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Current IMRT QA: Pros and Cons

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Current IMRT QA

- Patient specific, pre-treatment measurements
- The current standard of care for QA of IMRT treatments
- Lots of devices, methods, analysis, interpretation, etc.
- Discuss pros and cons of this general philosophical approach

Pro - 1

- Completes the link between what is planned and what is delivered.
  - Verify that the intended dose is delivered
    - It is the delivered dose that will determine outcomes
    - There are many steps between the TPS image and the delivered dose
  - Verify the deliverability of the plan
    - Dry run of treatment streamlines patient treatment

Pro - 2

- There are errors to be caught! IMRT QA is detection opportunity
  - IROC phantom data:
    - 10-17% of results fail loose tolerance. (Carson 2016; Edward 2020)
    - Beam modeling shortcomings have been identified in the majority of these cases. (Kerns 2017, Edward 2020)
  - Detailed clinical series have also identified errors (Mans 2010)
    - Data transfer
    - Accidental plan modification
    - Suboptimal beam modeling

Pro-3

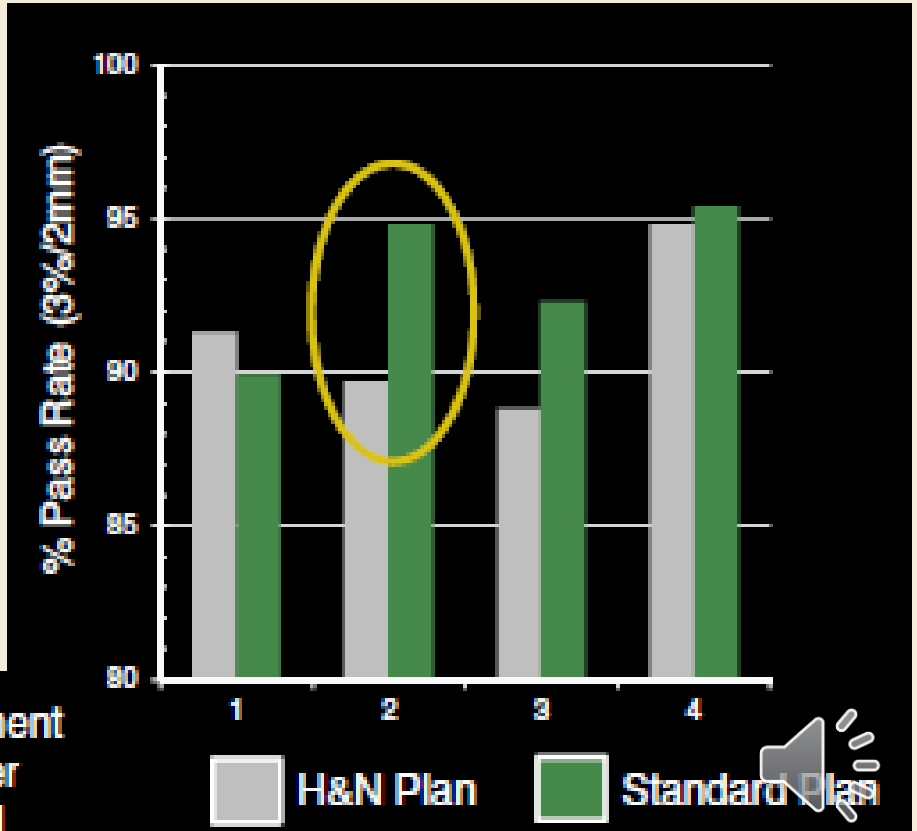
- Good measurement systems have the potential to detect a lot of failure modes
  - Not just calculation errors or delivery errors
  - Techniques like EPID transmission dosimetry can identify:
    - Anatomical changes
    - Patient setup errors
    - (Mans 2010, Olaciregui-Ruiz 2019)

Pro-4

- Well established
  - There is a long history of this approach to verifying complex treatments
  - Lots of available guidance in terms of literature and TG reports
  - Lots of available community experience
  - Don’t have to invent anything

Pro-5

- Clear cases of value
  - QA has caught errors, caused interventions
    - Dosimetric disagreement, deliverability, anatomical changes, data transfer errors.
    - (Mans 2010, Pulliam 2014)
  - Can highlight opportunity for improved planning techniques
    - (Letourneau 2013)



