A comprehensive evaluation of intracranial SRS treatment accuracy

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INTRODUCTION
In stereotactic radiosurgery (SRS) of intracranial lesions, high plan quality and accurate dose delivery are imperative. In clinical practice various SRS dose prescriptions, treatment techniques and different QA programs are used. This study provides a comprehensive overview of our geometric accuracy of frameless, linac-based intracranial SRS treatments. To our knowledge, this is the first study that presents an overview of MRI/CT-to-RT treatment accuracies in such detail, combining regular QA data with clinical data, for a specific treatment.

PURPOSE
1. To comprehensively evaluate and further improve frameless, linac-based intracranial SRS treatment accuracy at our institute
2. To provide detailed reference material regarding realistic machine and treatment accuracies to supplement the more coarsely defined tolerance limits available in guidelines

MATERIAL & METHODS
INTRACRANIAL SRS TREATMENT CHAIN
Figure 1 displays our frameless, linac-based intracranial SRS chain.

COMPREHENSIVE EVALUATION
• Review of protocols: imaging, treatment planning, setup, and QA protocols
• Measurements: e.g.: small fields (≤3cm³) and compared data with TPS beam fit, MRI-QA and table rotation inaccuracy measurements, kV-MV isocenter measurements, leaf/jaw position accuracy measurements
• Patient setup data
• Image registration data

RESULTS 1: SRS treatment accuracy at our institute

ORDER OF MAGNITUDE
≤ 1mm
• MR distortion
• MR-CT registration
• Small field dosimetry
• Dose grid (≤)
• Table movement
• QA machine
• Table rotation (≤ 1/10°)

≤ 0.03mm; 0.5 ≤ 0.15mm
• MR-CT translation error
• Water/Epidual translation error
• CBCT-CT translation error
• Image registration accuracy

≤ 1mm
• Table rotation (≤)
• Prescription
• MR-CT translation inaccuracy measurements

≤ 1/10mm
• Table rotation inaccuracy measurements
• Beam-on accuracy small fields (≤5mm)
• MR-CT translation error

GENERAL DEVELOPMENTS
• Radiation data registration
• Data transfer

RESULTS 2: reference material regarding realistic machine and treatment accuracies

- realistic treatment accuracies
- Supplement to guideline tolerances
- Enabling comparison and cross-fertilization between techniques and institutes

WORK IN PROGRESS
Currently, several improvements and investigations are ongoing with respect to the geometric accuracy of specific chain elements (see poster). An end-to-end test is being developed to further define and improve our overall SRS treatment accuracy. The chain element as well as end-to-end accuracy will be evaluated analogously for other stereotactic sites. In parallel to this work on the physics aspects of stereotactic treatment, clinical protocols are being evaluated to harmonize developments over sites and to anticipate new developments in stereotactic treatments.

Supplement to guideline tolerances
Items for further investigation

Figure 1. The intracranial SRS treatment chain elements:
• Prescription: 1x 24Gy or 1x 18Gy
• Immobilisation: hybrid thermoplastic mask
• Imaging/volume definition: CT, MRI, CT/MR registration, GVT defined on MRI
• Treatment planning: noncoplanar, dual-arc VMAT (table 0° and ±90°)
• Patient setup: extensive online GVT protocol (CBCT after each table correction and post-RT)
• Treatment verification: monitoring: EPID dosemetry post-RT and in vivo, and CBCT post-RT

Table 1. Precision of the separate elements in our intracranial SRS chain. '*'opposed with whether the uncertainty results in a shift or bias of the delivered dose distribution. \( R_{\%} \) is the radius including 95% of the measured points. Note that the summed value of these separate inaccuracies probably overestimates the total uncertainty in treatment delivery.