



RadioOnkologie und Strahlentherapie
Fakultät für Medizin
Technische Universität München

IRM.
HelmholtzZentrum münchen

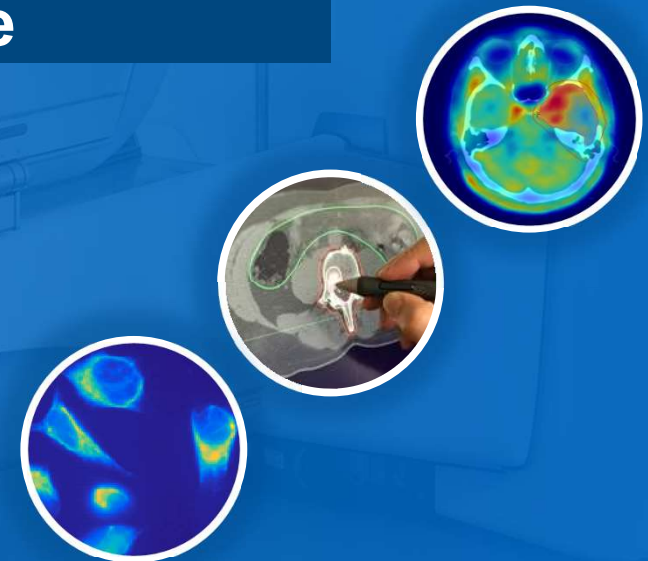


TUM

Imaging-based Clinical Decision Support Systems in Radiation Oncology - The potential role of Artificial Intelligence

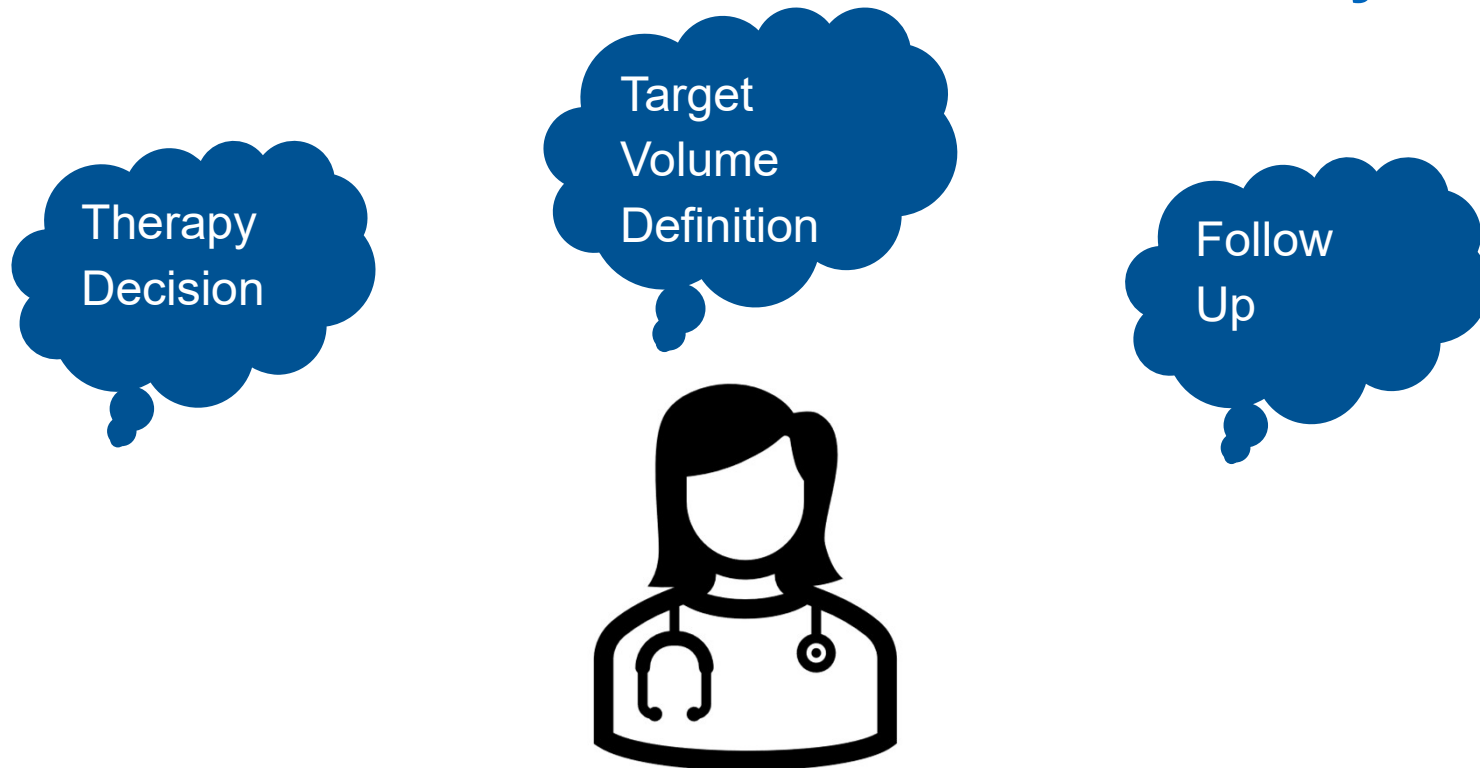
PD Dr. med. Jan C. Peeken

Technische Universität München
Fakultät für Medizin
Klinik für RadioOnkologie und Strahlentherapie
Institut für Strahlenmedizin (IRM)

