Gamma Knife® Center at Beaumont

Treatment Guidelines for Acoustic Tumors

Eligibility Criteria

- Neuroimaging evidence of cerebellopontine angle tumor of < 3 cm in extracanalicular diameter
- For tumors > 3 cm in greatest diameter, surgery as the first line of treatment would be recommended. Post–operative GK is a consideration for residual disease or at recurrence [see attached Management Algorithm for Acoustic Neuromas]
- Elderly patients or medically infirm where surgical resection would not be ideal
- Attempt at hearing preservation in small (<1.5 cm or medium sized tumors 1.5 cm-3 cm
- Recurrent or residual acoustic tumors previously resected
- Patient who otherwise is a candidate for microsurgery but refuses such an operative procedure.
- Patient who have had pre-operative testing of hearing, facial function, balance, etc. as indicated
- **For any patient having received prior radiotherapy**, those records should be obtained and available for review ≥ 24 hours in advance of GK radiosurgery
- The side of the patient to be treated should be noted in: Mosaiq, on the dry erase board in the frame application room and on the correct ear externally with an operating room marker.

Imaging Protocol

- The frame with the insulated posts/pins must be used so that heat generated by the T2 sequence is not transmitted to the patients.
- Axial and Coronal (optional) T1 Gadolinium enhanced MP-RAGE scan and CISS sequence with 1mm to 1.5 mm slice thickness to best delineate the acoustic lesion using an insulated frame.
- Fat sat images can be obtained in a post operative setting to distinguish between tumor and post operative tissue changes.
- CT to accurately delineate the cochlea and labyrinth.
- The entire brain need not be imaged on the day of treatment as long as a recent diagnostic MRI of the entire brain has been performed. The imaging slab must contain the structures of interest.

Target Definition

- GTV = T1-GAD enhanced lesion
- CTV = GTV
- For sub-totally resected tumors, CTV = resected surgical cavity plus residual tumor at discretion of treating surgeon and Radiation Oncologist
- Treating Radiation Oncologist and Neurosurgeon/Neuron-Otology Surgeon must be in agreement with respect to the target volume

Critical Structure Definition

- The adjacent critical structures include but are not limited to the Brainstem,
• Cochlea, (high frequency and low frequency hearing areas)
• Labyrinth.

**Dose Prescription**
• Dose should be prescribed to the isodose volume that encompasses the GTV. This is usually the 50% isodose volume but is not limited to be the 50%.
• The usual marginal dose prescribed is 12-13 Gy.
• Depending on the size of the acoustic neuroma, the range of commonly prescribed marginal doses ranges from 11-15 Gy, in addition to hearing status, vertigo status and facial nerve condition.
• Tolerance doses to adjacent critical structures should be considered for dose selection. The recommended doses are as follows.
  • Cochlea: mean dose <5 Gy, in patients with useful hearing
  • Labyrinth: mean dose < 5 Gy
  • Brainstem: mean dose <8 Gy, max dose < 15 Gy
• For any case in which a patient has received prior radiosurgery to the same or similar area, a secondary Physics check should be undertaken

**Follow up Schedule**
• Recommendation for brain MRI at 6 months, 1,2,3,4,5,7,10, and 15 years
• Audiogram [at 1, 3, 6, 12, 18, 24 months then annually for patients that have some hearing]
• Auditory Brainstem Response (ABR) see chart below
• Facial Electroneurography (ENOG) see chart below
• Electronystagmography (ENG) balance tests see chart below
• Follow-up test results as defined below should be documented on provided “Acoustic Neuroma Data Sheets” by the ENT physician and sent to the GK Center at Beaumont whenever possible for proper documentation of patient outcomes. Data sheet attached as Appendix A.

