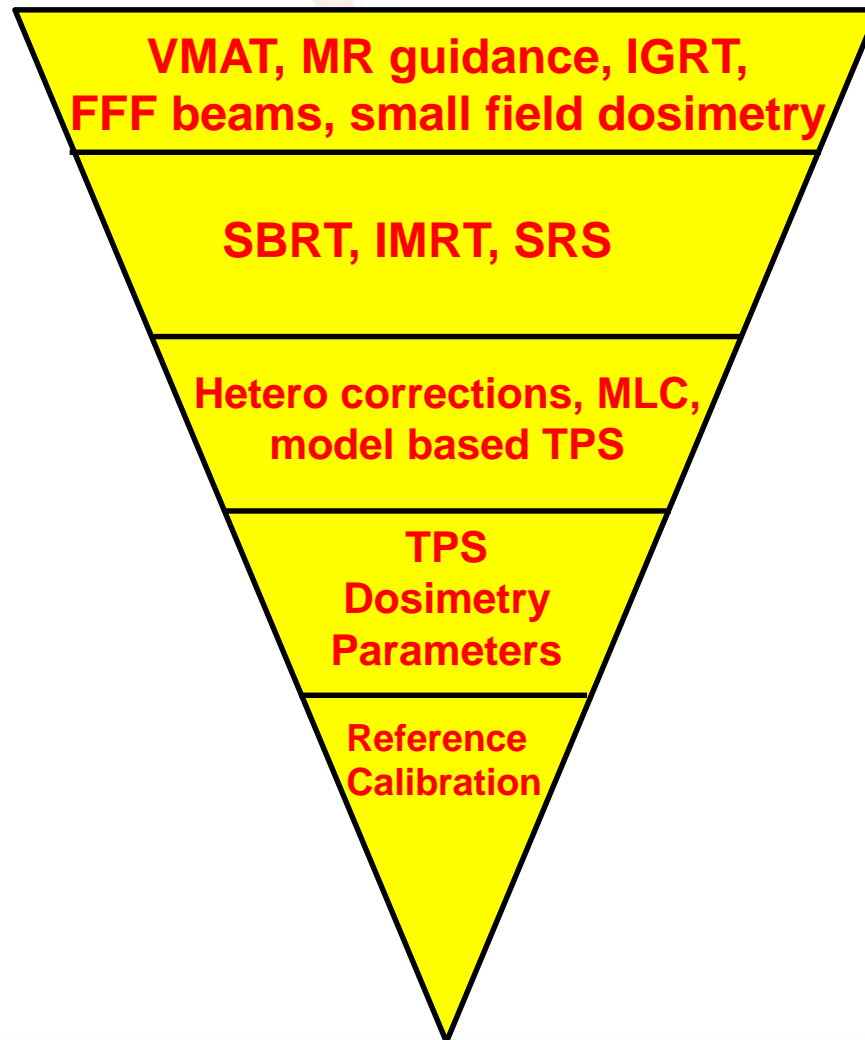
## **Human Error**

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

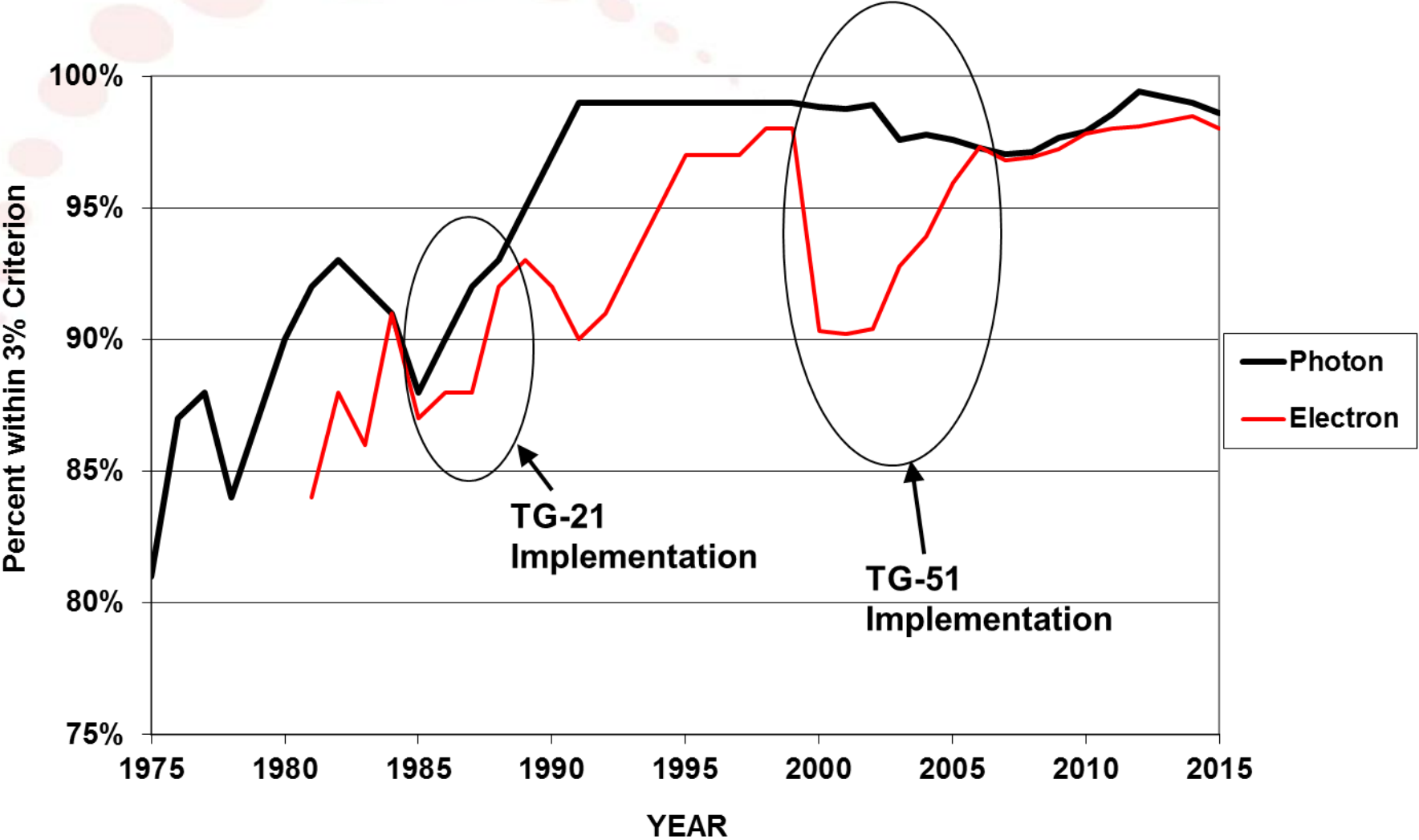
# As Human Medical Physicists

- 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

