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Lung and Liver Treatment Planning Protocol

Mayo Clinic Arizona

Wei Liu, PhD
Professor
Department of Radiation Oncology

Patient Selection

- Staged by PET/CT and brain scanning to rule out metastatic disease
- Definitive radiation therapy with curative intent
- Performance status <= 2
- Pacemaker
  - No critical dependence on pacemaker
  - Can turn off pacemaker during treatment
  - Cardiologists check before first treatment
  - Post-treatment pacemaker functioning check by cardiologists (weekly)
- No clear evidence of distant metastasis (stages 1-3)
- Evidence of significant dosimetric advantage judged by treating physician for proton therapy over IMRT

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Patient Selection

- Unresectable Stage II/III NSCLC (60-66 Gy[RBE]/33 fractions) and Esophagus Carcinoma
  - Respiratory motion amplitude < 10 mm
  - DIBH is needed if respiratory motion amplitude > 10 mm
- **Stage I NSCLC (SBRT, 48 Gy[RBE]/4 fractions or 50 Gy[RBE]/5fractions)**
- Re-irradiation(60 Gy[RBE]/30)

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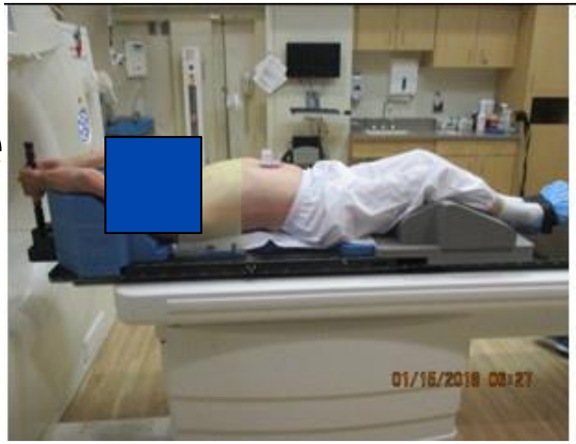
Patient Immobilization

- Orfit board + thermoplastic (free breathing)



Treatment Simulation

- 4D CT
- IGTV : an outline of the maximum intensity CT data (MIP)
- CTV: 8-mm isotropic expansion of the IGTV, edited clinically based on pattern of tumor spreading and anatomic boundaries such as vertebral body, chest wall and heart etc
- OTV: 5-mm (or 7-mm if 5mm plan robustness evaluation is used) expansion of CTV, used as the IMRT planning/evaluation and used as the proton plan evaluation (IGTV+13mm)
- STV: 7-mm expansion of OTV, edited clinically based on anatomic boundaries such as vertebral body, chest wall and heart etc.
- All normal structures are contoured on AVE CT
- CT artifacts are overridden by the nearby average HU

