Proton Therapy for tumors of the skull base - RESULTS

Eugen B. Hug, MD
Medical Director,
ProCure Proton Therapy Centers, NY
Petroclival Chondrosarcoma: 68 – 72 Gy(RBE) at 1.8 or 2.0 Gy(RBE)

GTV: 70.2 Gy(RBE) / 1.8 Gy (RBE)
OAR constraints: Brainstem Surface 64 Gy(RBE), Brainstem Center 53 Gy(RBE)
Skull Base Chordoma: 72-76 Gy(RBE)

67 y.o. F
s/p 2 major subtotal resection
Involvement of entire clivus, brainstem compression
extracranial extension
Posterior pharynx

GTV: 74 Gy(RBE) / 1.8 Gy (RBE)
CTV: 54 Gy(RBE)

OAR constraints: Brainstem Surface 64 Gy(RBE), Brainstem Center 53 Gy(RBE), Optic Nerves and Chiasm 60 Gy(RBE)
### Skull Base Chondrosarcomas: Proton series

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>Radiation</th>
<th>Mean dose</th>
<th>3-yr LC</th>
<th>5-yr LC</th>
<th>10-yr LC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Munz. MGH 1999</td>
<td>229</td>
<td>PT, RT</td>
<td>72</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hug, LLUMC 1999</td>
<td>25</td>
<td>PT, RT</td>
<td>71</td>
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<tr>
<td>Johnson, LLU '02</td>
<td>58</td>
<td>PT, RT</td>
<td>71</td>
<td></td>
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<tr>
<td>Noel, CPO 2004</td>
<td>26</td>
<td>PT, RT</td>
<td>67</td>
<td></td>
<td></td>
<td>91</td>
</tr>
<tr>
<td>Schulz-E., GSI 2007</td>
<td>54</td>
<td>Carbon, RT</td>
<td>60*</td>
<td>89</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Ares, PSi 2009</td>
<td>22</td>
<td>PT</td>
<td>68.4</td>
<td></td>
<td></td>
<td>94</td>
</tr>
</tbody>
</table>

*at 3.0 CGE per fraction
## Skull Base Chordomas: Proton

<table>
<thead>
<tr>
<th>Center</th>
<th>Year</th>
<th>Pts</th>
<th>Tx</th>
<th>Mean dose</th>
<th>3 y Local control</th>
<th>5 y Local control</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUNZENRIDER</td>
<td>MGH</td>
<td>1999</td>
<td>290 PT, RT</td>
<td>76</td>
<td>67</td>
<td>73</td>
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<tr>
<td>TERAHARA</td>
<td>MGH</td>
<td>1999</td>
<td>115 PT, RT</td>
<td>69</td>
<td></td>
<td>59</td>
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<tr>
<td>HUG</td>
<td>LLUMC</td>
<td>1999</td>
<td>33 PT, RT</td>
<td>71</td>
<td>67</td>
<td>59</td>
</tr>
<tr>
<td>NOEL</td>
<td>CPO</td>
<td>2005</td>
<td>100 PT, RT</td>
<td>67</td>
<td>86 (2 y)</td>
<td>53 (4 y)</td>
</tr>
<tr>
<td>SCHULZ-E</td>
<td>GSI</td>
<td>2007</td>
<td>115 Carbon RT</td>
<td>60*</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>ARES</td>
<td>PSI</td>
<td>2009</td>
<td>42 PT</td>
<td>74</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Protons: No large scale prospective or multicenter studies available

**Contouring / Dose Prescription:**

**Similar Volume Definitions (GTV, CTV)**

**Similar Dose Prescriptions:**

- 1.8 or 2.0 fraction dose
- GTV 66-78 Gy(RBE) total dose – MGH up to 82 Gy(RBE) (selective only)
### Treatment Results in Skull Base Chordoma