**Increase in Complexity**



# Evaluation of Reference Beam Output



# 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?

# 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

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

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

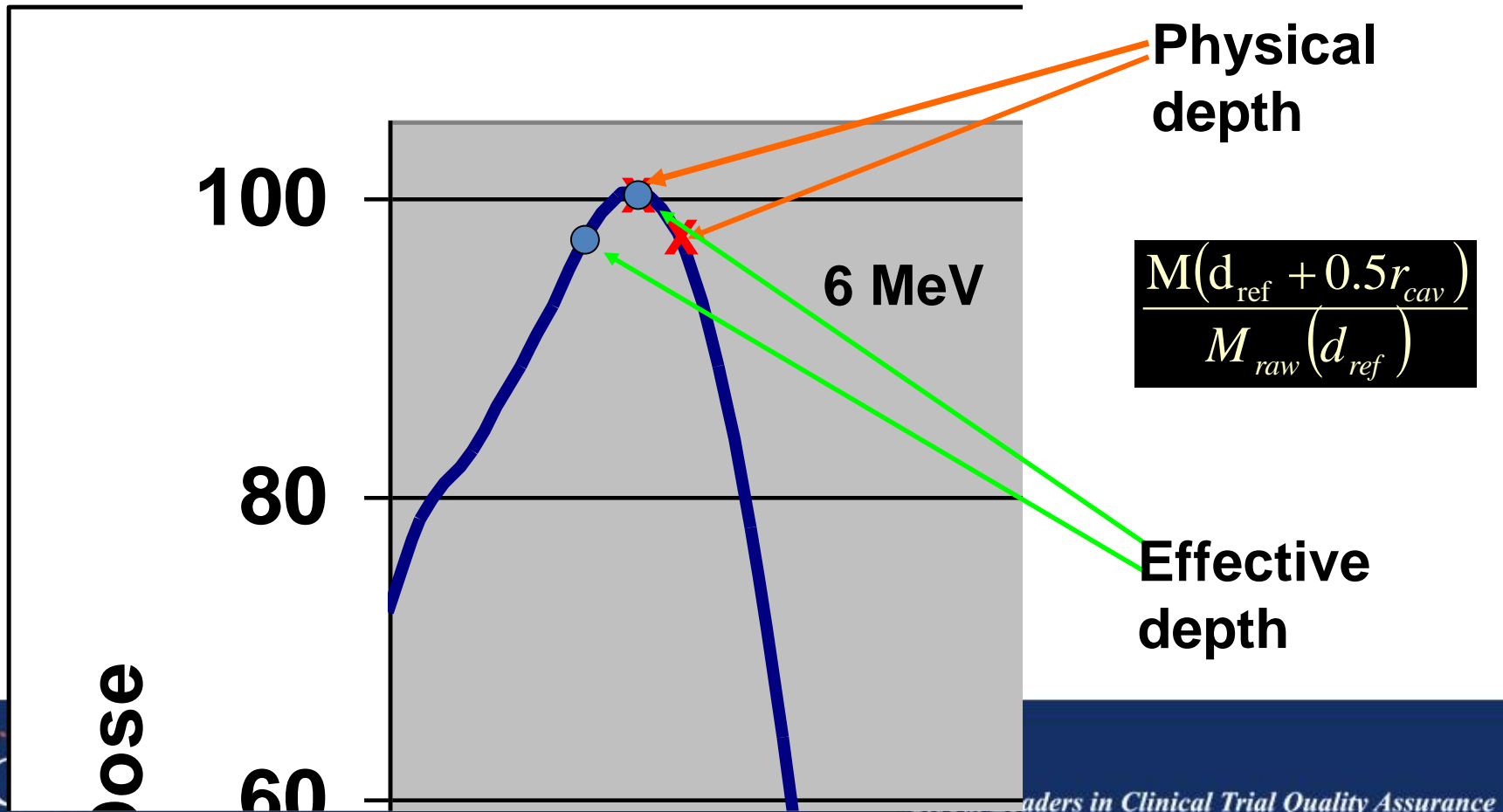
$$\text{Dose} = \cancel{M(d_{ref})} \cdot (\text{many factors}) \cdot \frac{M(d_{ref} + 0.5r_{cav})}{\cancel{M(d_{ref})}}$$