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**GKS ACOUSTIC NEUROMA PROTOCOL**

**FOLLOW-UP SCHEDULE**

**ONE AND 3-MO follow-ups have been deleted from the Table.**

<table>
<thead>
<tr>
<th>EXCEPTIONS</th>
<th>PRE</th>
<th>6 mos</th>
<th>1Y</th>
<th>18 mos</th>
<th>2Y</th>
<th>2Y + 6M</th>
<th>3Y</th>
<th>4Y</th>
<th>5Y</th>
<th>7Y</th>
<th>10Y</th>
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<tbody>
<tr>
<td>MD FOLLOW UP</td>
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<td>ENOG</td>
<td>ONLY IF FACIAL WEAKNESS</td>
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</table>

1-29-2014
Audiogram – hearing Test
ABR- Auditory Brainstem Response.
ENG- Electronystagmography.
MRI- Magnetic Resonance Imaging
ENOG- Electronaurography (this test is only done if facial weakness is present)

All imaging studies and test reports should be copied to the Gamma Knife Center at William Beaumont Hospital.
APPENDIX A
ACOUSTIC NEUROMA DATA SHEET

Patient Name: ___________________________________ DOB: __________________

FU Date: __________________

PTA Levels should be recorded using results for AIR Conduction Post-RS:
Hearing Level (dB) at 500 Hz: ______
Hearing Level (dB) at 1000 Hz: ______
Hearing Level (dB) at 2000 Hz: ______
Hearing Level (dB) at 4000 Hz: ______

Post-RS PTA 3-tone (dB): ________
Post-RS PTA 4-tone (dB): ________

Post-RS SRT (Speech Recognition Threshold): ______

Post-RS Speech Recognition (Speech Discrimination) (%): _____

Post-RS AAO Class: ______

Post-RS Gardner Robertson Grade: ______

Post-RS Facial Nerve Dysfunction: Y or N

Post-RS House Brackman Grade: ______

Post-RS Trigeminal Nerve Dysfunction: Y or N

Post-RS Other Facial Nerve Symptoms: None
Twitching
Numbness

Post-RS ENG: Normal
Unilateral Caloric Reduction
Contralateral Caloric Reduction
Bilateral Caloric Reduction
CNS Dysfunction

Post-RS ENG Results: ___________

ABR: ___________

Post-RS ENOG Results (for Facial N. dysfunction): ___________

Most Recent MRI Date: ___________
Most Recent MRI Maximum Dimension (cm): ___________

Most Recent MRI Results: Same Size, same homogeneous enhancement
Same size, decreased central enhancement
Decreased size, decreased central enhancement
Increased size, decreased central enhancement
Increased size, increased central enhancement
Decreased size, same central enhancement
Same Size, increased central enhancement
Increased size, same central enhancement
Gamma Knife® Center at Beaumont

Treatment Guidelines for Arteriovenous Malformations (AVM)

Eligibility Criteria

- The selection of the optimal treatment of AVMs is one which is multi-factorial and made by a multidisciplinary team approach that should involve the neurosurgeon, radiation oncologist and often interventional radiologist. AVM’s should generally be managed with surgery/microsurgery; Gamma Knife radiosurgery is generally considered for those AVM’s which are not considered surgically resectable or resectable without significant risk of neurological dysfunction. These patients may warrant treatment based on age, location, volume or medical history. Gamma Knife may also be considered as primary or repeat radiosurgery to residual or re-canalized AVM’s after prior radiosurgery or embolization.
  - Radiosurgery is most effective/has the highest rate of obliteration for small (< 10 cc) AVM’s.
  - A staged radiosurgery procedure should be considered for large AVM’s > 15 cc but may be dependent on the number of feeding vessels
    - 3-9 months between stages is considered appropriate
  - Combining embolization with radiosurgery should generally be considered for those with dural AVM’s

- In cases of prior hemorrhage due to the AVM, post-hemorrhage imaging must be obtained typically using MRI to document resolution of the hemorrhage prior to proceeding with or scheduling Gamma Knife. Resolution may take at least 2 to 3 months after hemorrhage.
- A standard angiogram will be required prior to (and in addition to) the angiogram performed on the day of the GK procedure. CT angiograms will not be considered a substitute for standard angiography.

Potential cases for Gamma Knife Radiosurgery are

- Deep-seated AVMs where surgery would be technically difficult
- Residual AVMs after prior embolization and / or surgery
- AVMs located near eloquent regions of the brain where surgery may lead to a compromise of neurological function
- Patient refuses surgery in an otherwise resectable AVM
  - Such patients should be appropriately counseled regarding the continued bleeding risks (and time course) after radiosurgery compared to surgery
- Patient is deemed a non-surgical candidate due to a high anesthesia risk or severe medical co-morbidities but the AVM is still considered too high risk for observation

The Spetzler-Martin Grading system for classification of AVMs should also be considered.
In general, in the absence of medical inoperability, a Spetzler-Martin grade of at least 3 would be considered most acceptable for Gamma Knife.

