Patient Specific QA for New Technologies and Online Adaptive Radiotherapy

Halcyon & Ethos

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RETHINKING MEDICAL PHYSICS

Disclosures

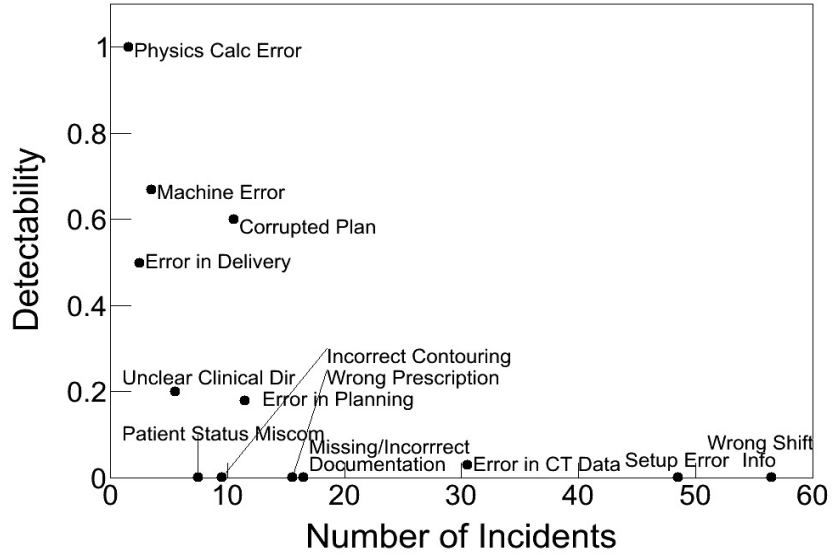
- Receive Grant Funding from Varian Medical Systems

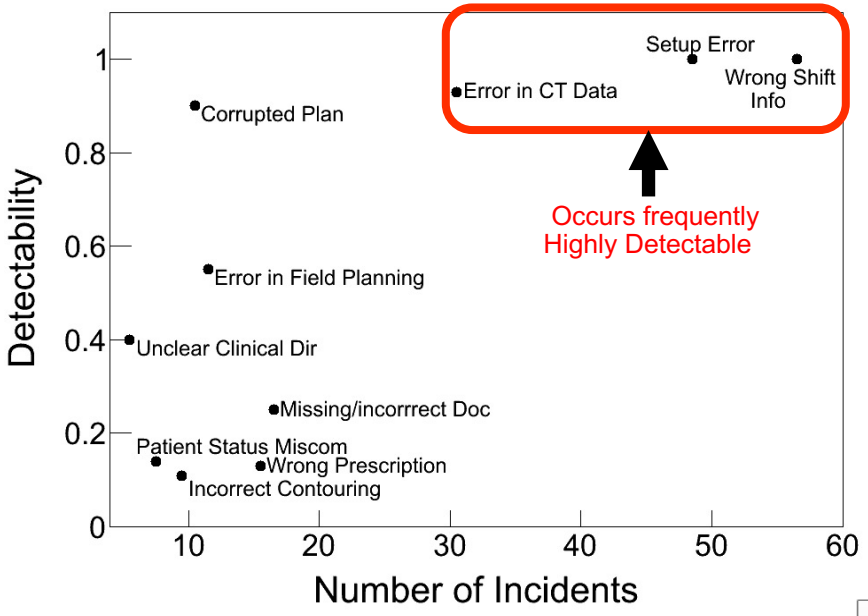
Outline

- In vivo Patient Specific QA
  - Errors that can be detected/Quality improvements
  - How to encourage implementation
  - Patient management
  - Halcyon
- Online Adaptive Radiotherapy
  - Risk profile
  - Patient Specific QA Challenges/Approaches
  - Ethos

Analysis of Incident Reports

- Review of incidents reported in continual safety improvement (CSI) database.
  - 343 events with 3 or 4 rating (severe or critical)
- Group into “error modes”.
- Determine which errors can ***ideally*** be detected by EPID measurements. Pre-treatment or in-vivo.
- For each error mode, compute fraction of events that can be detected.





Bojechko et al. Medical Physics 42 (9), 5363-5369

Errors Detected

Potential Error	Error Type	References
Machine-related	Transfer error	Mans et al. (2010), Mijnheer et al. (2015)
Plan-related	Dose calculation error	Mans et al. (2010), Fidanzio et al. (2015), Mijnheer et al. (2015)
	Immobilization system not included in the treatment plan	Fidanzio et al. (2015)
	Bolus material not taken into account	Mijnheer et al. (2015)
Patient-related: anatomy changes	Changes in atelectasis and pleural effusion	Piermattei et al. (2009), Mans et al. (2010), Persoon et al. (2012), Wendling et al. (2012), Persoon et al. (2013), Fidanzio et al. (2015), Mijnheer et al. (2015)
	Variation in patient contour when the patient becomes more relaxed during treatment	Mans et al. (2010), Fidanzio et al. (2015), Peca et al. (2015)
	Gas pockets in the planning CT scan resulting in an underdose in the PTV during treatment	Camilleri et al. (2014), Cilla et al. (2014), Fidanzio et al. (2015)
	Weight loss resulting in an overdose in the PTV during treatment	Mans et al. (2010), Camilleri et al. (2014), Cilla et al. (2014, 2016)
	Incomplete bladder filling resulting in an overdose in the PTV during treatment	Ricketts et al. (2016)
Patient-related: delivery errors	Bar of the treatment couch in the entrance beam during treatment	Piermattei et al. (2009), Fidanzio et al. (2015)
	Imperfect immobilization allowing the patient to move during treatment	Hanson et al. (2014), Cilla et al. (2016)
	Wrong patient setup during treatment	Fidanzio et al. (2015), Mijnheer et al. (2015)