<table>
<thead>
<tr>
<th>Authors</th>
<th>N</th>
<th>Median Total Dose</th>
<th>Median f/u (y)</th>
<th>Local Control Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Photon</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catton et al.</td>
<td>24</td>
<td>50.0</td>
<td>5.2</td>
<td>23 (3-y) 15 (5-y)</td>
</tr>
<tr>
<td>Romero et al.</td>
<td>18</td>
<td>50.1</td>
<td>3.1</td>
<td>17</td>
</tr>
<tr>
<td>Forsyth et al.</td>
<td>39</td>
<td>50.0</td>
<td>8.3</td>
<td>39 (3-y) 31 (5-y)</td>
</tr>
<tr>
<td>Magrini et al.</td>
<td>12</td>
<td>58.0</td>
<td>6.0</td>
<td>25 (3-y) 25 (5-y)</td>
</tr>
<tr>
<td><strong>Proton</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Munzenrider et al.</td>
<td>169</td>
<td>66-83</td>
<td>3.4</td>
<td>73 (3-y) 54 (5-y)</td>
</tr>
<tr>
<td>Noel et al. (CPO)</td>
<td>100</td>
<td>67.0</td>
<td>2.6</td>
<td>86 (2-y) 54 (4-y)</td>
</tr>
<tr>
<td>Igaki et al. (Tsukuba)</td>
<td>13</td>
<td>72.0</td>
<td>5.8</td>
<td>67</td>
</tr>
<tr>
<td>Ares et al. (PSI)</td>
<td>42</td>
<td>73.2</td>
<td>3.2 (Mean)</td>
<td>81</td>
</tr>
<tr>
<td><strong>Helium</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castro et al.</td>
<td>53</td>
<td>65.0</td>
<td>4.3</td>
<td>63</td>
</tr>
<tr>
<td><strong>Carbon</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shults-Erter et al.</td>
<td>96</td>
<td>60.0</td>
<td>2.6 (Mean)</td>
<td>81 (3-y) 70 (5-y)</td>
</tr>
<tr>
<td>NIRS</td>
<td>36</td>
<td>48-60.8</td>
<td>4.6</td>
<td>81 (SE ±0.8)</td>
</tr>
<tr>
<td>NIRS</td>
<td>27</td>
<td>60.8</td>
<td>3.8</td>
<td>94 (SE ±0.6)</td>
</tr>
</tbody>
</table>

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From: Kamada, ESTRO Teaching Course 2012
Scanning-beam Proton Therapy for Chordomas and Chondrosarcomas of the Skull base

Ares, Goitein, Hug et al. - PSI IJROBP 2009 Nov 15;75(4)

• N = 64 patients (Oct-98 Nov-05)
  – Chordoma 42 (65%)
    Chondrosarcoma 22 (34%)

• Mean age 44.5 years
• Mean follow-up 38 months (14 - 92 months)

• Prescription dose (mean) (at 2 CGE per frct.).
  • Chordoma (Ch) 73.5 CGE (range 67 - 74)
    Chondrosarcoma (ChSa) 68.4 CGE (range 63 - 74)

• GTV volume: mean 25.8 cc (1.5 - 100.5 cc)
(Ares et al. cont.)

Actuarial Local Control

<table>
<thead>
<tr>
<th>Condition</th>
<th>3 years</th>
<th>5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chordomas</td>
<td>87 %</td>
<td>81 %</td>
</tr>
<tr>
<td>Chondrosarcomas</td>
<td>94 %</td>
<td>94 %</td>
</tr>
</tbody>
</table>

Local control

P = 0.25
Disease Spec. Survival

Chordomas 90% 81%
Chondrosarcomas 100% 100%

Disease Specific Survival

(Ares et al. cont.)
Radiation induced toxicity (CTCAE v3.0)

- **High grade late toxicity (all Ch) → 4 pts (6%)**
  - optic pathway  
    - G 4 → 1 patient (unilat. blindness)  
    - G 3 → 1 patient (unilat. visual deficit)
  - neurologic  
    - G 3 → 2 patients (sympt. brain necrosis)

**Actuarial Toxicity-Free Survival: 94%**
**Prognostic Factor: Tumor Size and Local Control**

Improved LC for “smaller” size

- LLUMC: < 25 ml vs. > 25 ml (100% vs. 56%)  \( p = \text{signif.} \)
- CPO: <29ml vs. > 29ml  \( p = \text{signif.} \)
- PSI: > 25 ml vs. > 25 ml (90% vs. 74%)  \( p = \text{signif.} \)
- MGH: < 70 ml vs. > 70 ml (disease-free survival)  \( p = \text{signif.} \)
- LBL: < 20cc vs. <35 vs. > 35 cc (80% vs. 33%)  \( p = \text{signif.} \)