# Charge Measurements

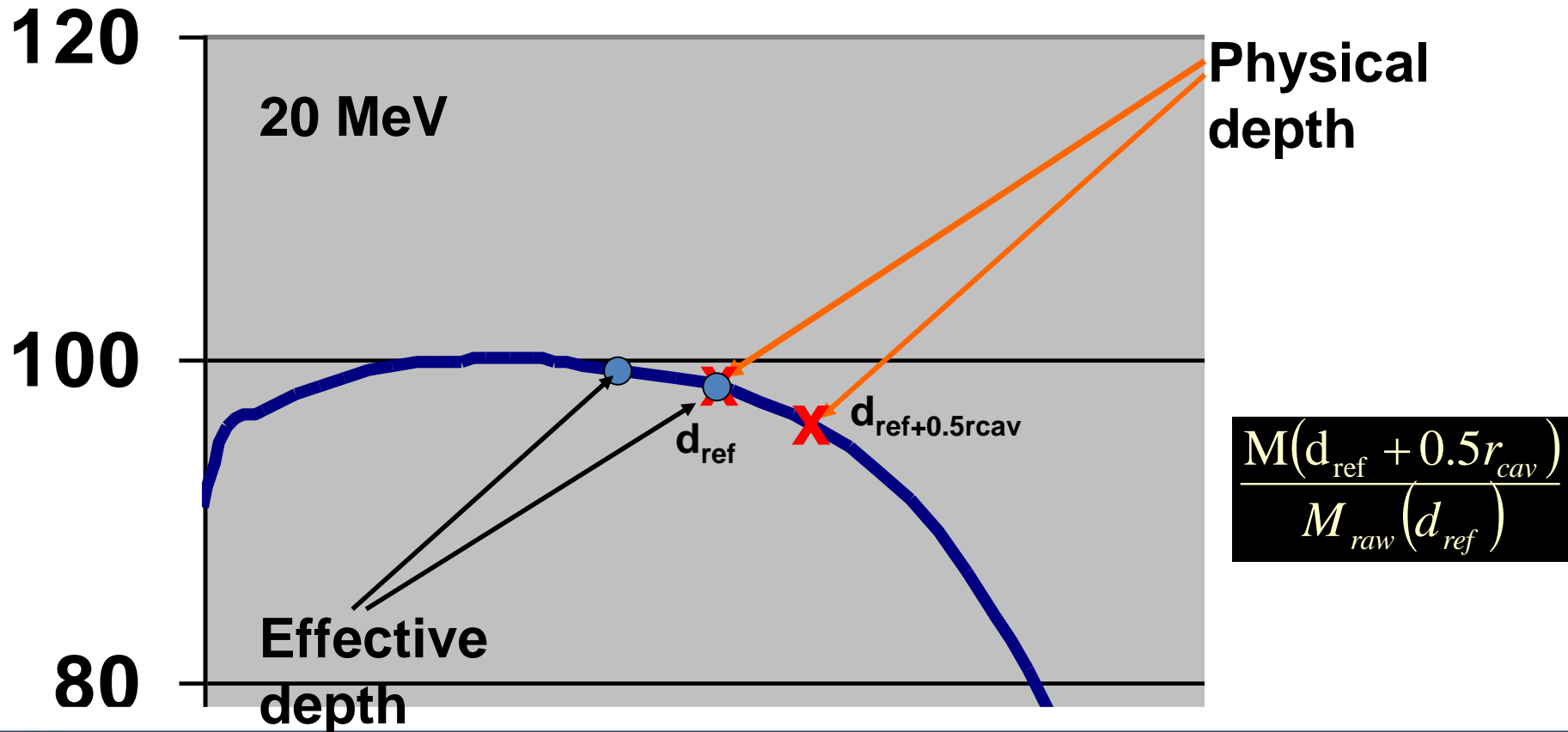
- Electron beam gradient ( $P_{gr}$ ) correction factor
  - $E < 12$  MeV;  $P_{gr} > 1.000$
  - $E \geq 12$  MeV;  $P_{gr} \leq 1.000$
  - Why? Because for low electron energies  $d_{ref} = d_{max}$  and this places the eff. pt. of measurement in the buildup region thus a ratio of readings greater than 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.