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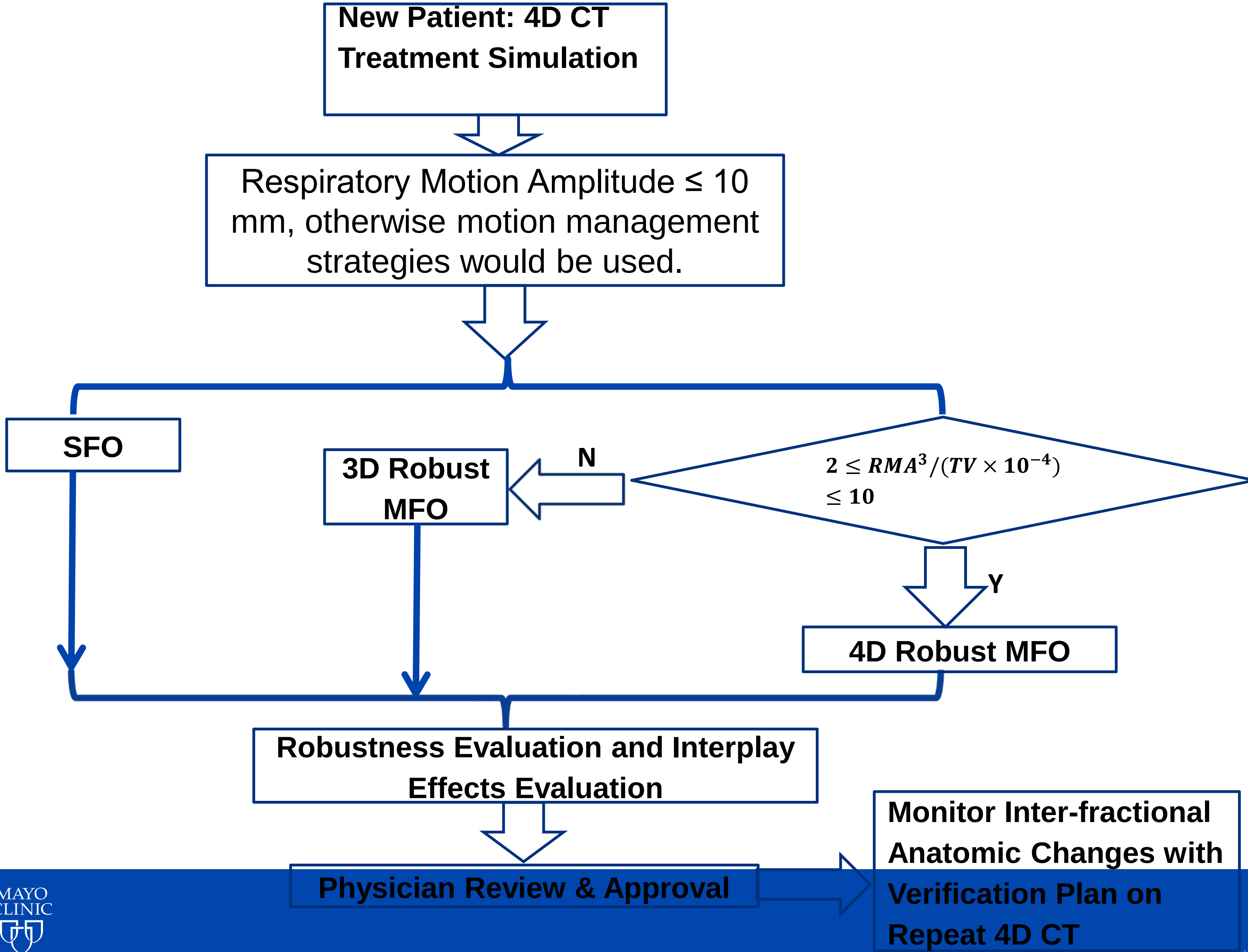
Treatment Planning

- SFO and robust MFO
- Start with VAC machine. ERS machine is used for shallow tumors.
- Usually 2-3 beams.
- The original plan is done on AVE CT with IGTV density override (HU=50 or maximum density according to Red Journal paper)
- Two verification plans are generated by recalculating the dose on T0 and T50. GTV_T50, CTV_T50 (by 8 mm expansion of GTV_T50) and GTV_T0, CTV_T0 (by 8 mm expansion of GTV_T0) are used for plan evaluation in these two verification plans.
- The original plan is adjusted until the verification and original plan dose distributions all meet the required prescription criteria including >95% CTV coverage and normal tissue dose volume constraints.

Motion Management

- If the respiratory motion amplitude is larger than 10 mm, some kind of motion management is needed:
  - DIBH (fiducial and fluoro to get the right breath hold)
  - Gating
- If the respiratory motion amplitude is between 5 mm and 10 mm, rescanning machine will be used (max MU limit = 0.01 MU).
- Evaluation of Interplay effects if the respiratory motion amplitude is larger than 5 mm.


New Patient: 4D CT Treatment Simulation
Respiratory Motion Amplitude ≤ 10 mm, otherwise motion management strategies would be used.
SFO
3D Robust MFO
N
$2 \le RMA^3/(TV \times 10^{-4}) \le 10$
Y
4D Robust MFO
Robustness Evaluation and Interplay Effects Evaluation
Physician Review & Approval
Monitor Inter-fractional Anatomic Changes with Verification Plan on Repeat 4D CT

Proton Plan Robustness Quantification
intra-field setup uncertainties are supported.

- Tools developed
  - Band of DVHs (Trofimov *et al.* 2010) ***(Eclipse)***
  - D95% of CTV in the worst case is larger than 95% of the prescription dose
    - Usually 5mm and 3% should be used for plan robustness evaluation if the tumor is in the middle of lung.
    - If the tumor is in the mediastinum area or attached to the chest wall, 3mm and 3% could be used.
    - Minor deviation: Difference of <5% between worst-case and nominal for CTV coverage
  - OAR meets the constraint in the worst-case dose
  - Plan robustness will be checked in all phases (T0, T50, and Ave).