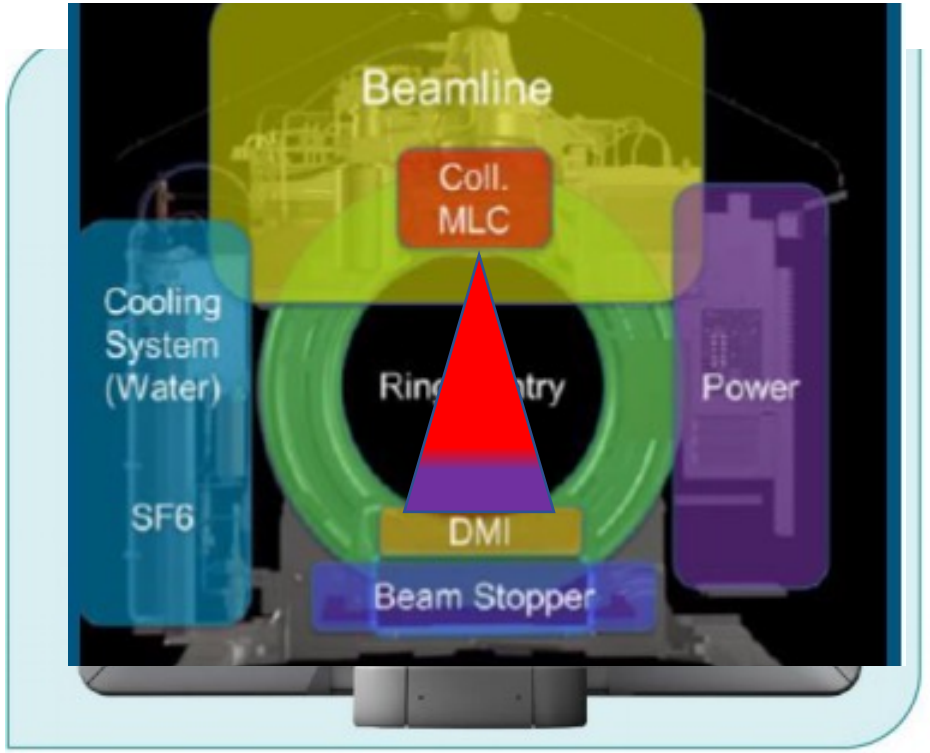
Clinical 3D dosimetry in Advanced Radiotherapy. [illegible]heer

Aids to Implementation

- Currently in clinical use
  - In-house Solutions
  - Commercial Products (Perfracion, EPIgray, Dosimetry Check, SOFTDISO)
- How to Expand Use
  - Automation
  - Knowledge of system capabilities
  - High sensitivity and specificity in error detection
  - Clinically actionable information
  - Easy to commission