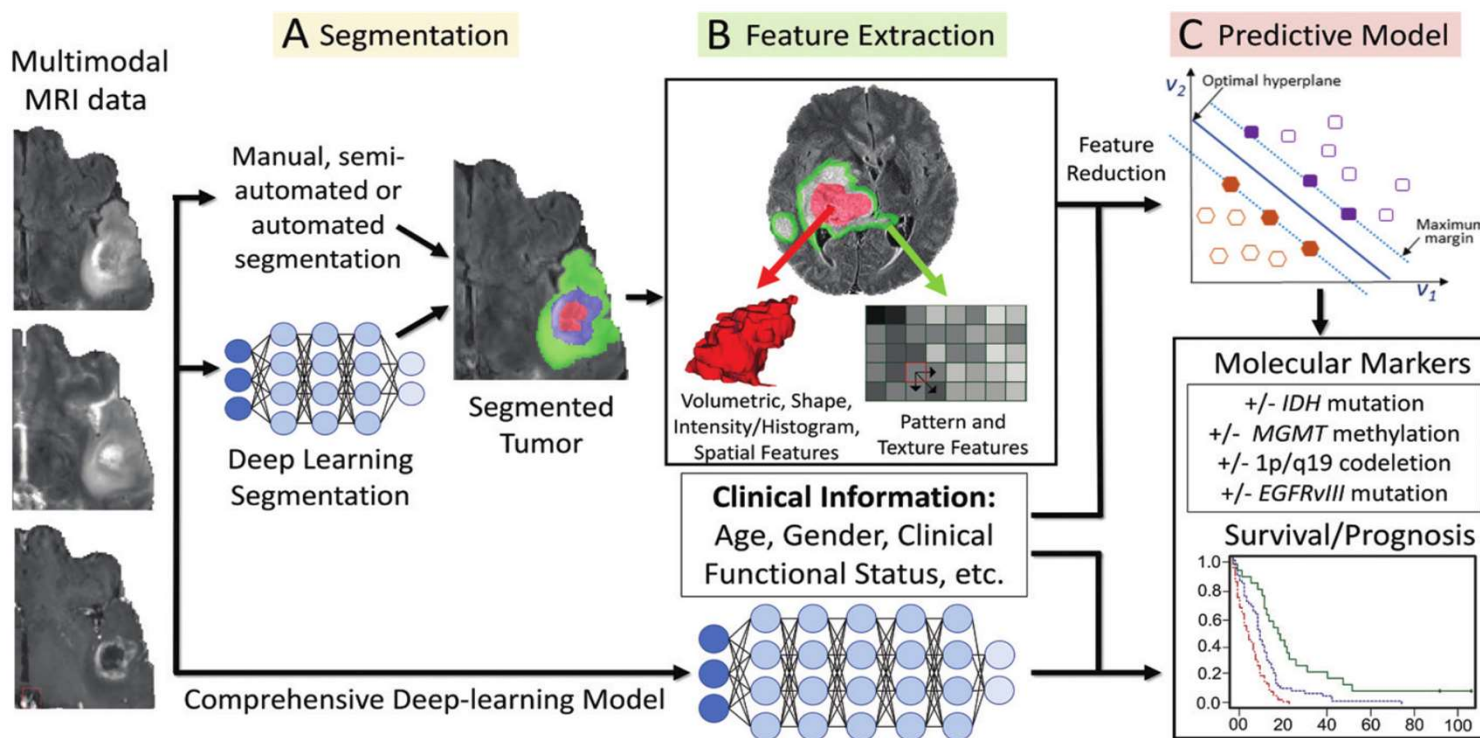




Clinical Decisions in Radiation Oncology

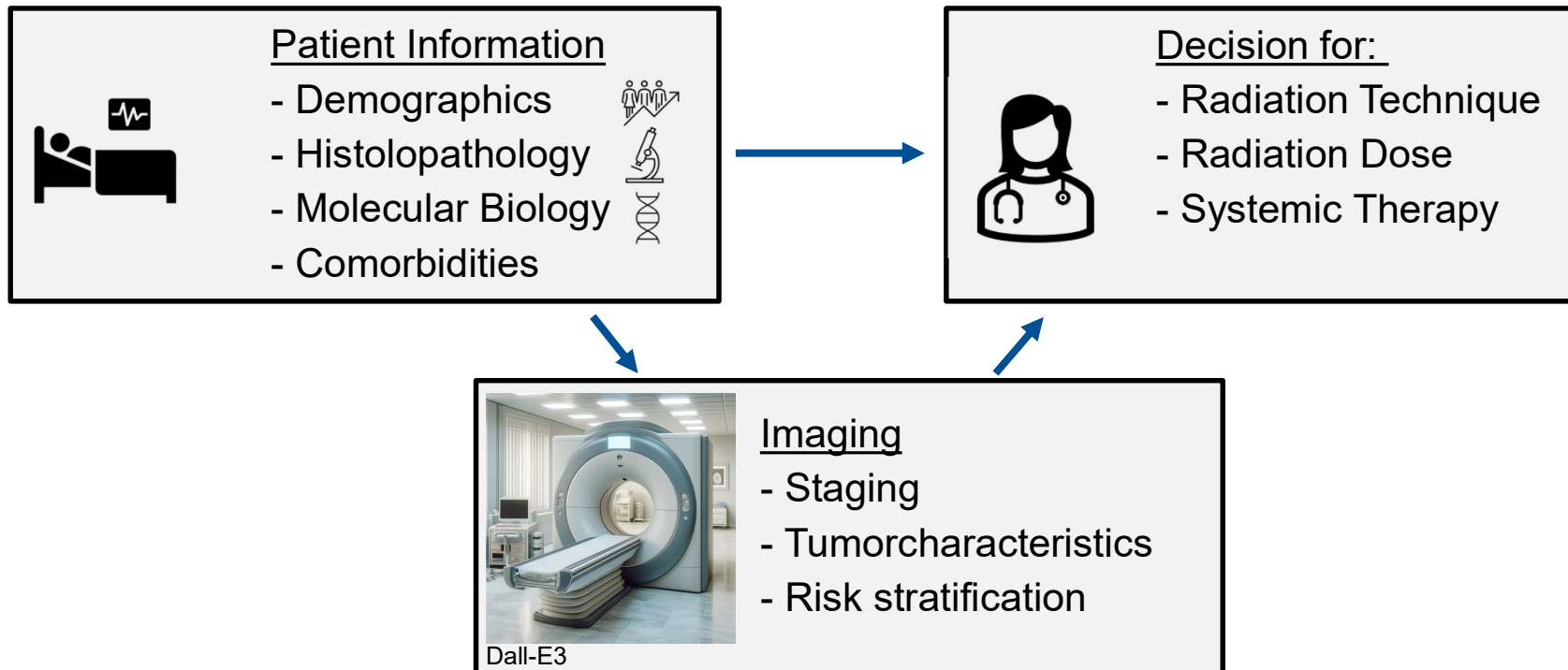


AI-based Image Analysis





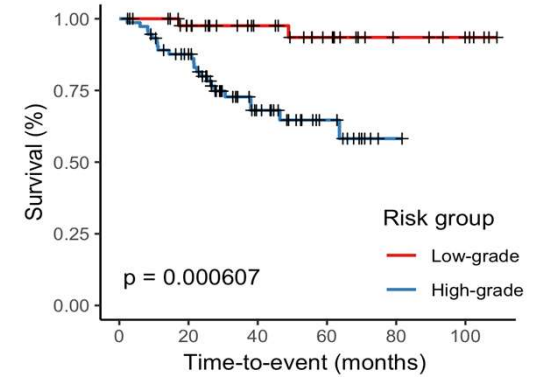
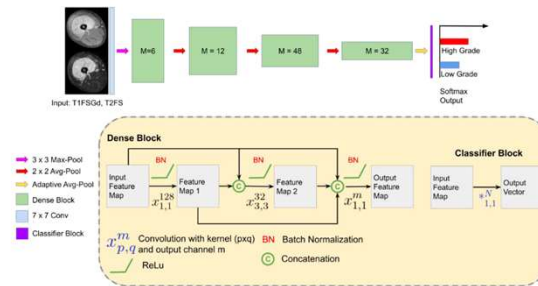
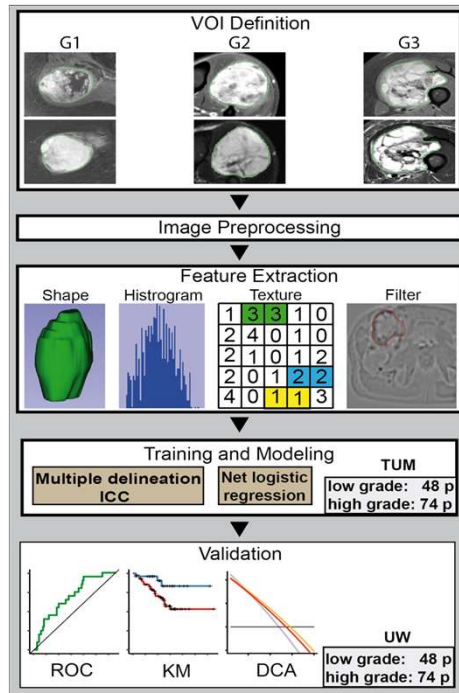
Therapy Decision