For any patient having received prior radiotherapy, those records should be obtained and available for review ≥ 24 hours in advance of GK radiosurgery.

**Imaging Protocol**
- MRI consisting of a sagittal scout, Axial T1 Gadolinium enhanced MP-RAGE or Flash using 1 mm or 2 mm thick slices depending on the size of the nidus.
- If the nidus is small (<10 cc), use a T2 sequence in addition to the T1 sequence. A T2 sequence requires a frame with insulated pins.
- The MRI should be followed by a CT.
- An angiogram will follow, injecting all of the feeding vessels. The feeding vessels would have been determined from earlier studies which should be shared with the Interventional Radiologist. The neurosurgeon should be present at the time of angiography to communicate with Interventional Radiology, select feeding vessels and choose appropriate images for GK planning.

**Target Definition**
- GTV = T1 MPR or Flash image definition of the nidus correlated with that which is defined in the angiographic images
- CTV = GTV
- Treating Radiation Oncologist and Neurosurgeon must be in agreement with respect to the target volume outline

**Critical Structure Definition**
Critical structure delineation is totally dependent on the location of the AVM nidus and the adjacent normal structures and eloquent areas. Normal tissue tolerances must be respected.

**Dose Prescription**
- Dose should be prescribed to the isodose surface that encompasses the CTV. By convention, this is the 50% isodose volume but is not limited to that (30% to 80% is the accepted isodose prescriptive level range).
- The dose range for the majority of AVMs is between a marginal dose of 15 – 25 Gy with the dose selection based on the volume of the AVM and the complication rates for the location of the nidus. Higher doses have been associated with higher obliteration rates.
- Tolerance doses to selected adjacent critical structures and eloquent areas should be considered for dose selection.
- Brainstem: max dose 8-15 Gy. NB. If the nidus is in the brainstem with a prior hemorrhage, a higher dose would be reasonable (16-18 Gy at the margin).
- Optic Chiasm/Apparatus: max dose 8 – 12 Gy
- Cranial Nerves: max dose 10-25 Gy (Motor nerves such as CN III-VI appear to tolerate a higher single fraction dose)
• For any case in which a patient has received prior radiosurgery to the same or similar area, a secondary Physics check should be undertaken

**Follow up Schedule**

• Clinical examinations and imaging according to the schedule outlined below to evaluate obliteration of the AVM:
  o MRI/MRA at 6 mos
  o Angiogram at 12 mos
    ▪ This angiogram will be Optional at discretion of the treating physicians as some advocate delay of angiography until MRI suggests obliteration and angiography does present a small risk of stroke
  o MRI/MRA at 18 mos
  o Angiogram at 24 mos
  o MRI/MRA at 30 mos
  o Angiogram at 36 mos if obliteration has not been proven via angiography by year 2/24 mos
  o Some advocate MRI/MRA at 6 month intervals with delay of angiography until MR demonstrates resolution of flow void

• CT is used if MRI is contraindicated.
• Obliteration generally follows 50% in year 1, 80% in year 2 and 90% in year 3.
• Small remnants present after apparent obliteration are not uncommon and should be followed closely. Repeat radiosurgery may be considered for small residuals.
• Any patients followed by neurosurgeons outside the Beaumont system should still be routinely followed as above with appropriate clinical and imaging follow-up provided to the GK Center at Beaumont.

The images, radiology report along with the patient condition status should be copied to the Gamma Knife Center at Beaumont.
Gamma Knife® Center at Beaumont