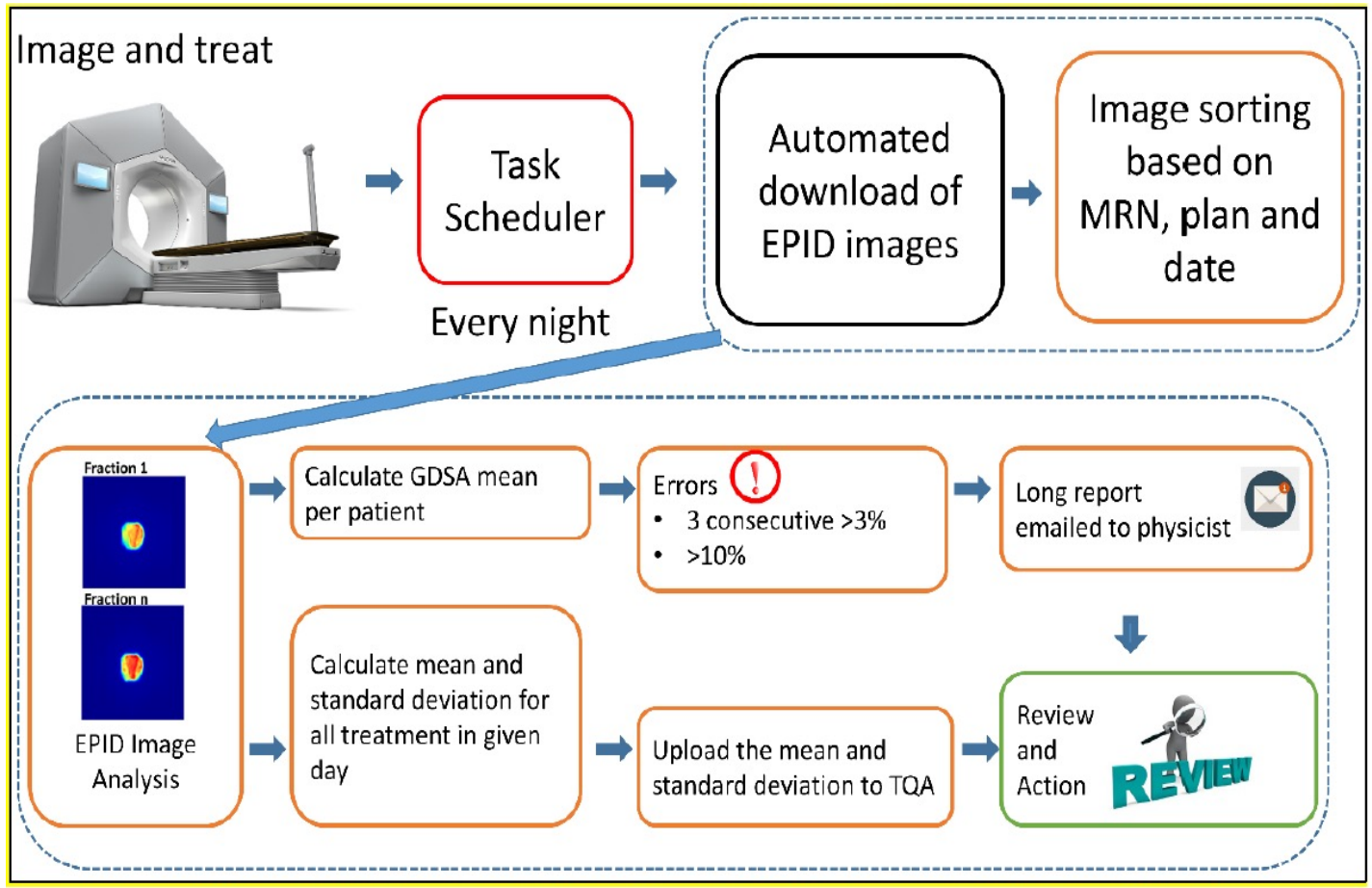
Halcyon

- Delivery on Halcyon, automatically collects EPID images.
  - UCSD started using Halcyon fall 2017, lots of data already collected
- Free data lying around. What can we do with it?
  - Per-fraction patient specific QA
  - Detection of patient related errors
  - *Changes in patient anatomy*
- *Pretreament PSQA is done with EPID and gamma analysis*