Therapy Decision

Tumor Characterization – Prediction of Tumor Grading



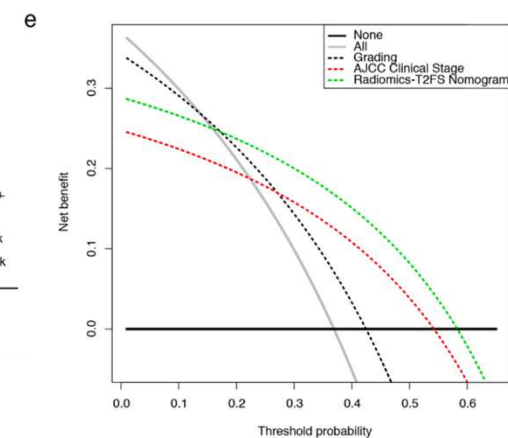
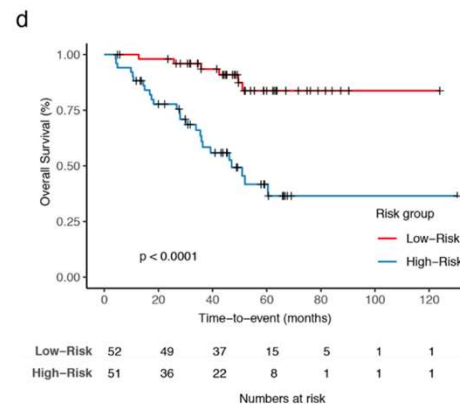
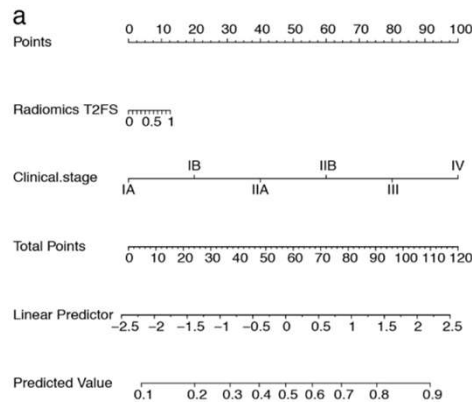
| | T2 Radiomics | T2 DenseNet |
|------------|--------------|-------------|
| AUC | 0.78 | 0.76 |