Loma Linda UMC Analysis

*J Neurosurg. 91:432-439, 1999*
Prognostic Factor: Tumor Size and Local Control

Improved LC for "smaller" size:
- LLUMC: < 25 ml vs. > 25 ml (100% vs. 56%)
- CPO: < 29 ml vs. > 29 ml
- PSI: > 25 ml vs. > 25 ml (90% vs. 74%)
- MGH: < 70 ml vs. > 70 ml (disease-free survival)
- LBL: < 20 cc vs. < 35 cc vs. > 35 cc (80% vs. 33%)

Note:
1) 5-year LC for ‘small’ lesions: approx. 85 – 95%
2) There is no evidence in the neurosurg. literature that local control is better following gross total resection compared to “small’ residual

Hug, Laredo, et al.
J Neurosurg. 91:432-439, 1999
Skull Base Chordomas: Importance of high-dose

**Tumor Compression of Critical Structures = under-dosage of GTV**

Influence of tumor compression on local control

*J Neurosurg. 91:432-439, 1999*

*Orsay/France:*
*Noel, et al.*
*Acta Oncol 2005;44(7):700-8*

- 95% GTV encompassed by 95% Isodose (p=0.01)
- Minimal dose < 56 Gy to GTV (p=0.04)
Skull Base Chordomas: Importance of high-dose

Paul Scherrer Institute:
5/6 failures with brainstem compression p=signif.

Mass. General Hospital
15/26 failures with BS or OC compression p=signif.
Skull Base Chordomas: Importance of high-dose

- The majority of skull base tumors require 70-76 Gy(RBE) GTV-dose
- This exceeds all OAR constraints of brainstem, optic nerves, optic chiasm and most other structures
- Underdosage of tumor causes failures (approx. 2/3 of failures)
- Goal: minimize “GTV shoulder” on DVH

- Hence: surgical decompression of OAR’s recommended
- Hence: only high OAR constraint will permit adequate tumor dose in many / most patients
## Skull base Chordomas and Chondrosarcomas: RS and Cyberknife LC data

<table>
<thead>
<tr>
<th>Study</th>
<th>Chordomas</th>
<th>Chondrosarcomas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>5-y LC</td>
</tr>
<tr>
<td>Krishan, 2005</td>
<td>25</td>
<td>32%</td>
</tr>
<tr>
<td>Martin, 2007#</td>
<td>18</td>
<td>63%</td>
</tr>
<tr>
<td>Hasegawa, 2007</td>
<td>30</td>
<td>72%</td>
</tr>
<tr>
<td>Henderson, 2009</td>
<td>18</td>
<td>59%</td>
</tr>
<tr>
<td>Liu, 2008</td>
<td>28</td>
<td>21%</td>
</tr>
<tr>
<td>Kano, Pittsburg ,2011</td>
<td>71</td>
<td>66%</td>
</tr>
<tr>
<td>Koga, U. Tokyo, 2010</td>
<td>14</td>
<td>combined Ch +ChS 43% 5-yr LC</td>
</tr>
</tbody>
</table>
Recent publication on photon- FSRT for Chordomas

Photon-based Fractionated Stereotactic Radiotherapy for Postoperative Treatment of Skull Base Chordomas

Darlene M. Bugoci, MD,* Michael R. Girvigian, MD,* Joseph C.T. Chen, MD, PhD, †
Michael M. Miller, MD,* and Javad Rahimian, PhD*
(Am J Clin Oncol 2012;00:000–000)

- Dept. of Rad. Onc, Kaiser Permanente, Los Angeles, CA
- OBJECTIVES:: Postoperative high-dose fractionated stereotactic radiotherapy (FSRT) as an alternative to proton radiotherapy (RT).
- FSRT between 2002 - 2009,
- 12 patients with skull base chordomas. IMRT and IGRT FSRT
- **Median dose of 66.6 Gy** (range, 48.6 to 68.4 Gy), at 1.8 Gy, prescribed to the 90% isodose line.
- Median follow-up 42 months.
- 5-year Overall survival 76.4%
- **Progression-free survival 46.9% at 2-years and 37.5% at 5-years.**
- Author’s CONCLUSIONS: “FSRT resulted in promising overall survival results comparable with the published literature of particle therapy without significant complications. Our technique for treating skull base chordomas can be considered a safe and less costly alternative to proton RT.”

