FDG-PET/CT Imaging Feedback
Tumor Response Assessment
Treatment Adaptation

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Main Subjects

1. Treatment tumor response assessed quantitatively using FDG PET/CT imaging feedback

2. Quantifying treatment objective with using tumor voxel dose response

3. Treatment planning optimization and delivery
FDG-PET/CT Imaging (?) for Tumor Response

- Tumor Metabolic Activity is most likely correlated to tumor cell Survival/Growth during the radiation treatment

- Therefore, change of metabolic image intensity (due to radiation dose) depends upon the tumor intrinsic radiosensitivities, proliferation, hypoxia, change of micro environment, etc.

- **PET**: $^{18}$F, $^{11}$C Glucose, Lactate, Glutamine, Glutamate

- **MRI**: Hyperpolarized [1-$^{13}$C] Pyruvate, Lactate, Glucose; APTw, Glu-CEST

*FDG-PET/CT is so far the most mature & popular modality to measure tumor metabolic activity!*
Adaptive Treatment Process:

- 2 feedback PET/CT images obtained within the 2\(^{nd}\) and 3\(^{rd}\) treatment weeks
- Utilizing deformable PET/CT image registration, the change ratios of tumor voxel SUV vs its pre-treatment baseline SUV are obtained and used to quantify tumor voxel response
Tumor Voxel SUV Change Ratio vs Radiation Dose

\[ \ln \left( \frac{SUV(d)}{SUV_0} \right) \]

Baseline SUV = 6

R-squared = 0.93

Baseline SUV = 8

R-squared = 0.94

Baseline SUV = 10

R-squared = 0.95

Baseline SUV = 12

R-squared = 0.94
Tumor voxel response matrix, $DRM = \exp(31.75xA)$, derived to have a similar numerical range as $SF_2$


- Tumor voxel SUV dynamics can be described using a linear random process with the slope $A$.
- The slope $A$ can then be estimated using the feedback images.
Figure 2  Cumulative frequency distribution of SF₂ values for head and neck tumours \((n = 88)\), carcinomas of the cervix \((n = 145)\), colorectal cancers \((n = 65)\) and lymphomas \((n = 8)\)

T Bjork-Eriksson, CML West, etc: "In vitro Radiosensitivity". BJR 1998, 77:2371-75
Relationship of Tumor Voxel $\text{SUV}_0$ & DRM vs Tumor Control
Tumor Voxel Control Probability (TVCP): Lookup Table

SUV_0 = 4.5

SUV_0 = 8.5

SUV_0 = 12.5

SUV_0 = 16.5

Effect of Dose Response Heterogeneity for Individual Tumors

TCP% of Individual Tumor (HPV-)

Dose (Gy of EQD2)
Effect of Heterogeneity in Individual Tumor
Target The Most Resistant Area
Dose: 115 95 80 70 60 54 Gy

Conv(Dash-line TCP = 0.25) vs DPbN (Solid TCP = 0.9)

CTV, GTV, R-parotid, L-parotid, Brainstem, Cord, Mandible
Tumor Response Guided Adaptive Treatment Process

Pre-treatment PET/CT → $SUV_0$ → DRM → $Rx$ → SRS or PRT Boost

Pre-treatment PET/CT

Treatment PET/CT
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