Halcyon

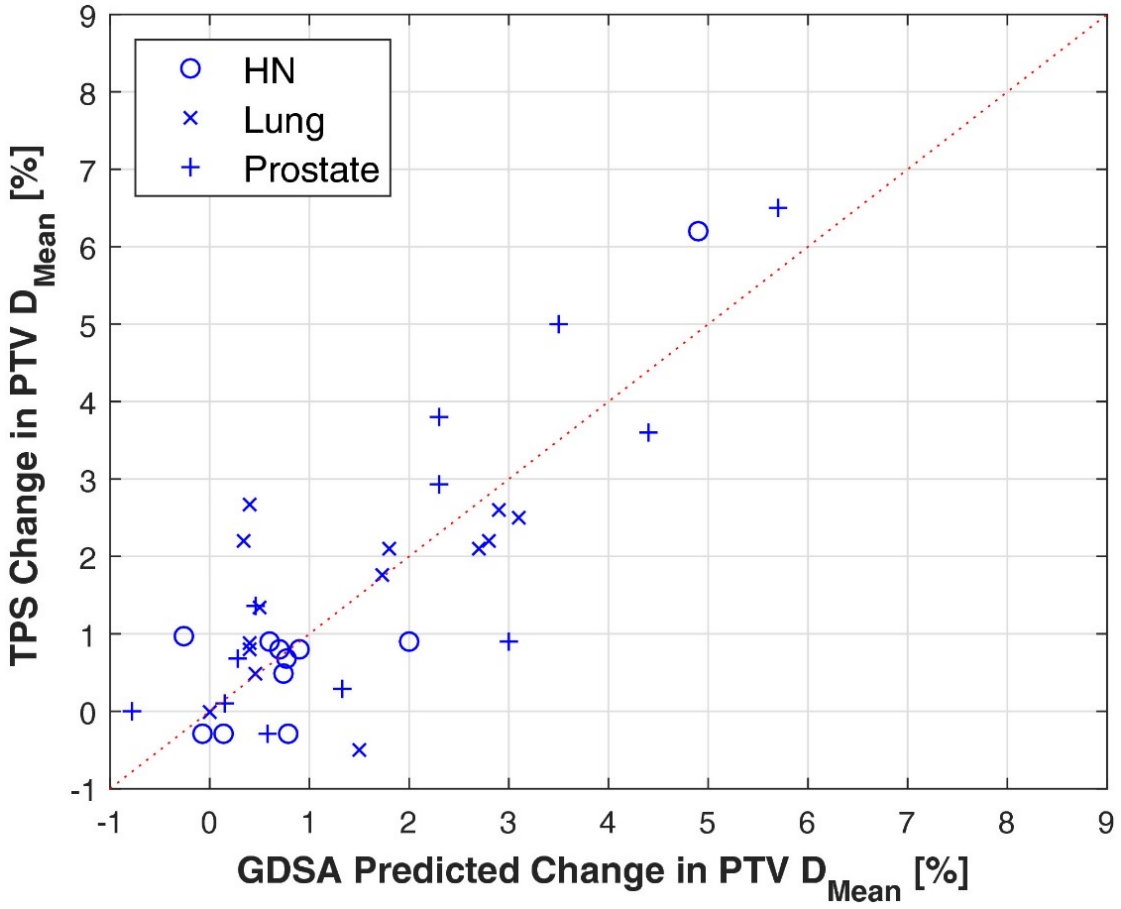
Automation



Courtesy of A. Chalise

Halcyon

Clinically actionable information

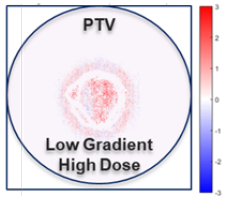


Steers et al. Medical Physics 47 (11), 5419-5427

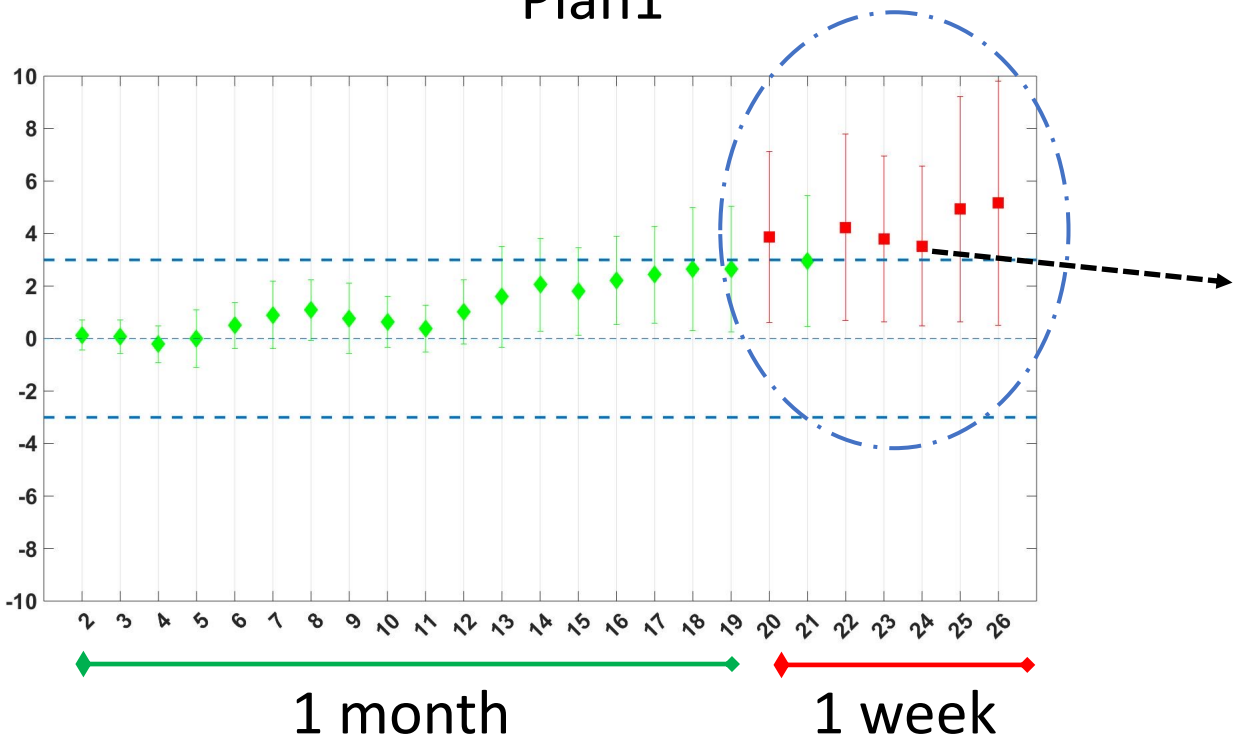
Patient Errors

Head & Neck weight loss

GDSA mean

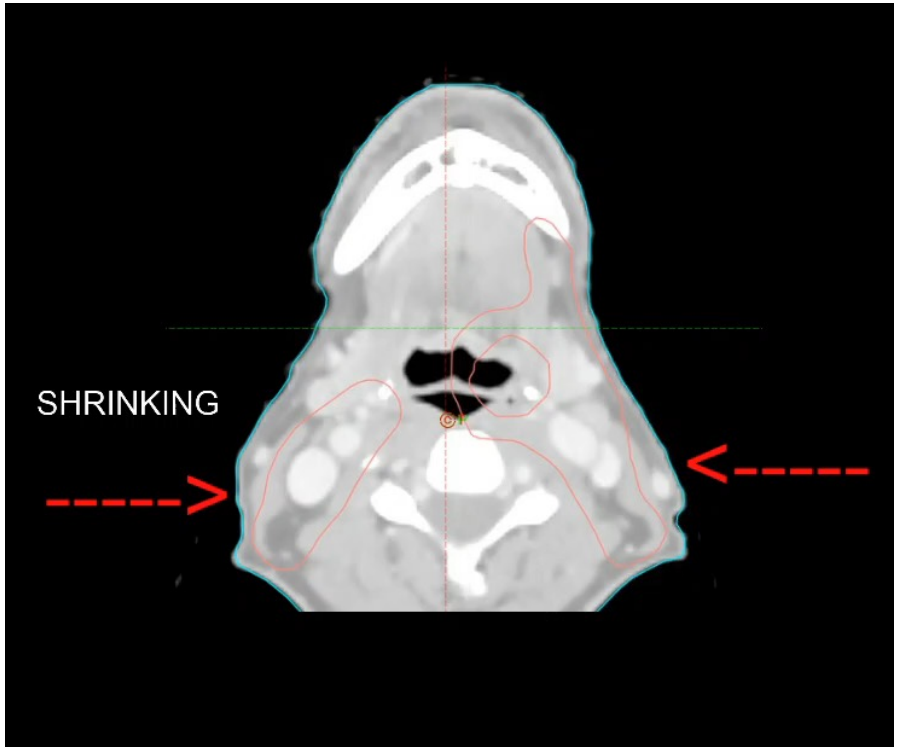


Plan1



Fraction

Fraction #24

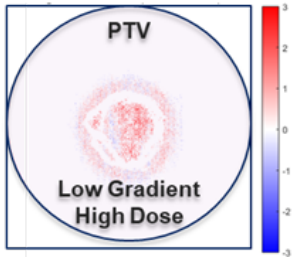


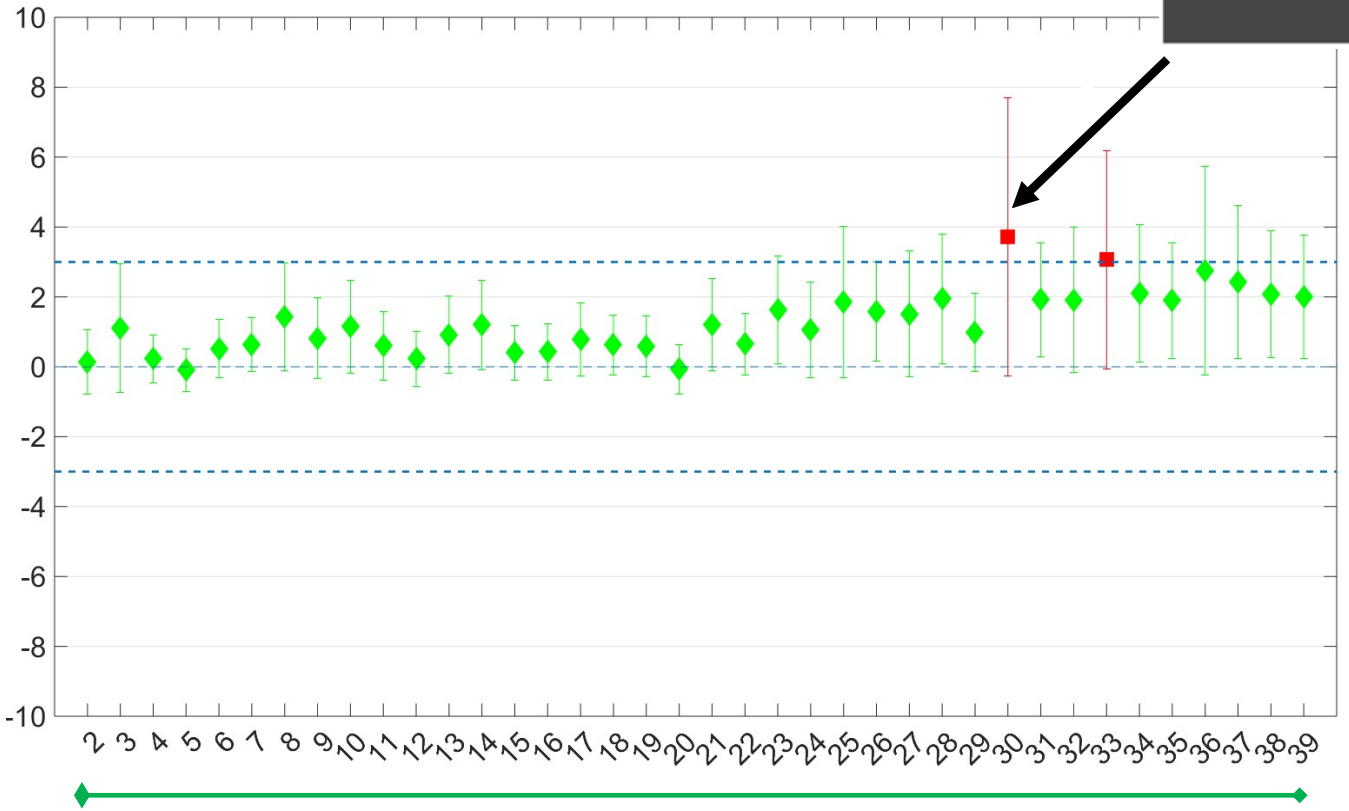
CT **CBCT**

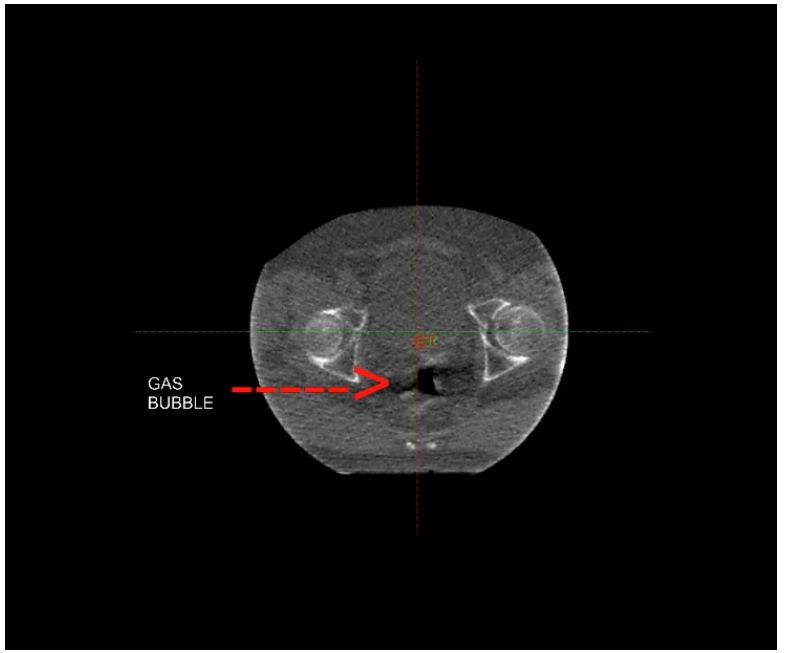
Patient Errors

Gas bubble - Prostate

GDSA mean





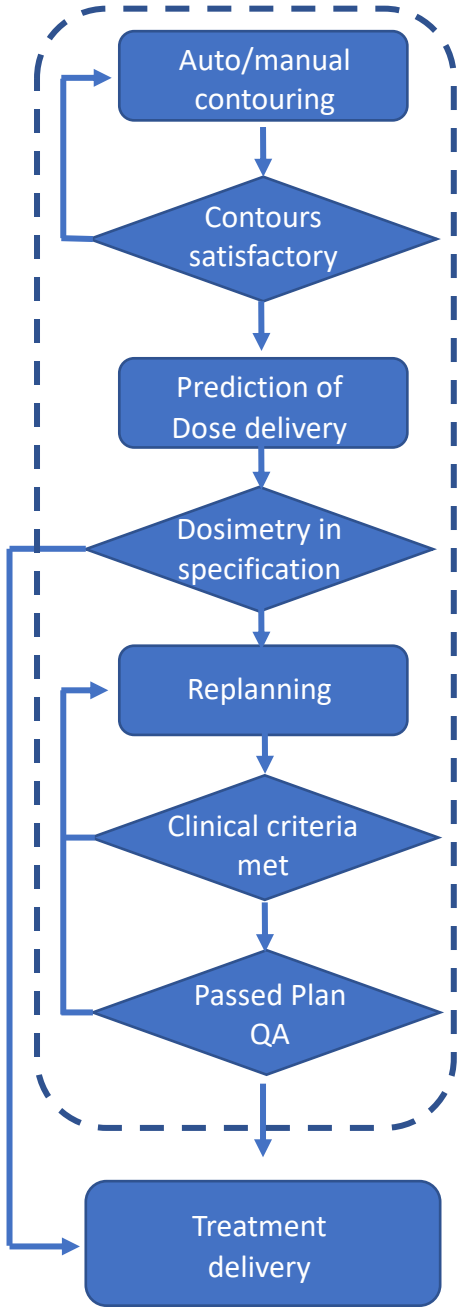


Further Developments

- How to Expand Use
  - Automation
  - Knowledge of system capabilities
  - High sensitivity and specificity in error detection
  - Clinically actionable information
  - Easy to commission

Online Adaptive Radiation Therapy

- Workflow is substantially changed from standard IMRT
  - Utilizing on-treatment imaging assess the patient and replan.



Glide-Hurst et al. Int J Radiation Oncol Biol Phys, Vol. 109, No. 4