*Note: Conclusion misleading. There is no salvage after failure. Patients will die of disease. Delay between LF and DoD about 2-3 years*
What are the results comparing:

Particle Therapy vs. Stereotactic or conv. photons

5-year Local Control rates (%)

Dose Gy (RBE)

Particles

Protons
- Munzenrider 1999
- Ares 2009
- Hug 1999

C-Ions
- Schulz-Ertner
- Mizoe

Photons
- Bugoci 2012
- Romero 1993
- Zorlu 2000
- Debus 2002
What are the results comparing:

**Particle Therapy vs. Stereotactic or conv. photons**

Protons
- Munzenrider 1999
- Ares 2009
- Hug 1999

C-Ions
- Schulz-Ertner

Photons
- Bugoci 2012
- Romero 1993
- Zorlu 2000
- Debus 2002

Protons for small Chordomas and distant from OAR, Chondrosarcomas

5-year Local Control rates (%)

Dose Gy (RBE)
Long-term Side Effects of high-dose Proton Therapy for Skull Base Tumors:

The risks of severe (> Grade 3) side effects following high dose, precision RT depend on several variables:

Tumor size, tumor compression of normal brain, critical structure involvement, dose to normal tissues, number of prior surgeries, general medical risk factors (diabetes, HTN, smoking,), KPS

**Rule of Thumb for Proton RT for Skull Base requiring > 70 Gy:**

- Low-risk group:  < 5%
- Mod.-risk group: 5-8%
- High-risk group:  > 8 % - ?? *

* PT as last modality after multiple failures
High-Dose Proton Therapy to the Base of Skull:  
*Temporal Lobe Toxicity*  

*B. Pehlivan, C. Ares, T. Lomax, E. Hug et al. IJROBP. 2012, 83(5):1432-40* 

**PSI:** 64 Skull Base Patients treated at (40 Chordoma, 22 Chondrosarc.) 

7 pts. censored: Only 2 pts. With Gr. 3, and 5 pts. With Grade 1 

Patient characteristics with G1 or G3 temporal adverse events 

<table>
<thead>
<tr>
<th>Patient #</th>
<th>Toxicity Grade</th>
<th>PT dose (Gy(RBE))</th>
<th>Overall F/U time (months)</th>
<th>LC</th>
<th>Dx of adverse event (months after PT)</th>
<th>Location temporal lobe change</th>
<th>Symptoms</th>
<th>Status MRI at last F/U</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>74</td>
<td>22</td>
<td>yes</td>
<td>12</td>
<td>Bilateral</td>
<td>Impaired short term memory, desorientation</td>
<td>Stable with edema reduction</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>74</td>
<td>23</td>
<td>yes</td>
<td>19</td>
<td>Bilateral</td>
<td>Impaired short term memory, desorientation</td>
<td>Stable with edema reduction</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>68</td>
<td>50</td>
<td>yes</td>
<td>35</td>
<td>Bilateral</td>
<td>N/A</td>
<td>stable on MRI resolution</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>74</td>
<td>21</td>
<td>yes</td>
<td>10</td>
<td>Bilateral</td>
<td>N/A</td>
<td>no change</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>74</td>
<td>61</td>
<td>yes</td>
<td>38</td>
<td>Left</td>
<td>N/A</td>
<td>no change</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>74</td>
<td>35</td>
<td>yes</td>
<td>31</td>
<td>Left</td>
<td>N/A</td>
<td>no change</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>74</td>
<td>21</td>
<td>yes</td>
<td>18</td>
<td>Right</td>
<td>N/A</td>
<td>increase</td>
</tr>
</tbody>
</table>

#: number; PT: proton-radiotherapy; F/U: follow-up; LC: local control; Dx: diagnosis; N/A: not applicable
High-Dose Proton Therapy to the Base of Skull: *Temporal Lobe Toxicity*

Table 3. Dose-volume values to 3 different neurological structures in relation with grade of CNS toxicity

<table>
<thead>
<tr>
<th>Grade Toxicity</th>
<th>D3 mean ± SD (Gy(RBE))</th>
<th>D2 mean ± SD (Gy(RBE))</th>
<th>D1 mean ± SD (Gy(RBE))</th>
<th>D0.5 mean ± SD (Gy(RBE))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>70 ± 5</td>
<td>71 ± 5</td>
<td>72 ± 5</td>
<td>73 ± 5</td>
</tr>
<tr>
<td>1</td>
<td>73 ± 5</td>
<td>74 ± 5</td>
<td>75 ± 4</td>
<td>76 ± 4</td>
</tr>
<tr>
<td>3</td>
<td>75 ± 1</td>
<td>76 ± 2</td>
<td>76 ± 2</td>
<td>77 ± 2</td>
</tr>
</tbody>
</table>