Therapy Decision

Tumor Characterization for Risk Assessment

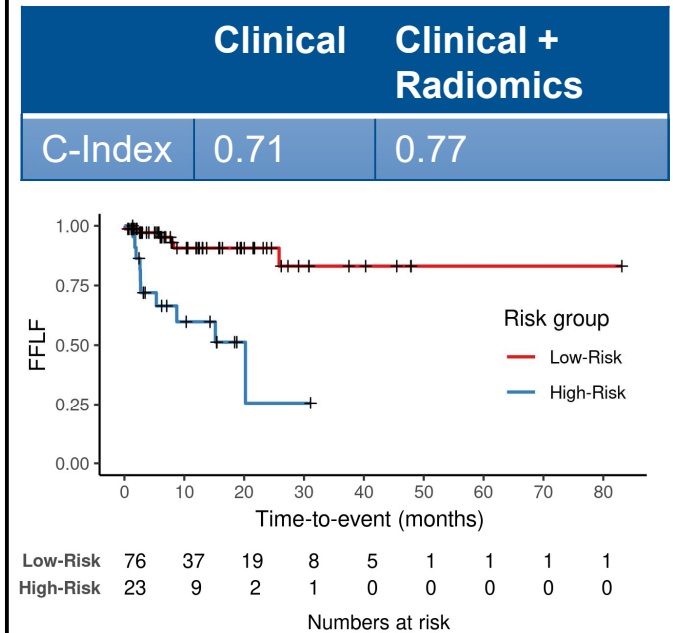
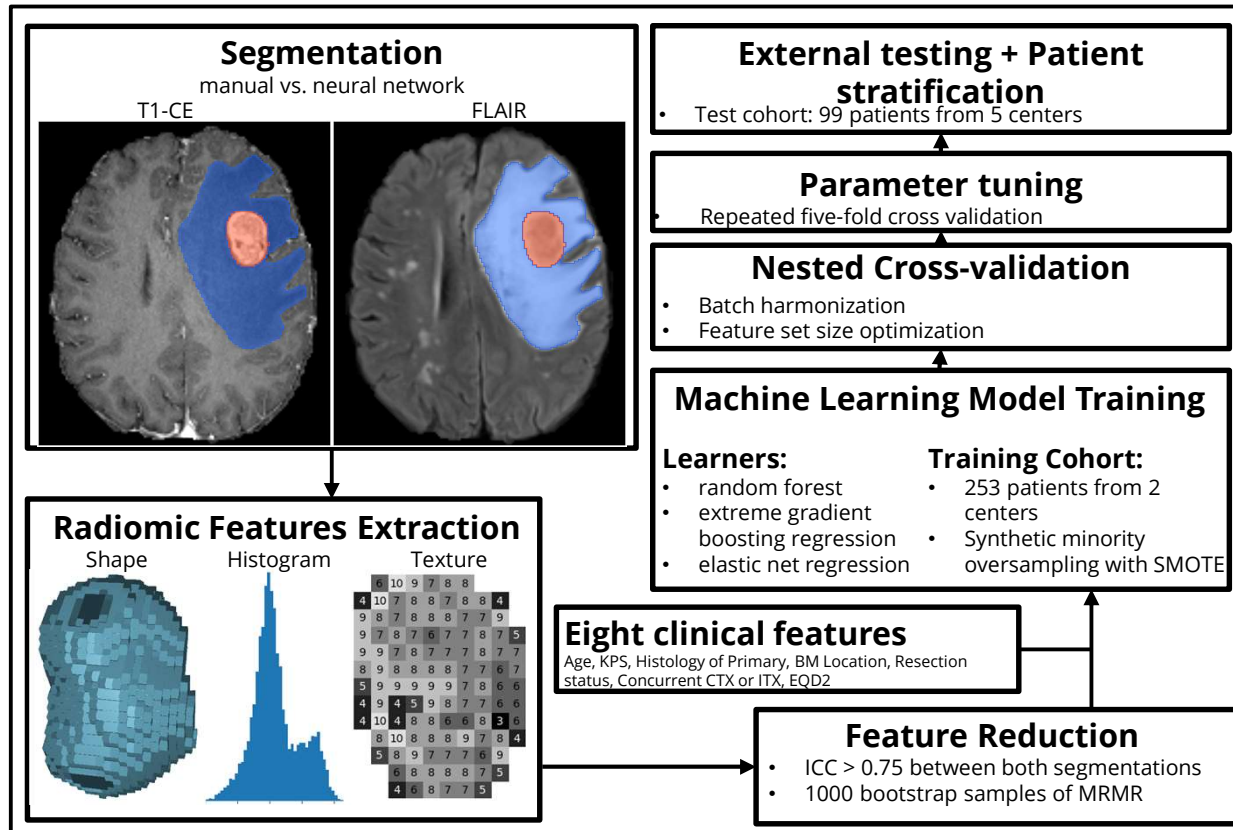
| | Concordance index (95%CI) |
|---------------------|---------------------------|
| AJCC | 0.69 (0.60-0.78) |
| AJCC+Radiomics-T2FS | 0.74 (0.64-0.84) |