Treatment Guidelines for Trigeminal Neuralgia

Eligibility Criteria:
- Trigeminal Neuralgia refractory to medical and/or surgical management (such as retro-mastoid craniotomy, microvascular decompression, or percutaneous retrogasserian rhizotomy)
- Trigeminal Neuralgia in elderly patients not suitable for other forms of surgical intervention
- Patient chooses stereotactic radiosurgery over other methods of surgical management when refractory to medical management
  - Microvascular Decompression should be strongly considered in young patients. Young patients should be appropriately counseled regarding the durability of MVD vs. Gamma Knife prior to proceeding with GK even in the setting of patient choice.
- Patient should have had an MRI of the entire brain at some time after the initial diagnosis of Trigeminal Neuralgia to verify there is no other cause for compression of the trigeminal nerve
- The Barrow Neurological Institute Pain (BNI) Score and the Visual Analogue Scale (VAS) Pain Level as well as current medications for trigeminal pain should be documented prior to Gamma Knife radiosurgery
- For any patient having received prior radiotherapy, those records should be obtained and available for review ≥ 24 hours in advance of GK radiosurgery
- The side of the trigeminal neuralgia must be noted: in Mosaiq, on the dry erase board and the ear of the treatment side must be marked externally using an operating room marker.
- In patients having prior radiosurgery for trigeminal neuralgia, the root entry dose to the brainstem for the combined treatments must not exceed 80 Gy.
- For any case in which a patient has received prior radiosurgery to the same or similar area, a secondary Physics check should be undertaken

Imaging Protocol:
- A limited MRI of the brain will be performed on the day of the procedure including the region of the trigeminal nerve, unless there is a contraindication to MRI. A contrast cisternogram is necessary if MRI is not possible. Anticoagulation therapy must be ceased 1 week prior to the cisternogram procedure if required. Gamma Knife Radiosurgery should not be performed if the trigeminal nerve can not be accurately identified using one of these 2 methods.
- Axial MP-RAGE (or equivalent) images including Gadolinium with a 1 mm slice thickness along with CISS sequences are the recommended imaging tools and require the use of an insulated frame.
- T2 or FIESTA sequences may also be considered.

Target Definition:
- The target definition must be agreed upon by both the radiation oncologist and the neurosurgeon.
- The symptomatic side of the patient’s face must be confirmed prior to treatment as well as the pain score.
**Dose Prescription:**

- The recommended dose in cases without a prior history of stereotactic radiosurgery to the trigeminal nerve is 40 Gy to the 50% isodose line (80 Gy maximum dose). This is accomplished usually by using a single 4 mm shot along the anterior section of the length of the nerve.

- A maximum dose of 70 Gy appears to be the minimum effective dose for radiosurgery-naïve patients, but doses as high as 90 Gy maximum dose have been used at other institutions.

- For repeat procedures (instances where there is an initial response to radiosurgery, but symptoms later recur), a dose of 30-35 Gy to the 50% isodose line (60-70 Gy maximum dose) should be considered.

- The treatment plan must be accepted and signed by both the radiation oncologist and neurosurgeon.

**Follow-up:**

- Specific imaging follow-up will not typically be required unless patient develops new apparently unrelated neurological symptoms.

- Patients should be followed at 2 weeks initially and then every 3-6 months for clinical assessments for 2 years and then every 1-3 years.

- At the time of follow-up, a VAS pain score, Barrow Neurological Institute Pain Score (BNI), and any medication use or discontinuation, along with any toxicities should be documented whenever possible.

- Trigeminal pain medications (in the absence of patient intolerance) should generally not be discontinued or tapered until trigeminal pain is gone.

- The patient’s clinical status should be documented and copied to the Gamma Knife Center at Beaumont.
Treatment Guidelines for Brain Metastases