Right temporal lobe

<table>
<thead>
<tr>
<th>Grade Toxicity</th>
<th>D3 mean ± SD (Gy(RBE))</th>
<th>D2 mean ± SD (Gy(RBE))</th>
<th>D1 mean ± SD (Gy(RBE))</th>
<th>D0.5 mean ± SD (Gy(RBE))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50 ± 23</td>
<td>52 ± 23</td>
<td>56 ± 22</td>
<td>58 ± 22</td>
</tr>
<tr>
<td>1</td>
<td>67 ± 15</td>
<td>69 ± 12</td>
<td>73 ± 9</td>
<td>75 ± 7</td>
</tr>
<tr>
<td>3</td>
<td>71 ± 4</td>
<td>73 ± 3</td>
<td>75 ± 2</td>
<td>76 ± 2</td>
</tr>
</tbody>
</table>

Left temporal lobe

<table>
<thead>
<tr>
<th>Grade Toxicity</th>
<th>D3 mean ± SD (Gy(RBE))</th>
<th>D2 mean ± SD (Gy(RBE))</th>
<th>D1 mean ± SD (Gy(RBE))</th>
<th>D0.5 mean ± SD (Gy(RBE))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>53 ± 21</td>
<td>56 ± 21</td>
<td>59 ± 20</td>
<td>62 ± 19</td>
</tr>
<tr>
<td>1</td>
<td>57 ± 18</td>
<td>62 ± 15</td>
<td>67 ± 12</td>
<td>70 ± 9</td>
</tr>
<tr>
<td>3</td>
<td>68 ± 1</td>
<td>71 ± 0</td>
<td>74 ± 1</td>
<td>75 ± 1</td>
</tr>
</tbody>
</table>

Q: What is a „reasonable“ temp. lobe max. Dose Constraint, i.e. balancing toxicity risk with risk of failure?

• $D_2 \leq 70$ or 72 Gy (RBE)?

Temporal Lobe toxicity constitutes the most frequent high-grade adverse event in high-dose skull base treatments. Approx. 3-5 %

Challenge: No clear tolerance threshold defined by ANY group
PTV of GTV frequently includes medial temporal lobes

Rec.: limit approx. 2 cc to $\leq 72$ Gy(RBE)
Proton Radiation Therapy for *Adenoid-cystic Carcinoma* of the Skull Base
### Adenoid Cystic Carcinoma with skull base invasion

<table>
<thead>
<tr>
<th>Institution/Publication</th>
<th>Particle</th>
<th># Pts.</th>
<th>Dose</th>
<th>Follow-up</th>
<th>Local control</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGH Pommier</td>
<td>Protons</td>
<td>23</td>
<td>Median 75.9 GyE at 1.8-2.0</td>
<td>Median 64 m</td>
<td>5-yr 93%</td>
<td>Mature f/u</td>
</tr>
<tr>
<td>NIRS Phase II 9602</td>
<td>Carbon</td>
<td>126</td>
<td>57.6 GyE then 64 GyE</td>
<td>Approx. 48 m</td>
<td>5-yr 76%</td>
<td>69 pts short f/U 95% to 64 GyE</td>
</tr>
<tr>
<td>GSI Schulz-Ertner</td>
<td>Carbon</td>
<td>29</td>
<td>Median 16 m</td>
<td>4-yr 77%</td>
<td>short f/u</td>
<td></td>
</tr>
</tbody>
</table>

GTV: 72-74 Gy (RBE)  
CTV: 60 Gy (RBE)
Adenoid-Cystic Carcinomas
with infiltration of the skull base

5-year Local Control (%)

Dose [ Gy (RBE)]

Protons:
- Pommier et al. MGH, 2006

C-ions:
- Schulz-Ertner et al. GSI – U Heidelberg
- Tsuji et al. NIRS

Photons:
- Chen (UCSF, 2006)
- Historic data

Neutrons (Seattle): without
- with SB invasion
Proton Radiation Therapy for *Meningiomas* of the Skull Base and complex anatomic configuration
Proton-Radiotherapy for skull base tumors: **Benign meningioma**