Peeken et al. EBiomedicine 2019

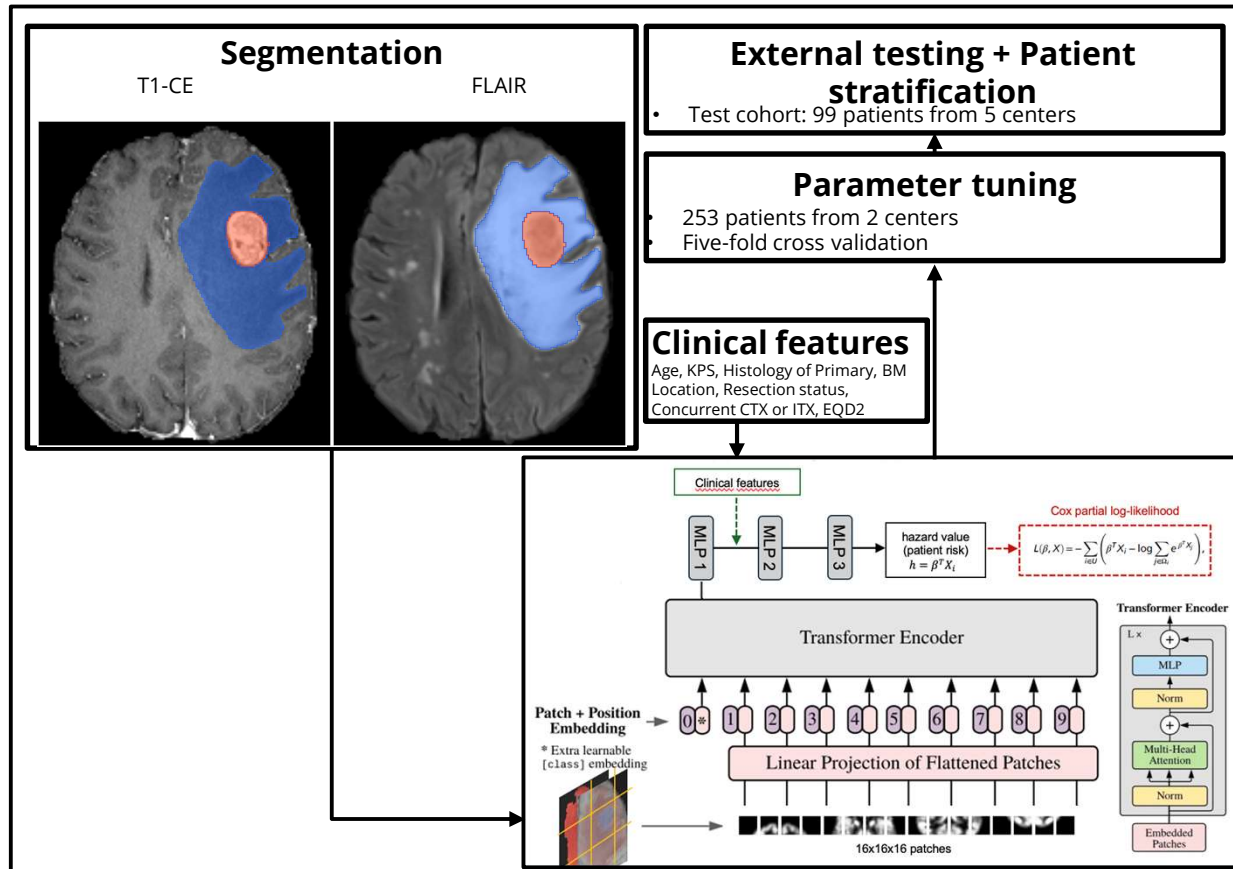


Risk Assessment for Local Failure

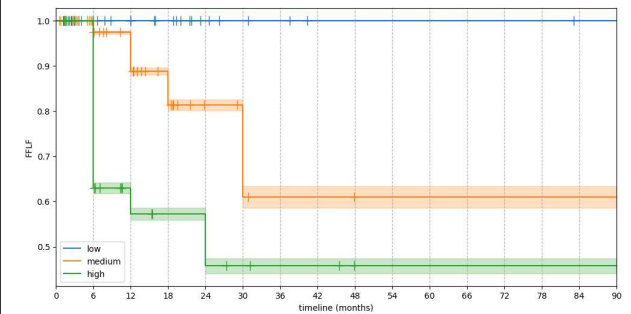




Radiomics-based Prediction of Local Control



| | Clinical + Radiomics | Vision Transformer |
|---------|----------------------|--------------------|
| C-Index | 0.77 | 0.80 |

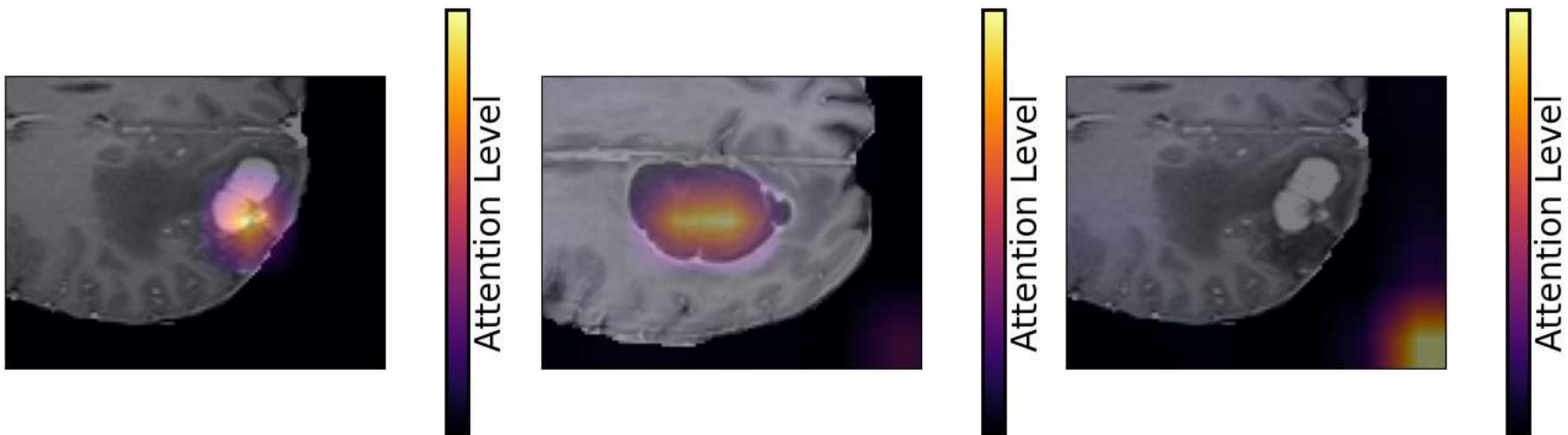


DEGR
AURORA Trial

Manuscript in preparation



AI Explainability?



- Technique: Beyond Attention: layer-wise relevance propagation of all attention heads
- Good overlap of attention and metastases in many cases
- However large attention artifacts across all patients



Target Volume Definition

- Tumor Detection

→ GTV Definition

- Microscopic Tumor Spread Estimation

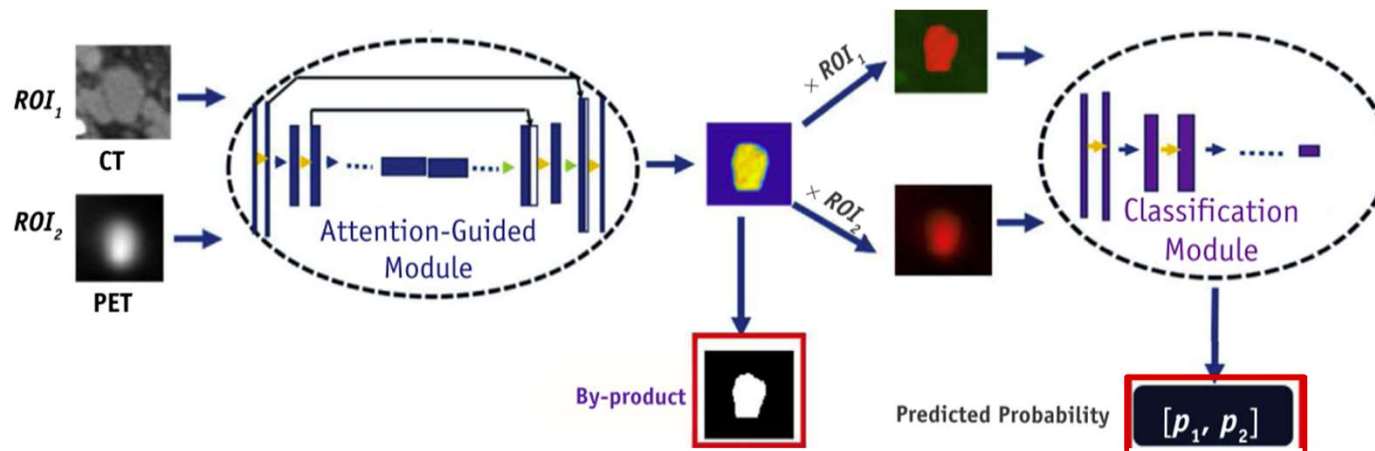
→ CTV Definition



Target Volume Definition Tumor Detection



Forner 2018



Patient cohort
N = 129 patients
N+: 120
N0: 671

| Accuracy | Sensitivity | Specificity | AUC |
|----------|-------------|-------------|------|
| 0.92 | 0.91 | 0.93 | 0.98 |