# Charge Measurements



# Charge Measurements



# 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**

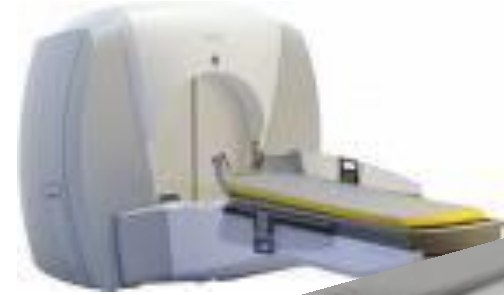
# Other Examples of Errors

- 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

# What about Advanced Technologies in Radiotherapy



TRACKING



TPS

HETERO CORRECTION



IGRT  
KV OR MV



IMRT



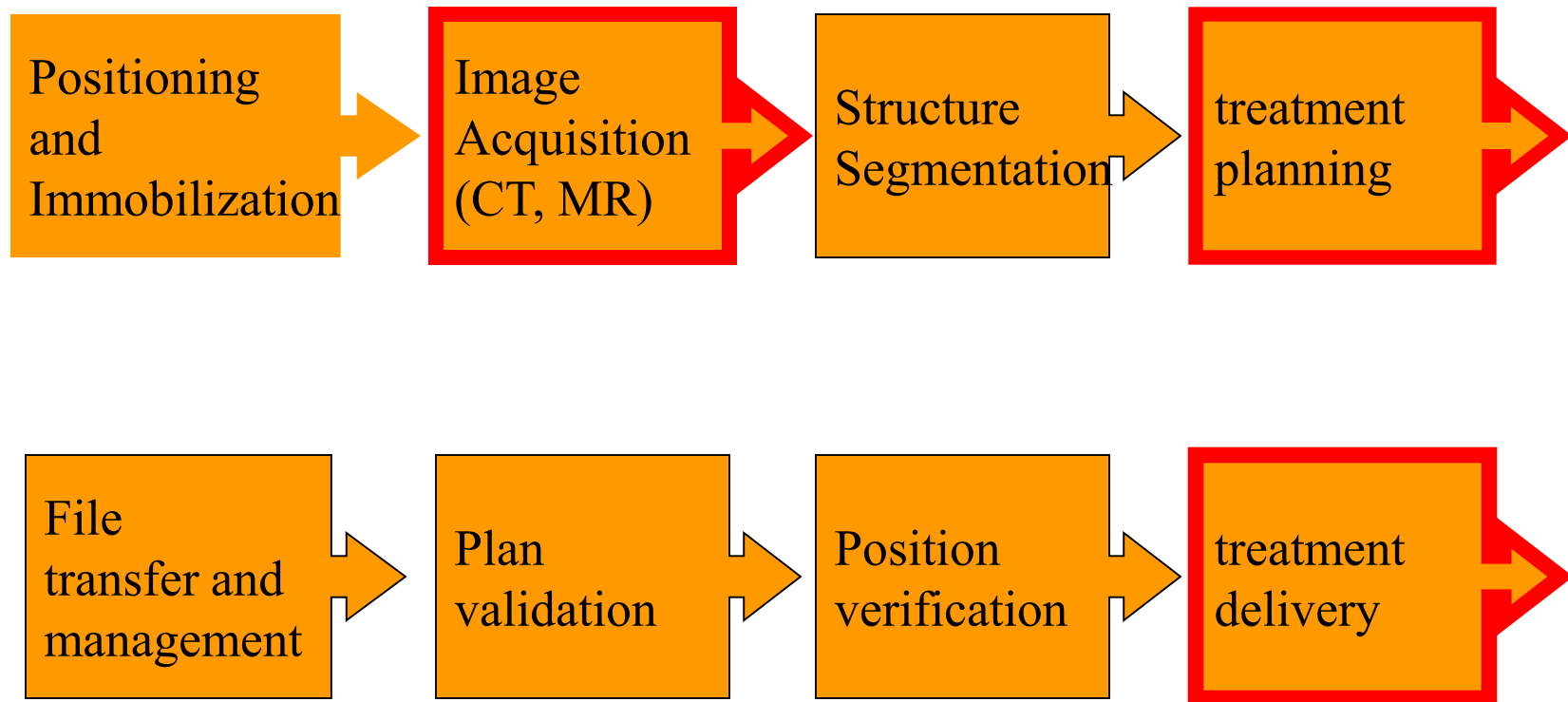
Respiratory  
Control



GATING

SBRT

# Imaging, Planning and Delivery - QA required at each step



# Imaging, Planning and Delivery

Can we troubleshoot the process or do I believe the manufacturer that all is fine?