Eligibility Criteria

- Anticipated life expectancy at the time of primary brain tumor therapy > 3 months
- Karnofsky Performance Status ≥ 70
- Radiosurgery may be considered for definitive treatment or post-operative treatment of limited metastases
- Pre-GK images are to be available for review no later than 48 hours after a tentative date is booked.
- There must be some documentation that the physician boarding the case has communicated with the neurosurgeon regarding the intended target(s) for a patient prior to the day of the procedure.
- No treatment is an emergency; therefore no case is to be booked for next day treatment without approval of the GK staff.
- Patients requiring on-going cardiac or respiratory monitoring should not be transported to the Department of Radiation Oncology or the Gamma Knife Center due to the potential for medical instability in an outpatient department. Only patients requiring anesthesia for treatment with the presence of appropriate anesthesia personnel would normally be allowed. If GK treatment is deemed appropriate, the patient should be stabilized to the point that monitoring is not necessary prior to transport to the department.
- For any patient having received prior radiotherapy, those records should be obtained and available for review ≥ 24 hours in advance of GK radiosurgery.
- For patients receiving prior radiation treatment to a nearby site, real or perceived, the new treatment plan must be reviewed with respect to the previous plan(s) by a secondary physicist. Image fusion for confirmation and a composite dose plan should always be considered.
- Standard of care for small cell lung and lymphoma is whole brain external beam radiation. Persistent lesions can be boosted with Gamma Knife treatment; GK may also be considered for progressive or recurrent lesions.
- If the patient has received prior radiotherapy, those records must be available at least 24 hours prior to the planned radiosurgery procedure.
- MRI scan of the entire brain must be done within 14 days of the planned SRS procedure if the slice thickness is more than 2 mm and can be up to but not exceeding 21 days if the slice thickness is 2 mm or less.
  - A contrast-enhancing tumor should be visualized not merely a flair/T2 abnormality alone
  - If there is a contraindication to MRI (e.g. pacemaker, internal metal hardware), a contrast CT scan may be substituted, recognizing the limitations for identifying elsewhere brain lesions
    - CT contrast dose may be reduced in the setting of contrast allergy, impaired renal function, solitary kidney, or dehydration
- Maximum dimension of a single lesion ≤ 4 cm*
  *The addition of whole brain RT should be strongly considered for lesions > 3 cm in size due to a high risk of local failure after SRS alone
  - Size limitation holds true for resected or unresected lesions
- Irrespective of tumor size or volume, if the radiographic tumor appearance is consistent with leptomeningeal disease whole brain RT would be indicated. Gamma Knife radiosurgery alone is not considered appropriate therapy for leptomeningeal
disease; whole brain RT is considered standard. Spinal imaging and/or CSF cytology should be considered as clinically appropriate in this setting.

- 1-4 metastatic lesions:
  - Combined target volume ≤ 34 cc
- 5-10 metastatic lesions, at least 1 of the following:
  - Combined target volume ≤ 34 cc
  - “Radioresistant” tumor histology & combined target volume ≤ 34 cc
    - Melanoma
    - Renal cell carcinoma
    - Sarcoma
  - Failure after whole or partial brain RT however integral dose and the Conformity should be considered
  - SRS may be considered according to overall tumor volume as described below
- ≥ 11 metastatic lesions:
  - Should generally receive primary treatment with whole brain RT pending bullet below
  - May consider boost treatment of a symptomatic or problematic lesion after whole brain RT
- For patients with > 3 lesions having a good performance status and low overall tumor volume, stereotactic radiosurgery may be considered according to the results reported by Chang et al. J Neurosurg 2010; 113 Suppl: 73-78 and Baschnagel et al (Beaumont) J Neurosurg 2013 119(5): 1139-44. A total tumor volume of > 2cc was predictive of overall survival in both these series.
- Brainstem lesions:
  - Although brainstem lesions could receive primary treatment with standard fractionated RT (whole or partial brain), for metastases from melanoma, renal cell, sarcoma (radioresistant histologies) and patients with limited disease from lung, breast or other histologies, radiosurgery alone can be considered as primary therapy.
  - Radiosurgery may also be considered with incomplete tumor response or tumor progression after prior therapy
  - Stereotactic radiosurgery may be considered for small isolated lesions < 2 cc.

### Approximate Tumor Volume by Maximum Tumor Size

<table>
<thead>
<tr>
<th>Lesion Maximum Diameter</th>
<th>Estimated Spherical Volume</th>
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</thead>
<tbody>
<tr>
<td>4.0 cm</td>
<td>33.5 cc</td>
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<tr>
<td>3.5 cm</td>
<td>22.4 cc</td>
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<tr>
<td>3.0 cm</td>
<td>14.1 cc</td>
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<tr>
<td>2.5 cm</td>
<td>8.2 cc</td>
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<tr>
<td>2.0 cm</td>
<td>4.2 cc</td>
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<tr>
<td>1.5 cm</td>
<td>1.8 cc</td>
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<tr>
<td><strong>1.0 cm</strong></td>
<td><strong>0.5 cc</strong></td>
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</tbody>
</table>

### Imaging Protocol
- The following 3 MRI scan sequences using single dose Gadolinium equivalent of the entire brain with the stereotactic frame in place on the day of the procedure (Reduced dose multihance may be used in the setting of impaired renal function)
  - An insulated frame/pins will be required for all cases

1-29-2014
- T1 FLASH MRI is the standard imaging platform for the 1 mm slice thickness images
- Standard T1 Axial Post-contrast images with a 5 mm slice thickness due to superior image quality
- FLAIR or T2 images for confirmation of edema to surround small enhancing lesions
- Any spectroscopic exams to determine tumor progression (areas within 6-10 mm of a previous radiosurgically treated volume) must be performed and results received 48 hours to 14 days prior to the newly scheduled Gamma Knife treatment.