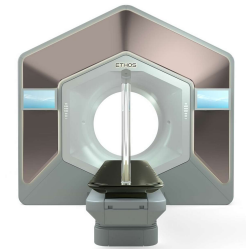
The DARTBOARD trial

Phase-II Trial, n = 50 Patients

Intervention: Daily Adaptive (1mm PTV margin) vs IGRT (5mm PTV margin)

Target Concept: Involved Node Radiotherapy:

- Primary Tumor: 70 Gy
- Suspicious Nodes (PET/CT) : 63 Gy
- Nodes on Same level **or detected by AI algorithm**: 56 Gy



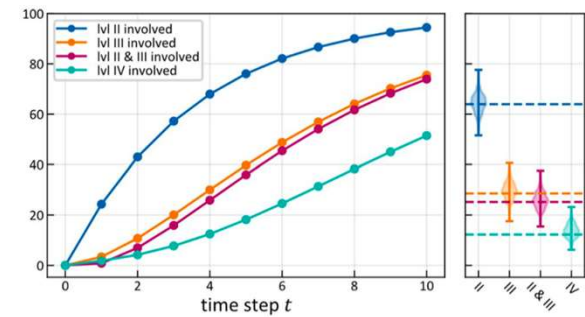
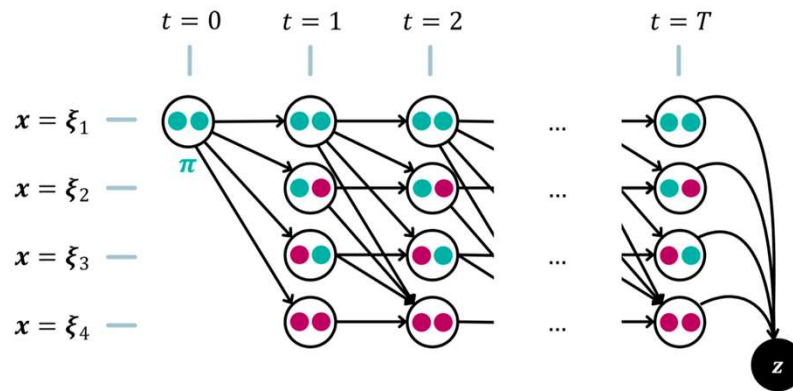
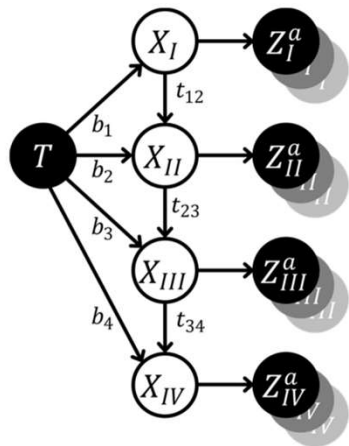
Preliminary Results:

Adaptive vs. IGRT

- Adaptive RT: sign. lower doses in Parotid ipsilateral and submandibular bilateral
- Adaptive RT: Toxicity only G2+ Dermatitis significant lower

Target Volume Definition Microscopic Tumor Spread

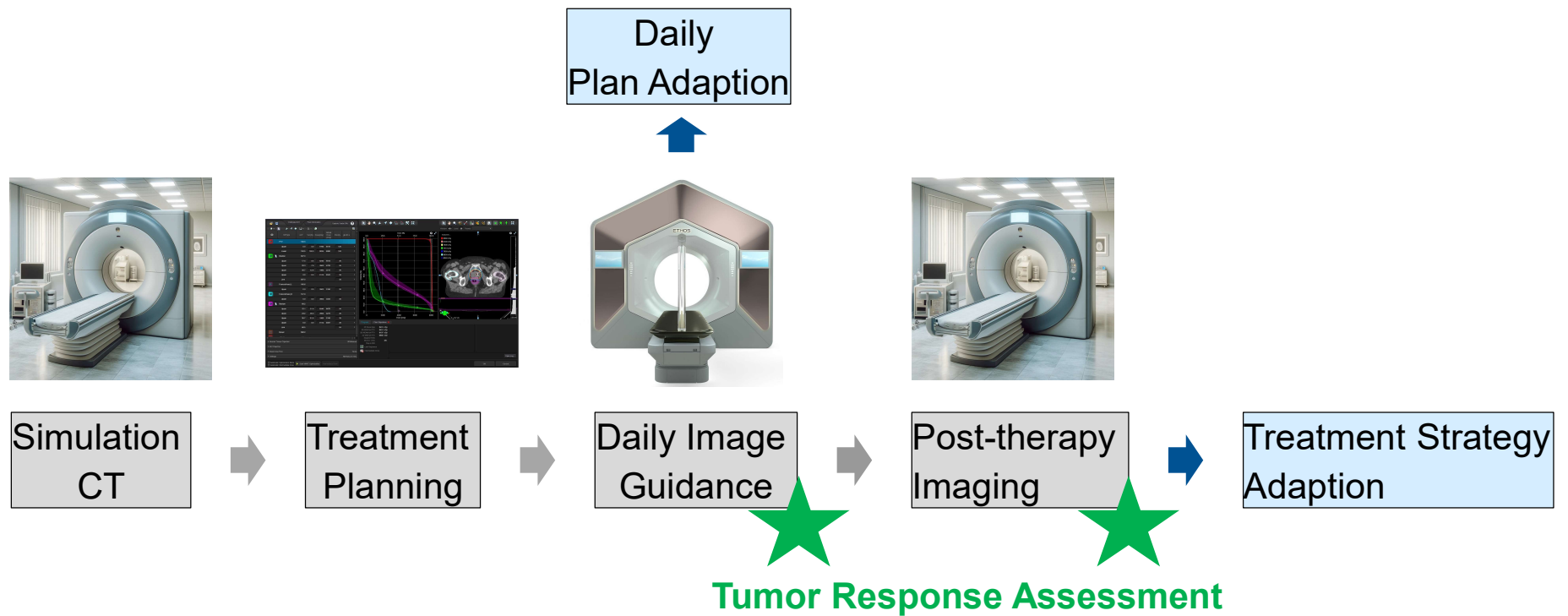
- Probabilistic risk modeling of lymphatic spread in head and neck cancers
- Hidden Markov Model with Markov chain Monte Carlo for Learning of the transition probabilities