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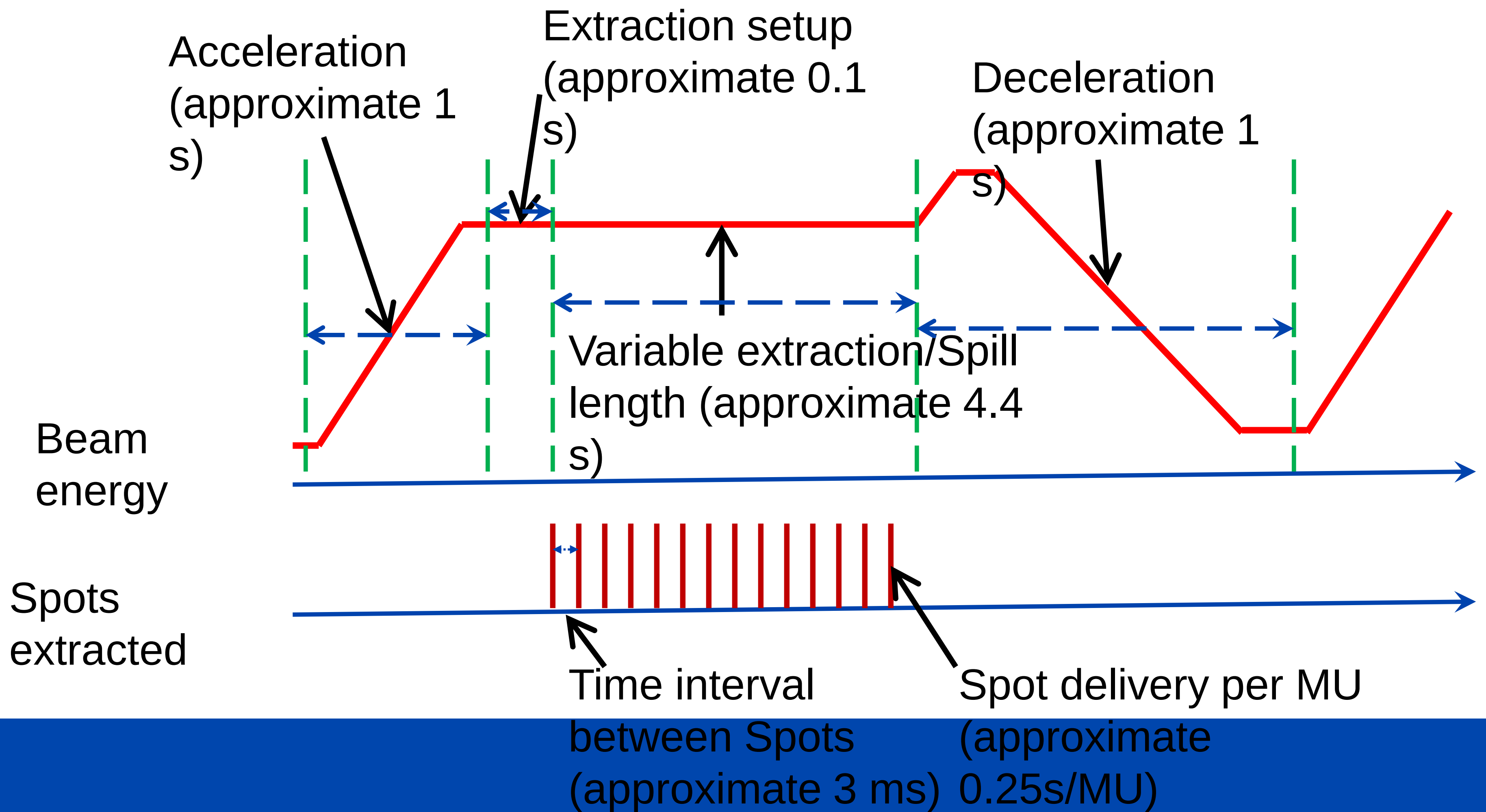
Evaluation of interplay effects (motion > 5mm)

Clinical Judgement Criteria:

- D95% of CTV is at least 95% of the prescription dose
  - ❑ Minor deviation: Difference between interplay effect and nominal for CTV < 5%



Adaptive re-Planning

- Repeated 4D CT simulation (weekly or after 2 to 3 weeks of treatment)
- Maintain target coverage (>95% for CTV) and avoid overdosing critical structures
- The original plan is calculated on the repeated 4D CT scans.
- Contours are deformed from the planning CT to repeated CT
- The treating physician review the new contours and dose-volume histograms.
- Plan robustness will be checked in all phases (T0, T50, and Ave) just as in the initial planning
- A new plan will be generated if needed and the same patient QA will be done before treatment