**Target Definition**
- GTV = T1 Gadolinium enhancing tumor
- Treating Radiation Oncologist and Neurosurgeon must be in agreement with respect to the target definition.
- The combined treatment volume of all lesions should be assessed and compared to the total brain volume, especially in the patients who have received prior external beam therapy and/or chemotherapy.
- Volume of brain tissue greater or equal to 8 and 10 Gy should be evaluated as well.
- **Critical Structure Definition**
The following structures should be contoured when a lesion is located within 10 mm of the critical organ:
- Optic nerves – from the posterior aspect of the globe to the posterior aspect of the orbit
- Optic chiasm
- Brainstem – from the midbrain to the foramen magnum
- Motor cortex at the discretion of the treating physicians

**Dose Prescription**
- Dose should be prescribed to the isodose surface that encompasses the GTV (30-90% isodose line)
- For brainstem lesions, the prescribed marginal dose should be 10-15 Gy
- For all other lesions in non-eloquent areas, the prescribed dose should be 12-24 Gy
- RTOG criteria can be used as a general guideline based on lesion size:
  - Careful consideration must be paid to tumor and treatment volumes in addition to maximum linear dimensions.

<table>
<thead>
<tr>
<th>Lesion Maximum Dimension</th>
<th>Single Fraction Radiosurgery Dose*</th>
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<tbody>
<tr>
<td>≤ 2 cm</td>
<td>21-24 Gy</td>
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<tr>
<td>2-3 cm</td>
<td>18 Gy</td>
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<tr>
<td>&gt; 3 cm</td>
<td>15 Gy</td>
</tr>
</tbody>
</table>

*SRS dose for a boost in combination with whole brain RT to 37.5 Gy in 2.5 Gy fractions

- When treating multiple lesions in relatively close proximity, “crosstalk” should be minimized such that the dose to the area between the lesions is ≤ 10 Gy
- Critical structures should be considered for dose selection. A lower dose than described above may be selected for lesions close to critical structures

**Critical Structure Constraints**
### Critical Structure Maximum Point Dose Notes

<table>
<thead>
<tr>
<th>Critical Structure</th>
<th>Maximum Point Dose</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Optic Nerve/Chiasm</td>
<td>8-10 Gy</td>
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<tr>
<td>Cranial Nerves in the Cavernous Sinus</td>
<td>20-25 Gy</td>
<td>Motor nerves such as CN III-VI appear to tolerate a higher dose</td>
</tr>
<tr>
<td>Brainstem</td>
<td>10 -15 Gy</td>
<td>Except in the case of a brainstem lesion</td>
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</table>

- For any case in which a patient has received prior radiosurgery to the same or similar area, a secondary Physics check should be undertaken

### Follow-Up Schedule

- Brain MRI every 3 months for the first year then every 6 months. Typically the first post-GK MRI is obtained 6-8 weeks following treatment.
- The images, radiology report and the patient condition status should be copied to the Gamma Knife Center at Beaumont.

- PREPARED BY GK Management
Eligibility Criteria

- Surgical resection of a meningioma with appropriate pathological evaluation will typically be considered appropriate first line management.
- Gamma Knife may be considered as upfront therapy for tumors in difficult or high risk surgical locations, in patients medically unfit for surgery, and in patients that refuse surgery.
  - Radiosurgery is a common first line therapy for meningiomas of the skull base and/or cavernous sinus.
  - For these or similar high risk patients, biopsy would not be required (treatment according to imaging diagnosis).
- Post-operative treatment may be considered for sub-totally resected tumors, high risk gross totally resected tumors (such as atypical meningioma after fractionated RT or recurrent tumors after prior resection), and recurrent tumors.
  - Combination of Fractionated RT + radiosurgery should be considered in the case of atypical meningioma
- For lesions that are significantly close to the optic chiasm, a staged approach may be considered.
- Surgery initially should clearly be considered in cases with extensive edema to avoid persistent symptoms or complications after radiosurgery.
- All patients having tumors in close proximity to the optic nerves/chiasm should have a baseline Neuro-Ophthalmology evaluation and subsequent follow-up at the Ophthalmologist’s discretion.
- Tumors in the skull base/cavernous sinus region in close proximity to the pituitary should be considered for baseline and subsequent follow-up endocrine evaluations
- For any patient having received prior radiotherapy, those records should be obtained and available for review ≥ 24 hours in advance of GK radiosurgery.