Ludwig et al. Scientific Reports 2021

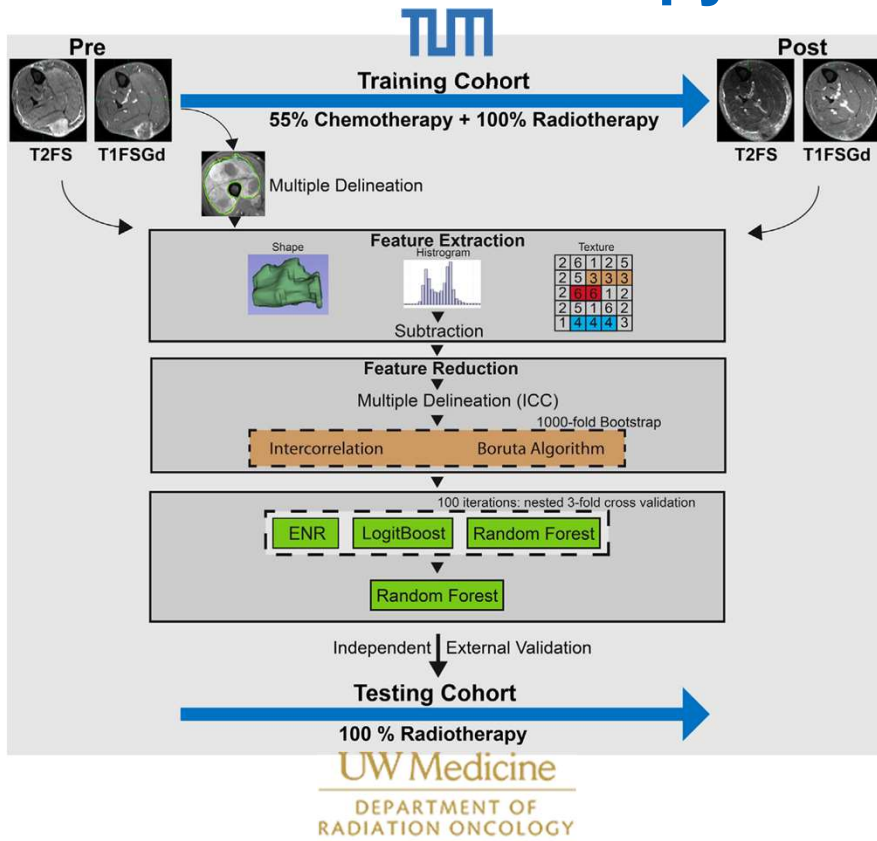


Adaptive Radiotherapy





Therapy Response Prediction



External Validation:

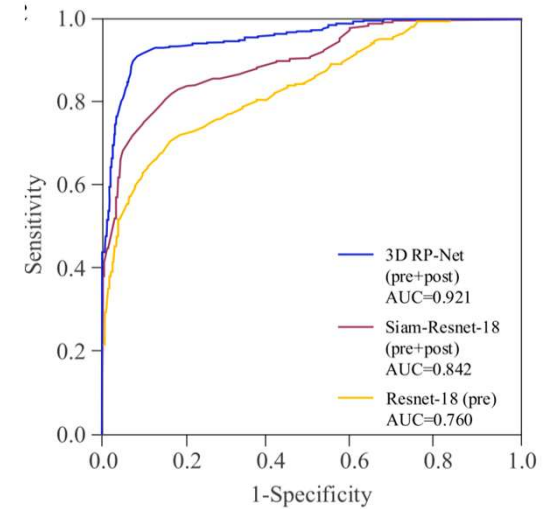
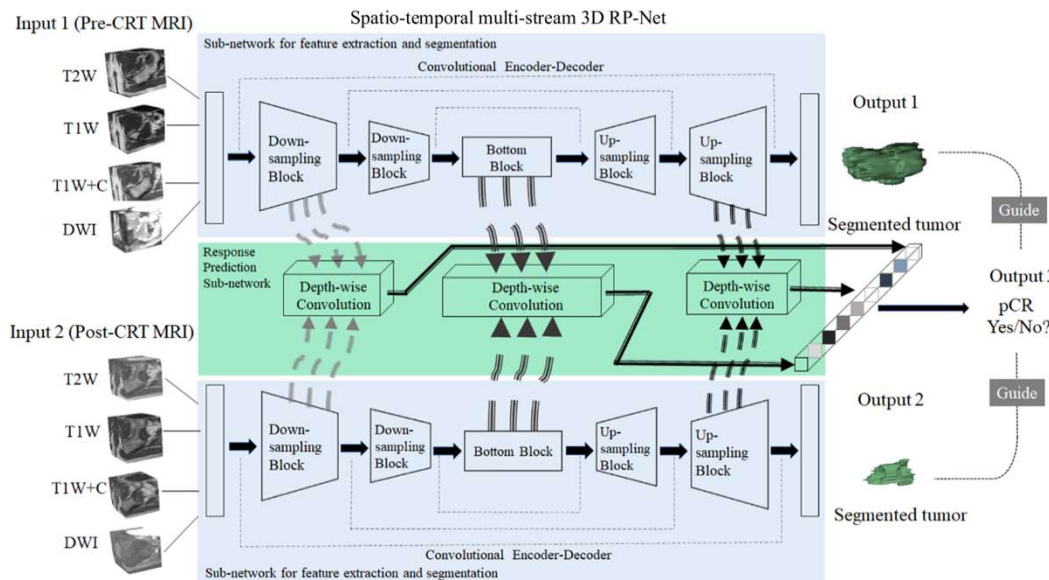
| | AUC Pathologic Complete Remission |
|------------------------|---|
| AJCC | 0.51 (0.25 – 0.75) |
| RECIST | 0.60 (0.33 – 0.86) |
| Volume | 0.70 (0.48 – 0.90) |
| Delta-Radiomics | 0.75 (0.56 – 0.93) |



Therapy Response Prediction

Train:
327 patients

Test:
141 patients



| Cohort | AUC | Sensitivity | Specificity | PPV | NPV |
|---------------------|------|-------------|-------------|-------|-------|
| External validation | 0.92 | 90.7% | 92.0% | 83.0% | 95.7% |