Identifying Errors

- FMEA analysis of ART compared to standard IMRT.
- For ART
  - Identified different, but not more, risks than standard IMRT.
  - Can be implemented with proper mitigations.

	Failure	QC strategy
(1)	Isocenter documentation	Automated isocenter capture, checklists, monitoring trends in daily patient shifts
(2)	Miscommunication of planning directives and failure to properly account for dose accumulation	Well-defined protocols, stable clinical workflow, staff training, integrated record management, electronic physician order, and whiteboard systems
(3)	Poor dataset fusion	Automated fusion tools, specialty training for onsite staff
(4)	Incorrect target/structure delineation and construction	Automated contour integrity verification software
(5)	Poor plan optimization and or incorrect dose computation	Automated software verifying: • dose computation • leaf sequencing • plan integrity
(6)	Poor plan review	Automated comparisons between planning goals and achieved goals, decision support software
(7)	Incorrect interpretation of plan data for treatment delivery	Independent verification software comparing data indicated by the planning to data read by the delivery system
(8)	Failures in treatment parameter setup on treatment machine	Simulated delivery, pretreatment (running gantry rotations and MLC patterns without dose output) Retrospective MLC QA, post-treatment
(9)	Failures occurring during treatment delivery	Transmission detectors Real-time MLC/gantry monitoring

Noel et al. Medical Physics 2014 41(8):081717.

Challenges for PSAQ in ART

- Patient specific & Plan specific QA
- For initial plan pretreatment QA can still be done
- For online adaptation
  - Predelivery not feasible when patient is on the table
  - Additional plans created frequently increasing workload
  - Must be performed in an accelerated time frame

Approaches

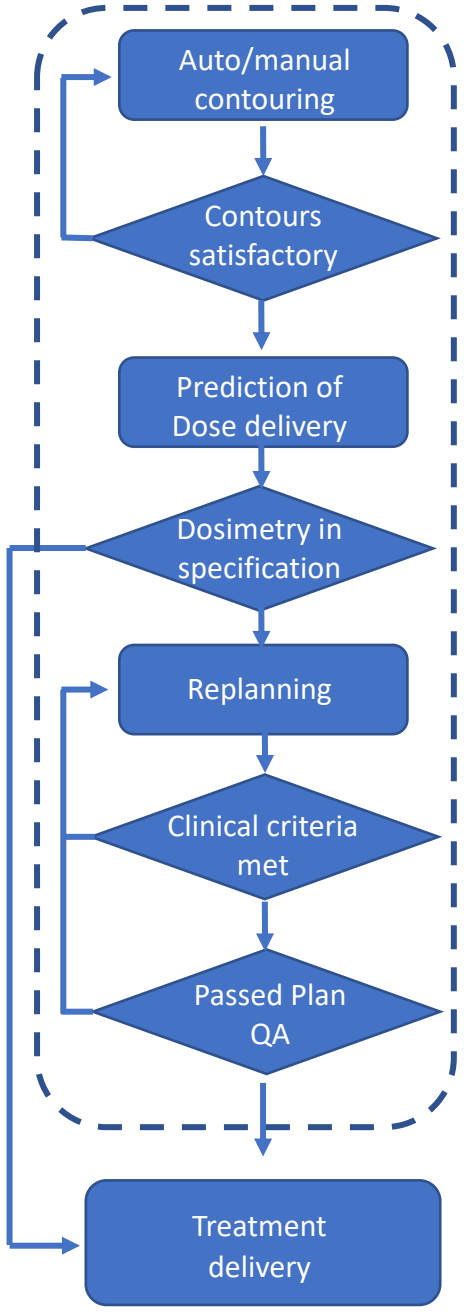
- Using data from machine log files.
  - Perform a “dry-run”
  - Retrospective analysis
  - Real time
- Independent secondary dose calculation
- Transmission measurements
  - Comparison with expected image
  - Back-projection to calculated dose

