Patterns of Brain Tumor Recurrence Predicted From DTI Tractography

Anitha Priya Krishnan¹, Isaac Asher², Dave Fuller², Delphine Davis³, Paul Okunieff², Walter O’Dell¹,²

Department of Biomedical Engineering¹, Radiation Oncology² and Imaging Sciences³
University of Rochester Medical Center, Rochester, NY USA 14642
Stereotactic Radiotherapy (SRT)

- Radiation oncologists: 4 - 30mm isotropic margin for gliomas
  - Small margin: recurrences
  - Large margin: damage normal tissue

- Clinical observation
  - Recurrence often at the boundary of treatment margin

- Goal:
  - Develop appropriate anisotropic treatment margins using Diffusion Tensor Imaging (DTI)
Goal

- Qualitative correlation of paths of elevated water diffusion along white matter tracts from Tractography with recurrent site.
- Hypothesis: paths of elevated water diffusion along white matter tracts provide a preferred route for migration of cancer cells.
Migration Along WM Tracts

- Migration of cancer cells along WM tracts in Glioblastoma:
  - 1938 Scherer HJ.
  - 1961 Matsukado et al.
  - 1988 Burger et al.
  - 1989 Johnson et al.

- Correlate CT with topographic anatomy and postmortem MR imaging with neuropathologic findings

- Our approach: Correlate White matter tracts from DTI of each patient with recurrent site
DTI of Glioblastoma

- Scalars from DTI (Fractional Anisotropy and Apparent Diffusion Coefficient)
  - 2003 Price et al [1]
  - 2004 Hein et al [2]
  - 2005 Beppu et al [3]
- Vectors from DTI (principal Eigen vector)
  - 2004 Field et al [4]
Patient Selection

- **Category 1: distant recurrence**
  - Small island of recurrent tumor in the DTI dataset acceptable

- **Category 2: local recurrence**
  - close to (within 2 cm) or on the boundary of the treatment plan
  - No sign of recurrence in the DTI dataset
Image Acquisition

- GE signa 1.5T MRI scanner
- EPI sequence, 20 axial slices, voxel dimensions 0.976×0.976×6 mm
- 25 diffusion gradient directions, $b = 1000$, 3 reference ($b = 0$) scans
DTI Analysis

- Tractography: DTIStudio and FSL (FMRIB's software library)
- DTIStudio [5]: Fiber Assignment by Continuous Tracking (FACT)
DTI Analysis

FSL [6]:
- Probabilistic fiber tracking
- Calculates uncertainty in the fiber direction
- Can track fibers in gray matter

Fiber probability maps for seed point in optic tract
Yellow – high probability, Red – moderate relative probability
Results: Category 1 (n = 3)

- Primary GBM
- Spot on left horn not treated
- Fiber tracts passing through:
  - Primary tumor
  - Recurrent site
- Tumor growth
Results: Category 1
Results: Category 2 (n = 4)

- Pretreatment MR T1
  - Primary Glioma
  - Yellow – High probability. Red – Medium relative probability of connection

- SRS treatment plan

- Fiber Map from FSL

- Recurrence tumor

- Post contrast Axial MR T1 3 months after SRS
Results: Category 2

Pretreatment MR T1

SRS treatment plan

Fibers from primary

Recurrence tumor

Post contrast Axial MR T1 3 months after SRS
Results: Category 2
Conclusions & Future Work

- Preliminary results on a small number of patient datasets suggest that the hypothesis is correct.

- Future Work
  - High resolution DTI dataset using 3T MR
  - Improved Fiber analysis
  - Verification with animal models
References