Patient Follow Up

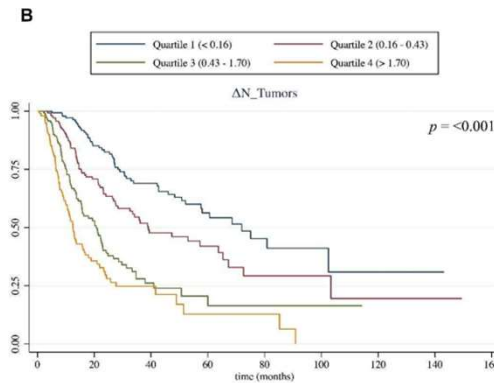
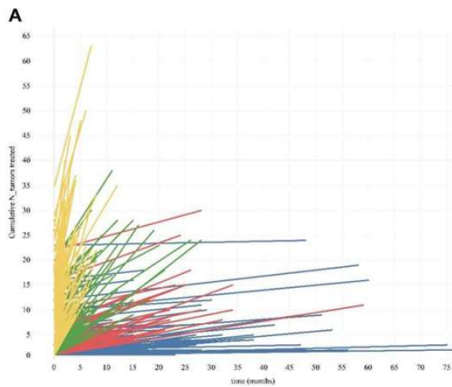
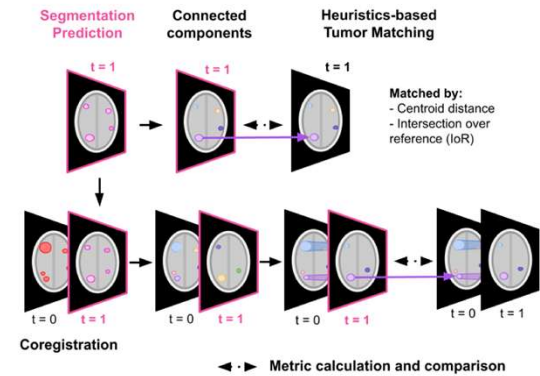
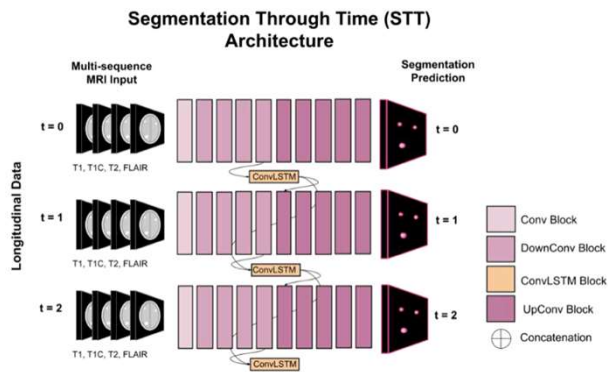
- Follow Up Schedules
- Tumor Recurrence Detection





Follow- UP Imaging

- 907 patients
- Gammaknife-Radiosurgery

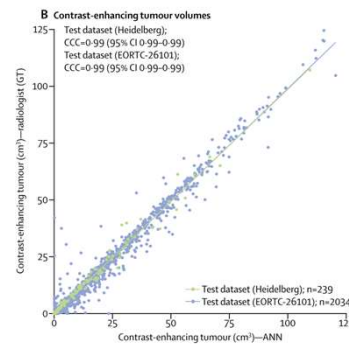
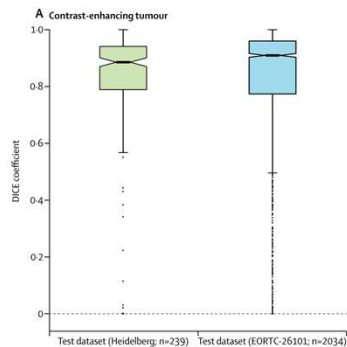
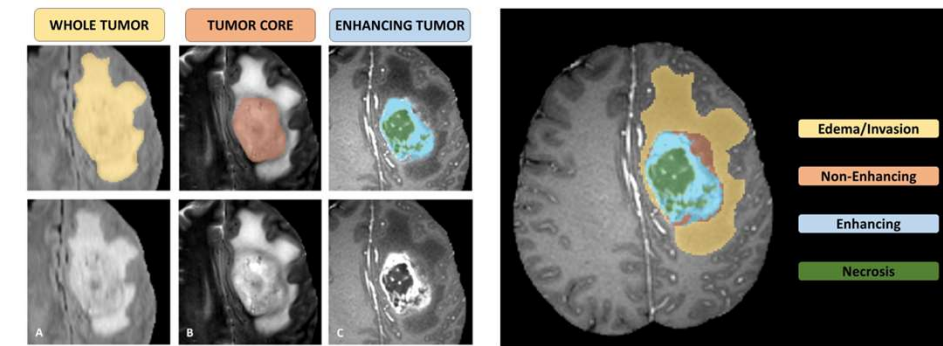


Multivariate Cox Regression

| | HR (95% CI) |
|--|------------------------------|
| Change of number of Metastases / Month | 1.3 (1.2 - 1.4), $p < 0.001$ |
| Histology Breastcarcinoma | 0.6 (0.4 - 0.9), $p = 0.02$ |
| Histology Gastro-Intestinal | 2.6 (0.4 - 3), $p = 0.01$ |



Follow Up Diagnostics



| | Point estimate | Z value | p value |
|------------------------------------|---------------------|---------|---------|
| Quantitative ANN assessment | | | |
| Time to progression* | HR 2.59 (1.86-3.60) | 5.64 | <0.0001 |
| Treatment regimen† | HR 1.14 (0.87-1.47) | 0.95 | 0.34 |
| c-index of the model | 0.62 (0.59-0.66) | .. | .. |
| Central RANO assessment | | | |
| Time to progression* | HR 2.07 (1.46-2.92) | 4.12 | <0.0001 |
| Treatment regimen† | HR 1.14 (0.87-1.47) | 0.95 | 0.34 |
| c-index of the model | 0.57 (0.54-0.61) | .. | .. |

ANN=artificial neural network. HR=hazard ratio. RANO=Response Assessment in Neuro-Oncology. Z value is the ratio of each regression coefficient to its SE. 95% CIs are shown in parentheses where appropriate. *Time to progression is included as a time-dependent covariate. †Included as binary covariate (initial treatment containing bevacizumab vs no bevacizumab).

Table 3: Cox proportional hazards regression models for overall survival with time to progression in the EORTC-26101 test dataset by assessment method



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Thank you for your attention

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