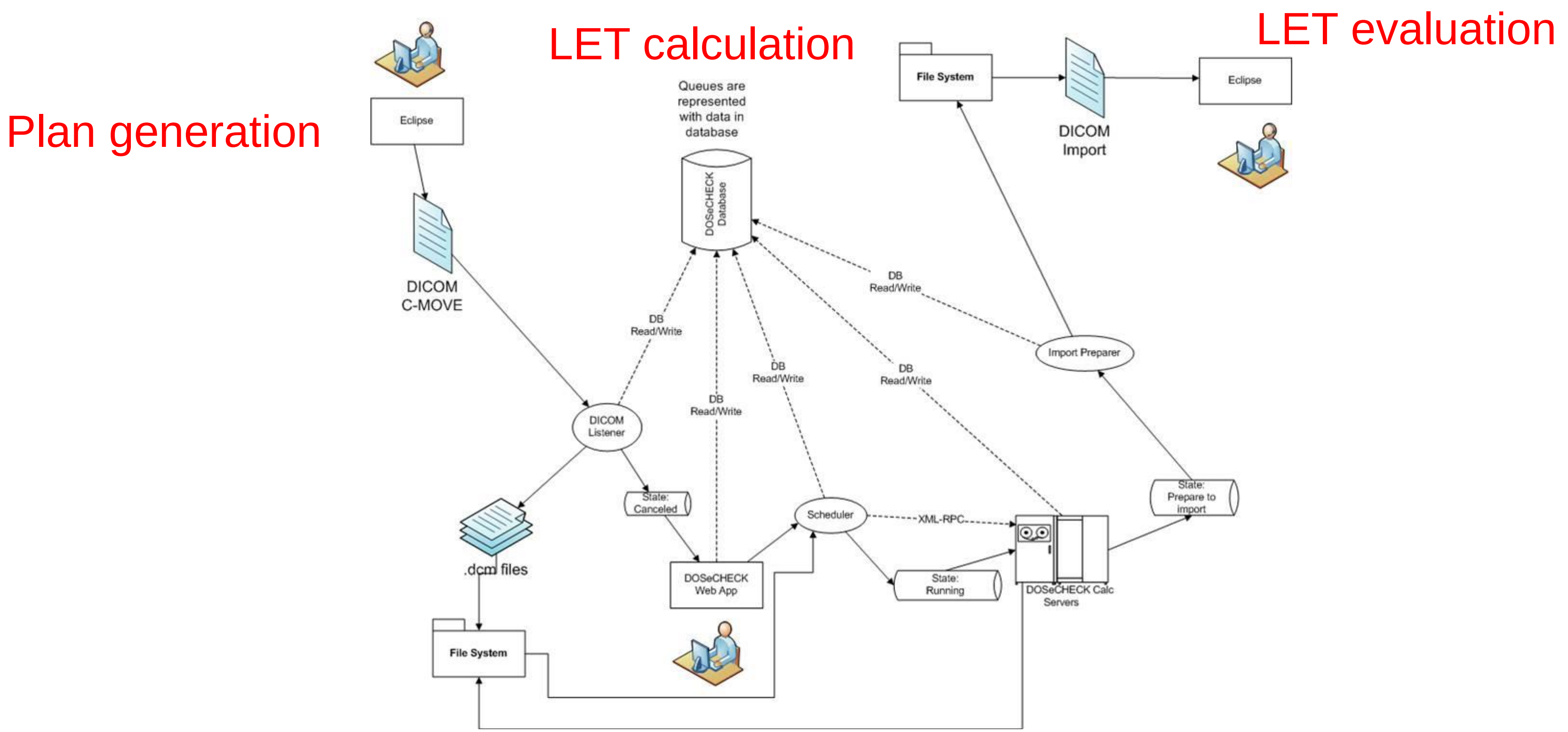
Second Dose Check

- In-House developed Semi-analytical and Monte Carlo 2nd dose calculation check:
  - Ballpark check:
    - Whether the difference of the mean dose of targets is within 3% and D95% is within 5% between Eclipse and 2nd check calculation