Ethos

Deformable Image Registration

Secondary Independent Dose Calc

Retrospective Analysis of Log Files



Online adaptive

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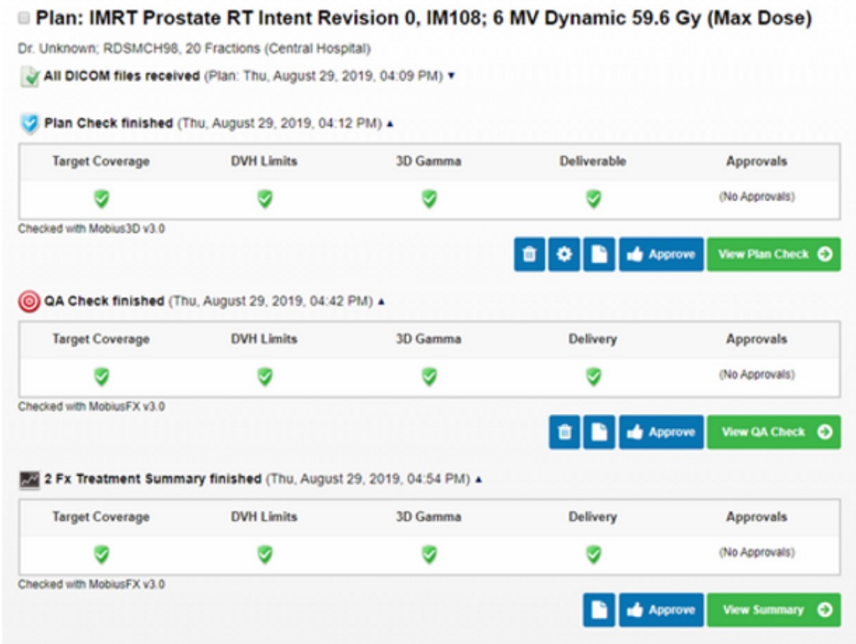
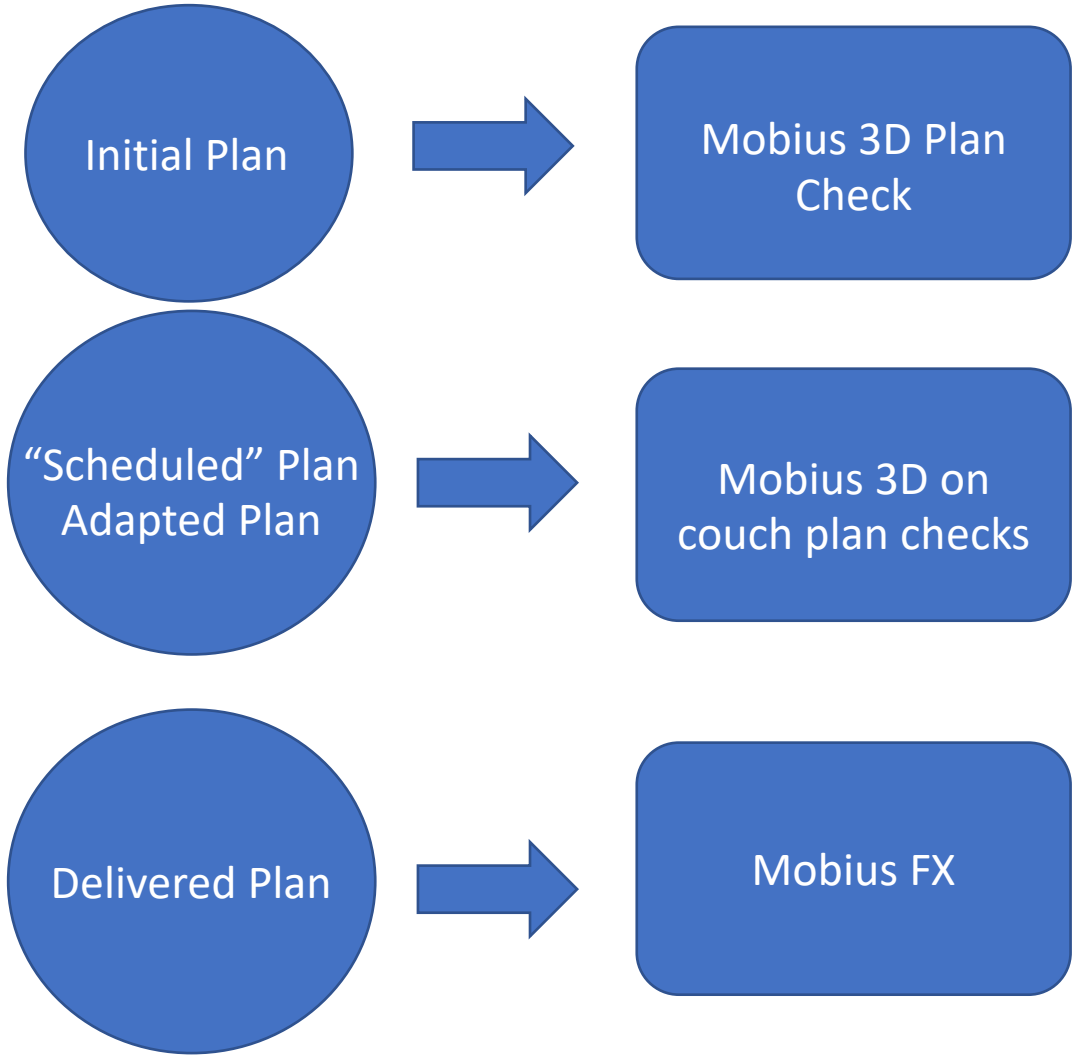
MobiusAdapt