Cons-1

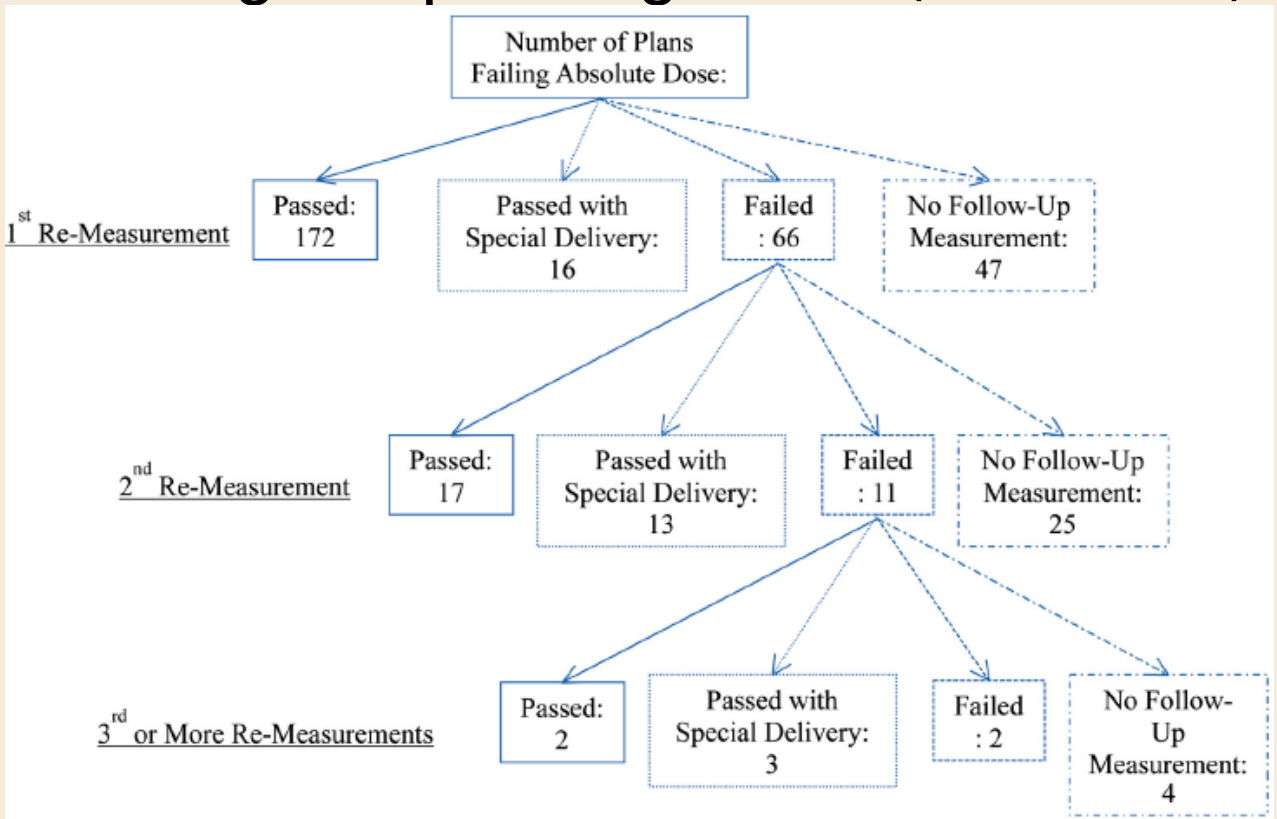
- Time consuming
  - Spend a lot of hours on this task
  - These are unpleasant hours as they are evenings/weekends
  - This task often falls on highly paid highly educated physicists
  - Acceptable if it’s time well spent

Cons-2

- Incomplete evaluation
  - Rarely assessing dose in patient geometry
    - Geometrical array
  - Rarely assessing dose in heterogeneous environment
    - Just on array surface
    - Even calculations into patient anatomy often use simplistic dose calculation algorithms
  - Rarely capture dose in framework for clinical interpretation
    - No DVH info, hard to relate %pixels passing to clinical judgements
  - Anatomy changes during treatment

Cons-3

- We usually don't act on failures
  - When IMRT QA fails, we usually repeat measurements and repeat until we get a passing result (Pulliam 2014)



MD Anderson experience of 301 failed ion chamber-based IMRT QA results

Cons-3 Continued

- We usually don't act on failures
  - Survey of 1,455 institutions highlighted similar results (Mehrens 2020)
  - Main approach to failing IMRT QA is re-measure
    - Other strategies: use relative mode, change passing criteria, replan
    - Most approaches: make the current situation work
- It is understandable that we don't do much with these issues
  - Not an easy solution (replanning is a lot of work)
  - IROC shows lots of errors originate with beam model. This isn't the time to be fixing a beam model…..
  - Patient already on table
- If we don't act on problems, why are we doing this??
  - Current approach is not working

Cons-4

- Devices don't catch errors
  - Dosimetrically unacceptable plans are called fine

