

were quantified. Hippocampal volumes were retrospectively delineated and dosimetry was evaluated in patients treated with upfront SRS. RESULTS: 143 patients with a total of 2198 lesions met criteria for inclusion with 75 patients treated with upfront SRS and 68 treated as salvage from prior WBRT. Median age was 57 (IQR: 46–65) and median KPS 80 (IQR: 70–90). Histologies included breast (n=52), lung (n=49), melanoma (n=30), and other (n=12). Median number of lesions per patient was 13 (IQR 11–17) with median total volume of treatment of 4.1 cc (IQR 2.0–9.9). 12-month FFP per lesion for upfront and salvage treatment was 96.8% (95% CI: 95.5–98.1) and 83.6% (95% CI: 79.9–87.5) respectively ($p < 0.001$). 12-month FFNM for upfront and salvage FFSRS was 18.8% (95% CI: 10.9–32.3) versus 19.2% (95% CI: 9.7–37.8) respectively ($p = 0.90$). Mean hippocampal dose was 150 cGy (IQR 100–202). Symptomatic ARE was observed in 2% of patients or 1% of treated lesions. CONCLUSIONS: High rates of local control can be achieved when treating patients with greater than 10 BM with hippocampal doses that are dramatically lower than for HS-WBRT. Hippocampal sparing is readily achievable with expected rates of new metastatic lesions developing in treated patients with low rates of symptomatic ARE.

RADI-22. CHARACTERIZING CLINICAL SURVIVAL PATTERNS USING MACHINE LEARNING: AN ANALYSIS OF BRAIN METASTASIS PATIENTS TREATED WITH STEREOTACTIC RADIOSURGERY

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INTRODUCTION: Increased sophistication in machine-learning algorithms and artificial intelligence have begun to unveil patterns that would be otherwise unappreciated in clinical medicine. Here we applied one such algorithm, Iterative Factorial Analysis of Mixed Data (IFAMD), to better understanding combinations of clinical variables that influence clinical survival of brain metastasis (BM) patients treated with stereotactic radiosurgery (SRS). **METHODS:** A dataset of 6,326 BM patients was collated from four SRS centers (University of California, San Diego, Katsuta Hospital Mito Gamma House, Tsukiji Neurological Clinic, and Melanoma Institute of Australia). IFAMD was applied to the analysis of the following clinical variables: age, Karnofsky Performance Status (KPS), cumulative intracranial tumor volume (CITV), total number of metastases, histology (breast, gastrointestinal (GI) cancer, renal cell carcinoma (RCC), melanoma, and lung cancer), systemic disease control, and survival in months. **RESULTS:** Our machine learning algorithm defined three groups of patients who exhibited differential survival. The group who is most likely to die within 3 months of SRS included patients with lower KPS, poor systemic disease control, higher CITV, higher number of metastasis, and who carried a diagnosis of GI cancer. Patients who are most likely to survive beyond twelve months of SRS fall into two distinct categories. The first consisted of subsets of lung and breast cancer patients with higher KPS, controlled systemic disease, and lower CITV. The second consisted of young breast cancer patients with systemic disease control, independent of KPS, CITV, and the number of metastases. **CONCLUSION:** Clinical survival after SRS for BM is defined by combinations of known prognostic factors. A prognostic factor critical for survival prognosis in one sub-population of BM patients may bear little relevance in another patient sub-population.

RADI-23. CLINICAL RISK ASSESSMENT SCORE TO ESTIMATE THE LIKELIHOOD OF PSEUDOPROGRESSION VERSUS TUMOR RECURRENCE FOLLOWING STEREOTACTIC RADIOSURGERY FOR BRAIN METASTASES

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OBJECTIVE: A major challenge in the follow-up of patients managed with stereotactic radiosurgery (SRS) for brain metastases (BM) is to differentiate pseudoprogression (PP) from tumor recurrence (TR). A clinical score based on tumor and treatment related factors would be valuable when selecting appropriate treatment. **MATERIAL AND METHODS:** Follow-up images of 97 consecutive patients treated with SRS for 406 BM were analyzed. Of these 100 (24.6 %) BM in 48 (49.5 %) patients responded either with TR (delayed growth; 53 (13.1 %) BM) or PP (temporary volume increase; 47 (11.6 %) BM). Differences between the 2 groups were analyzed and used to develop a PP risk assessment score (PP-RAS). **RESULTS:** Significant factors associated with a higher incidence of PP versus TR were: primary lung cancer vs. other primaries, BM volume ≤ 2 cc (or BM ≤ 1.5 cm in diameter), Target cover ratio > 98 % and prior radiation SRS or WBRT. Based on the presence (0) or not (1) of these 5 parameters, a risk assessment

score for PP versus TR was established. A PP-RAS score of 0 corresponds with high likelihood of PP vs. TR, whereas a score of 5 corresponds with a high risk of TR. A score of ≤ 1 point was associated with 100 % PP, 2 points with 57 % PP and 43 % TR, 3 points with 57 % TR and 43 % PP, whereas ≥ 4 points were associated with 84 % TR and 16 % PP, $\pi=24.57$, $df=4$, $p < 0.001$). **CONCLUSION:** Based on these 5 parameters at the time of SRS our risk assessment score could robustly differentiate between PP versus growth following SRS. The score is user-friendly and may be a useful tool to guide the decision making whether to retreat or observe at appropriate follow-up intervals.