Black Box

# Understanding Complex treatments

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

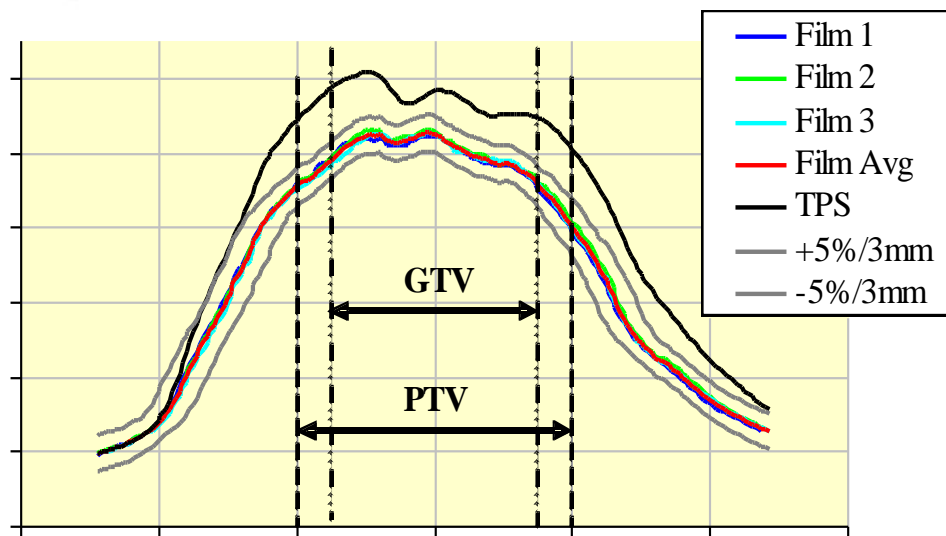
A la TG-100





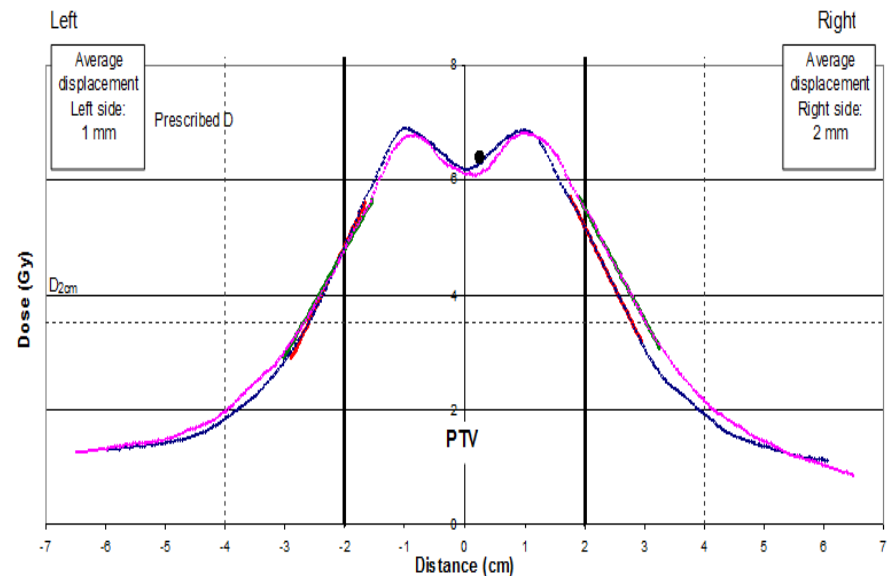
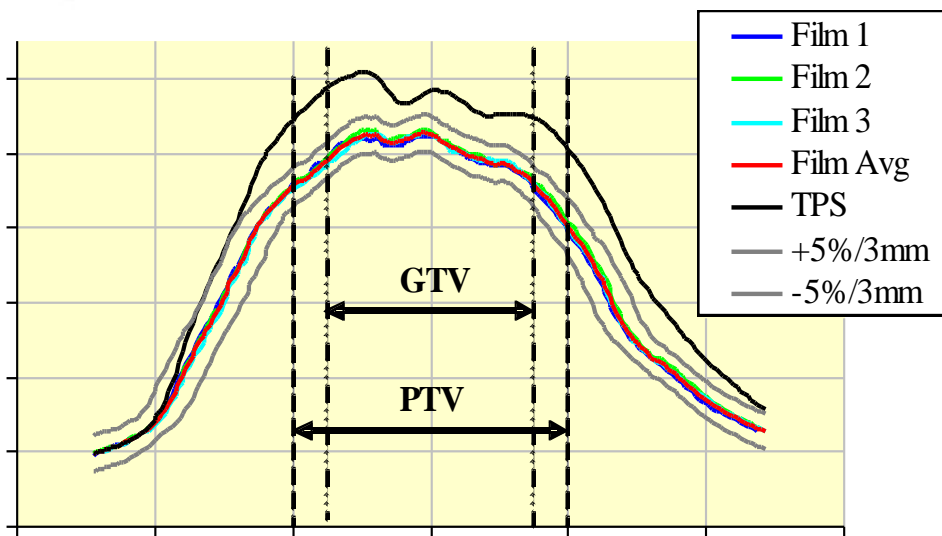
# CyberKnife Findings

- 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.



# CyberKnife Findings

- Implementation of Monte Carlo algorithm in lung resulted in results that were  $\pm 2\%$ .



**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**

# 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.**



# Thank you Questions?