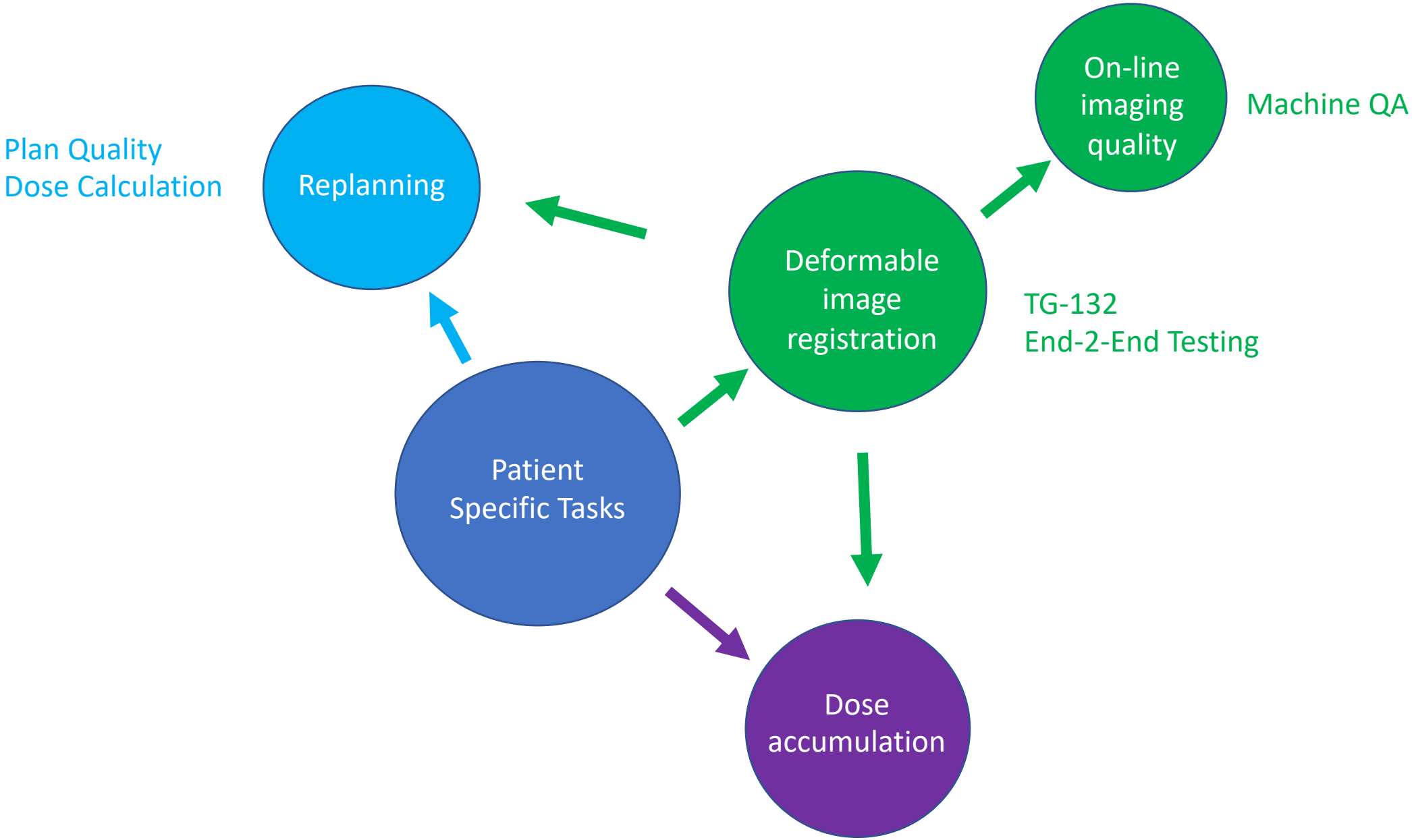
- Mobius3D
  - Performs second check on treatment plans
  - Uses independent collapsed cone convolution/superposition algorithm.
- MobiusFX
  - Uses Trajectory Log Files, MLC encoder data.
  - Ensure that planned = delivered



MobiusAdapt

- Initial plan QA
  - Plan check with Mobius3D
- On-couch QA
  - Scheduled and adapted plan checks
- Delivery QA
  - Use log files to compute dose and compare to plan that waws delivered




Plan Quality
Dose Calculation
Replanning
On-line imaging quality
Machine QA
Deformable image registration
TG-132
End-2-End Testing
Patient Specific Tasks
Dose accumulation

Conclusions

- New treatment platforms will help shifting PSQA to include more Patient information
- With newer platforms/more data available
  - In-vivo images
  - Adapted contours, dose distributions
  - Log file data on a per/fraction level

- More per-fr