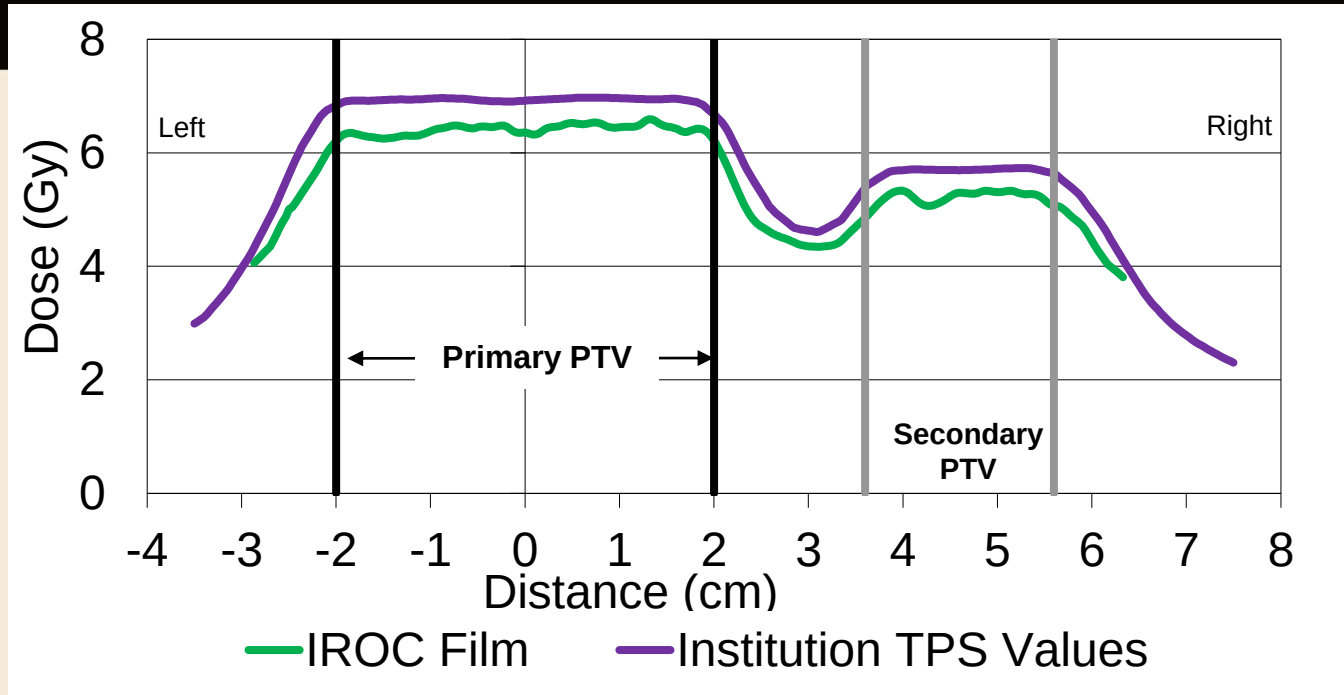
Kruse 2010, Nelms 2011, Stasi 2012, Nelms 2013, Kry 2014, McKenzie 2104, Defoor 2017, Kry 2019

  - Low sensitivity, high specificity
    - Doesn't fail bad plans, but doesn't fail good plans. Doesn't fail anything!!!
  - IROC phantom results not predicted by inst. IMRT QA (Kry 2019)

Device	# Tests	# Poor	Sensitivity (%)	Specificity (%)
All	337	59	5 (3 identified)	99
MapCheck	121	20	5 (1 identified)	100
ArcCheck	93	16	0 (0 identified)	100
EPID	58	16	0 (0 identified)	100
Ion chamber	44	8	25 (2 identified)	94

Cons-4

- Devices don’t catch errors
  - This phantom result:
    - 8% systematic underdose
    - ArcCheck QA, 3%/3mm, absolute dose mode
    - 97% and 100% of pixels passed



- Also don’t necessarily catch patient issues
  - Per-Fraction: translations of 2 cm before detected (Hseih 2017)
  - EPID: Translations of 1 cm not always well detected (Olaciregui-Ruiz 2019)
  - Rotations less than 8 degrees not well detected (Olaciregui-Ruiz 2019)

Cons-5

- Clinical QA thresholds are unrealistic
  - Even TG-218 suggested criteria don't appear to be adequate
  - To detect **80%** of poor or failing IROC phantom results: (Kry 2019)

Criteria	IROC phantom result	Threshold (% pixels)
3%/3mm	Fail (>7% error)	**99.7**
2%/2mm	Fail (>7% error)	**100**
3%/3mm	Poor (>5% error)	**99.8**
2%/2mm	Poor (>5% error)	**99.2**

  - These criteria are not clinically implementable

Summary

- Conceptually current IMRT QA is very important, very robust technique to probe plan, delivery, even the patient.

But, overwhelmingly,

- Methods/devices don't actually work well
  - Usually don't catch errors
- Program of IMRT QA doesn't work well
  - Even when IMRT QA indicates a problem, we don't/can't act on it.

- We need to improve on the current status of IMRT QA

END