Imaging Protocol

- Post-frame placement, thin-slice (1 mm), an axial T1 flash MRI scan encompassing the entire head.
- T2 or CISS MRI sequences may be considered depending on tumor location and for any cases involving the skull base or cavernous sinus region and requires the use of an insulated frame.
- Fat suppression technique should be considered in cases of prior surgery.
**Target Definition and Dose Prescription**
- PTV = GTV = visualized tumor
- Radiation Oncologist and Neurosurgeon should agree on the contoured tumor volume.
- Minimum dose is prescribed to the tumor margin (typically the 50% isodose line). Margin doses of 12-16 Gy should be considered if able to respect critical structure dose constraints.

**Critical Structure Dose Constraints**
- Cranial nerves in the cavernous sinus ≤ 26 Gy.
- Optic Nerves and Optic Chiasm ≤ 8-12 Gy depending on dose volume histogram analysis.
- Brainstem peripheral doses 10-15 Gy depending on tumor location.
- For any case in which a patient has received prior radiosurgery or radiotherapy to the same or similar area, a secondary Physics check should be undertaken.

**Follow-Up**
- Follow-up Imaging should be performed initially at 3-6 months depending on extent of edema, tumor location and grade (with neuro-ophthalmology and endocrinological evaluations if necessary), 12 months, and 24 months, and annually thereafter. MPRAGE T1 and T2 sequences would generally be required with fat saturation dependent on presence or absence of prior surgery.
- All follow-up information should be copied to the Gamma Knife Center at Beaumont.
Treatment Guidelines for Primary Brain Tumors

*Eligibility Criteria*

All patients planned to undergo Gamma Knife radiosurgery for “primary” brain tumors such as low or high-grade glial tumors and non-meningiomatous tumors should undergo a multi-disciplinary evaluation at the Beaumont Neuro-Oncology Tumor Board prior to a final decision to administer radiosurgery.

- Anticipated life expectancy at the time of primary brain tumor therapy > 3 months
- Karnofsky Performance Status ≥ 70
- Completion of fractionated external beam RT +/- chemotherapy as indicated according to histology as primary therapy.
  - For any patient having received prior radiotherapy, those records should be obtained and available for review ≥ 24 hours in advance of GK radiosurgery
  - After whole or partial brain RT, integral dose and the Conformity Index should be evaluated
- Preoperative images are to be available for review no later than 48 hours after a tentative date is booked.
- No treatment is an emergency; therefore no case is to be booked for next day treatment.
- Persistent lesions can be considered for Gamma Knife radiosurgery.
- Resection cavities may be considered for Gamma Knife radiosurgery, however, as primary therapy, a planned boost has not been proven beneficial. Therefore, such cases would typically be in the setting of resected recurrent lesions.
- MRI scan of the entire brain within 14 days of the planned GKRS procedure if the slice thickness is more than 2 mm and can be up to but not exceeding 21 days if the slice thickness is 2 mm or less.
  - If there is a contraindication to MRI (e.g. pacemaker, internal metal hardware), a contrast CT scan may be substituted

Maximum dimension of a single lesion ≤ 4 cm*unless it is a resection cavity and the preoperative tumor size was limited to a similar 4 cm maximum target volume ≤ 34 cc although resection cavities may sometimes be slightly larger
  - Failure after whole or partial brain RT however integral dose and the Conformity Index should be evaluated

Radiosurgery may be considered with incomplete tumor response or tumor progression after prior therapy
**Imaging Protocol**
- MRI should include single Gadolinium or its imaging equivalent using 1 mm slice thickness through the entire brain.
  - Multihance may be used in the setting of impaired renal function
- A 3 Tesla imaging study using Multihance can be used preoperatively which can be fused with the MRI performed on the day of treatment.
- MRI scan (single dose Gadolinium equivalent) of the entire brain with the stereotactic frame in place on the day of the procedure
- Any spectroscopic exams to determine tumor progression must be performed and results received 48 hours to 14 days prior to the newly scheduled Gamma Knife treatment.