RADI-24. VENTRICULOMEGALY AFTER STEREOTACTIC RADIOSURGERY (SRS) FOR BRAIN METASTASES (BM): A PILOT ANALYSIS OF TWO INSTITUTIONAL EXPERIENCES

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INTRODUCTION: Ventriculomegaly, or dilatation of the cerebrospinal fluid (CSF) space, occurs after whole-brain radiation (WBRT) of brain metastasis (BM) patients due to either 1) hydrocephalus or 2) cerebral atrophy from radiation-induced white matter injury. In this study, we examined whether cumulative radiation from repeat stereotactic radiosurgery (SRS) increases the risk of ventriculomegaly. **METHODS:** Patients were included if they underwent SRS of BM from 2007–2017 and had imaging follow-up. We examined a cohort of 214 patients treated at the University of California San Diego (1,106 BM) and a second cohort of 148 patients (1,760 BM) treated at Karolinska Institutet. Ventriculomegaly was defined according to established morphometric criteria. Patients were grouped according to the development of new ventriculomegaly at last follow-up. Demographic, clinical, and dosimetric factors were compared between groups using univariable and multivariable logistic regressions. **RESULTS:** In the UCSD cohort, 63 patients (29%) presented with ventriculomegaly before SRS. Of 151 remaining patients with normal ventricular size before first SRS, 30 (20%) developed new ventriculomegaly. The odds of developing ventriculomegaly increased with history of WBRT (OR 5.247, $p < 0.001$) and trended toward significance with a greater number of SRS treatments (OR 1.296, $p=0.075$). In the Karolinska cohort, the odds of developing new ventriculomegaly trended towards significance with a greater number of SRS treatments (OR 1.605, $p=0.26$). To test whether this trend would achieve significance in a larger sample, we repeated the analysis in the combined cohort of 362 patients. The association between number of SRS treatments and developing ventriculomegaly reached significance (OR 1.254, $p=0.049$). **CONCLUSIONS:** These pilot findings suggest that cumulative radiation from repeat stereotactic radiosurgery (SRS) potentially increases the risk of ventriculomegaly. Based on our study, a prospective study of >350 patients will be needed to further test this hypothesis.

RADI-25. REPEAT STEREOTACTIC RADIOSURGERY FOR RECURRENT BRAIN METASTASES

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INTRODUCTION: Mainstream modality of treatment of oligo-metastatic disease is stereotactic radiosurgery (SRS). While the local control rate is nearing 90%, 7% of lesions and 10 to 15% of patients develop radiation necrosis post treatment. In the face of increasing lesion size and evidence of recurrence, re-treatment of the enlarging lesion with radiosurgery can be attempted. The aim of the project is to evaluate outcomes of lesions treated with repeat SRS. **METHODS:** We conducted a retrospective review of all patients that were treated with Gamma Knife radiosurgery at our institution from 2000 to 2018. Fifty-one lesions in 39 patients were identified that had recurrence during follow-up period and were treated with a second single-fraction SRS. **RESULTS:** A combination of imaging studies, such as PET and/or perfusion studies, lesion biopsy, and clinical course were used to make the diagnosis of lesion recurrence. The average radiation dose at first treatment was 21 Gy, and the average dose at second treatment was 19 Gy. The median time between treatments was 16.8 months, ranging from 2.5 to 75.3 months, and the median follow-up after second treatment was 10.2 months. Of 51 lesions that received two SRS treatments, 49% (25 lesions) continued to progress at a median interval of 4.8 months post treatment, of which 35% (18 lesions) were diagnosed as radiation necrosis based on biopsy results or advanced brain imaging. The overall rate of radiation necrosis post second SRS treatment was determined to be 16% per lesion and 21% per patient. **CONCLUSION:** Recurrent brain metastases that are re-treated with single fraction SRS are associated with a higher risk of radiation necrosis. Alternative treatment strategies, including fractionation of subsequent SRS treatments, radiation dose reduction, and combination with laser ablation could be considered to ensure symptom and disease control to reduce the rate of subsequent radiation necrosis.