Axial and coronal Gd-enhanced T1-wMRI

Spheno-orbital meningioma.
Spot scanning based Proton Therapy at PSI for Meningiomas – 5-year actuarial data

Weber et al. IJROBP Dec. 2011

• 39 patients,
• Proton Therapy between 1997 – 2/2010. (exclusively protons)
• Age: 3.2 – 76 years (3 pediatric pats.)
• Gender: M:F = 9:30

• Histology: 34 histologically proven, 5 radiographic Dx.
• Histology: WHO (2007): Grade I: 23(58%), II: 10(25%), III: 2(5%)
• Location: 32(83%) skull base, 7(17%) Non-skull base
Spot scanning based Proton Therapy at PSI for Meningiomas – 5-year actuarial data

*Weber et al. IJROBP Dec. 2011*

- **GTV:** range: 0.76 cc – 546 cc (mean: 56 cc)
- **PT:** fractionated, at 1.8-2.0 Gy(RBE)
- **Total Dose:** 52.2 – 68.4 Gy(RBE) (mean: 57.5)
- **Follow-up:** 6.2 – 147 months (mean: 63 months)

- **Local Control:** 33 pts., LF: 6 pts.
- **Overall Survival:** 6 pts. D, 4 pts. DoD
- **Late, high-grade Toxicity:** 5 pts.
Local control

LC: 85% at 5 years – 39 pts.

Weber et al. IJROBP Dec. 2011
Local control

LC: 85% at 5 years – 39 pts.

Benign Meningiomas: LC 100% (5-yrs.)

Grade II-III: LC ~60%

High Grade Toxicities: 3 pts. with optic neuropathy
<table>
<thead>
<tr>
<th>Institution/Publication</th>
<th>Particle</th>
<th># Pts.</th>
<th>Dose</th>
<th>Follow-up</th>
<th>Local control</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI/Heidelberg Combs 2010 Radiother Oncol 95(1)</td>
<td>Carbon</td>
<td>10 atypical anaplastic</td>
<td>18 GyE carbon boost 50.4 Gy photons</td>
<td>77 m median</td>
<td>5yr 86% for „primary RT“ = 6/8 patients</td>
<td>Statistical power of 5-yr rates(?)</td>
</tr>
<tr>
<td>PSI Weber (IJROBP 2011)</td>
<td>Protons</td>
<td>39 29 benign 10 atypical or malignant</td>
<td>53-58 GyE benign 60-66 GyE atyp or anapl.</td>
<td>55 m median</td>
<td>5-yr 100% benign 5-yr 58% atyp. or anaplastic</td>
<td></td>
</tr>
<tr>
<td>MGH Wenkel 2000; 84(5)</td>
<td>Protons</td>
<td>46 Benign only</td>
<td>Mean 59 Gy(RBE)</td>
<td>53 m median</td>
<td>5-yr 100% benign</td>
<td>10-yr LC 88%</td>
</tr>
<tr>
<td>MGH Hug (J Neuroonc. 2000; 48(2)</td>
<td>Protons and photons</td>
<td>31 15 atypical 16 malignant</td>
<td>&lt; 60Gy&gt;</td>
<td>Mean 59 m</td>
<td>5-yr 38% atyp 5-yr 52% mal. 5-yr 80% with protons vs. 17% photons (signif.)</td>
<td>8-yr LC 19% atyp and 17% mal.</td>
</tr>
</tbody>
</table>
Patient: V.Y. 63 y.o. M; Hx of left sided weakness, sensory deficits, and neck pain

Preop. MRI 12/2012

Chordoma of C4 Vertebral body, extensive spinal cord compression, involvement of left vertebral artery
Chordoma of the Cervical Spine

Patient: 63 y.o. M; Postop. MRI 2/2013

Posterior approach: Laminectomy, Facetectomy, Currettage of C4, subtotal resection
Stabilisation with rods and screws. Note: no ipsilateral rod

Residual TUMOR
Chordoma of the Cervical Spine
Chordoma of the Cervical Spine

Patient: V.Y. 63 y.o. M;
Chordoma of the Cervical Spine

Patient: V.Y. 63 y.o.

Total dose: 75.6 Gy(RBE) at 1.8 / frct.
Chordoma of the Cervical Spine

Patient: V.Y. 63 y.o.

Total dose: 75.6 Gy(RBE) covers 82%; 71.8 Gy(RBE) = 95% Iso covers 92%