Bringing Automation to Proton Clinics

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Overview

• Proton plan checks
  • Passive: MU, compensator and other checks
  • PBS: robustness, max/min MU/spot, range shifter consistency, layer/volume repainting
• Automated collision detection
  • Gantry model
  • Auto correction on snout extension
  • Challenges
• PBS Commissioning
• Some new developments

MU, App/Comp Check

• Ensure compensators meet clinical protocols, e.g. ridge height
• Review aperture boundary within snout opening
• Ensure manufacturability by checking min and max height
• Avoid “islands” that might break off
• Center-specific beam data
• Calculate MU!
**Compensator Visualization**

XiO TPS  
ProCureMU

**Compensator Fabrication**

**Additional plan check items**

- Field name reflects geometry, i.e. G3307905AO
- Max and Min MU/Spot for PBS
- Beam/couch angle within the usable range
- Range Shifter is identical for all beams
- Dose grid less than 3mm

* (Limited to plan DICOM files only)
MU determination

- XIO allows user to specify a scaling factor “Weight”
- Dose to water phantom is obtained either from a QA plan, or by calculating the Track File Factor
- Output factor is measured at commissioning, relative to the calibration condition, R16/M10 for ProCure
- Depth dependent Field Size Factor is measured at commissioning
- $MU = \text{Weight} \times \text{TFF} \times \text{FSF}$
- Measurement is only needed for small fields, esp off-axis

MU Second Check

- Total/Fl x Daily Dose
- Calculates daily dose from MU and delivery scheme
- Compare with Rx Daily dose
  - NOT total dose
  - NOT frac

Additional plan check items

- Field name reflects geometry, i.e. G330T90SAO
- Max and Min MU/Spot for PBS
- Beam/couch angle within the useable range
- Range Shifter is identical for all beams
- Dose grid less than 3mm
- CT: slice thickness, calibration table, and association with plan
- Beam/couch angle within the useable range
- Dose grid extent encompasses target, OAR and beam
- Dose calculation engine (Monte Carlo or Analytic)
- Layer repainting is properly set for lung and liver cases
- Specific contours exist for each treatment site
- Air gap is reasonable

Shikui Tang, private communications
Automated plan robustness

- Plan with $r \times N$ fractions ($r$ is the # of volume repainting, $N$ is the actual # of fractions)
- Deliver each fields $r$ times each day
  - Standard workflow
  - Tedious and time consuming to send each field $r$ times

Auto robustness evaluation

Stacked volumetric repainting

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- Deliver each fields $r$ times each day
  - Standard workflow
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PBS Spot Size and Location

- Measurements
  - ISO, ISO+15cm, ISO-15cm
  - 18 energies

- Spot divergence
  - $\sigma_{x,y}(z)$
  - Potentially $\sigma_{x,y,\theta}(x,y,z)$

- SAD/Spot location
  - $\mu_{x,y}(z)$

PBS spot size/location analysis

ML prostate plan

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