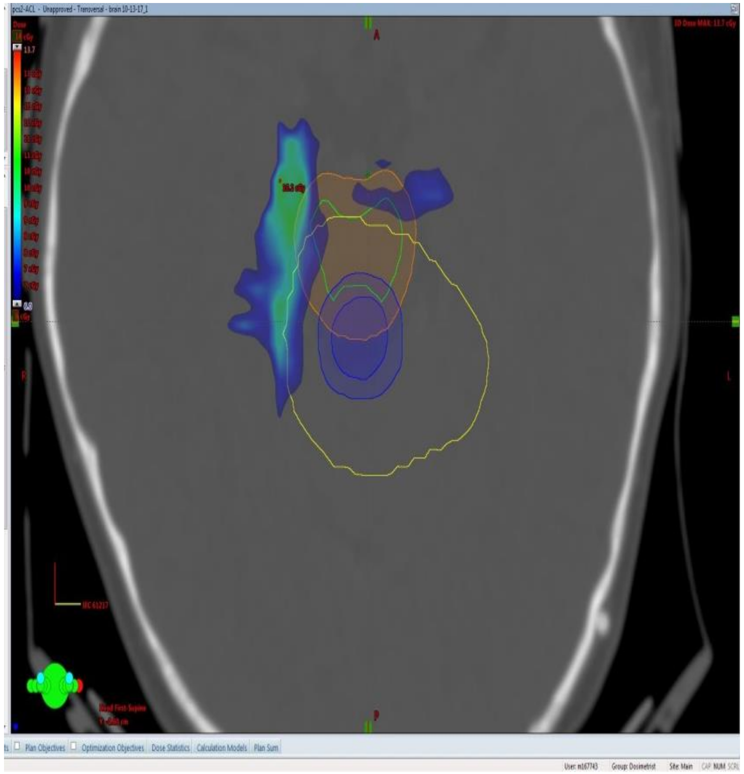
Use of LET at Mayo Clinic in Arizona

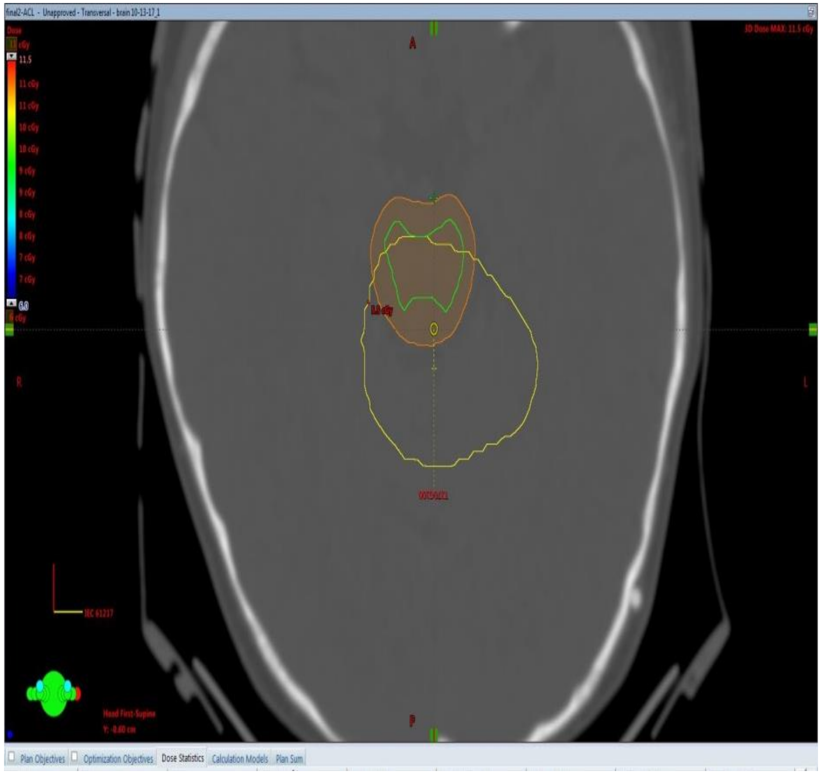
- Every patient receives an LET calculation
- LET distribution are imported into Varian Eclipse TPS for display purposes.
- A planning goal is to keep LET below 6 keV/μm within the high dose region of nearby critical organs.

Computational Environment



Initial plan LET distribution Final plan





Patient Quality Assurance

- 2D ion chamber matrix (digital phantom)
- The planned and measured 2D dose distributions are compared by using the gamma index with a passing requirement of at least 95% of the pixels satisfying 3% dose or 3-mm distance to agreement criteria.