**Target Definition**
- GTV = T1 Gadolinium enhancing tumor
- Treating Radiation Oncologist and Neurosurgeon must be in agreement with respect to the target definition.
- The treatment volume should be assessed and compared to the total brain volume, especially in the patients who have received prior external beam therapy and chemotherapy.
- Volume of brain tissue greater or equal to 8 and 10 Gy should be evaluated as well.

**Critical Structure Definition**
The following structures should be contoured when a lesion is located within 10 mm of the critical organ:
- Optic nerves – from the posterior aspect of the globe to the posterior aspect of the orbit
- Optic chiasm
- Brainstem – from the midbrain to the foramen magnum
- Motor cortex at the discretion of the treating physicians

**Dose Prescription**
- Dose should be prescribed to the isodose surface that encompasses the GTV (30-80% isodose line)
- For brainstem lesions, the prescribed marginal dose should be 10-15 Gy
- For Ependymomas, depending on the treatment volume, 10-22 Gy marginal dose may be considered appropriate.
- For Low Grade Astrocytomas, depending on treatment volume and location, 10-16 Gy marginal dose may be considered appropriate.
- For High Grade Gliomas: the younger the age, the higher the KPS, and the smaller the volume, the better the survival. A marginal dose of 10-28 Gy may be considered appropriate.

Critical structures should be considered for dose selection. A lower dose than described above may be selected for lesions close to critical structures.
## Critical Structure Constraints

<table>
<thead>
<tr>
<th>Critical Structure</th>
<th>Recommended Maximum Point Dose</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optic Nerve/Chiasm</td>
<td>8-10 Gy</td>
<td>Motor nerves such as CN III-VI appear to tolerate a higher dose</td>
</tr>
<tr>
<td>Cranial Nerves in the Cavernous Sinus</td>
<td>20-25 Gy</td>
<td></td>
</tr>
<tr>
<td>Brainstem</td>
<td>10 -15 Gy</td>
<td>Except in the case of a brainstem lesion</td>
</tr>
</tbody>
</table>

- For any case in which a patient has received prior radiotherapy or radiosurgery to the same or similar area, a secondary Physics check should be undertaken

### Follow-Up Schedule

- Brain MRI every 2-3 months for the first year then every 6 months
- The images, radiology report and the patient condition status should be copied to the Gamma Knife Center at Beaumont.
Eligibility Criteria

- Prolactinoma
  - Postoperative in cases of incomplete resection or persistent hormone elevation in patients not responsive to medical management (i.e. bromocriptine)
  - Recurrent, symptomatic tumors refractory to medical management
  - Definitive therapy in patients with tumors who are refusing surgery

- All Other Endocrine-Active Tumors (GH, ACTH, TSH, LH/FSH)
  - Postoperative following subtotal surgical resection evidenced by imaging or persistent postoperative endocrine abnormality
  - Definitive therapy in those patients not medically operable or refusing surgery
  - Recurrent tumors (definitive or postoperative)
  - Cases of persistent endocrine abnormality likely will require continued medical management as latency for normalization following radiosurgery may be as long as 1-2 years

- In the case of Secretory tumors, Endocrine agents such as Octreotide and Bromocriptine have been shown to confer relative radioresistance to tumors undergoing stereotactic radiosurgery.
  - These agents should be stopped at least 4-6 weeks prior to GK
  - They generally may be resumed approximately 4 weeks post-radiosurgery

- Nonfunctioning Pituitary Adenoma
  - Postoperative following subtotal surgical resection
  - Definitive therapy in medically inoperable patients or in those refusing surgery
  - Baseline Neuro-ophthalmology and Endocrinology exams must be performed as well as subsequent follow up exams.

- Maximum lesion dimension is suggested not exceed 4 cm

- Radiosurgery should not be performed in any patient with a pituitary tumor identified in the near-postpartum period, i.e. within 6 months post-partum.

- For lesions that are significantly close to the optic chiasm, a staged approach could be considered

- All patients should have baseline Endocrinology evaluation and follow-up

- All patients should have baseline Neuro-Ophthalmology evaluation and subsequent follow-up at Ophthalmologist’s discretion

- For any patient having received prior radiotherapy, those records should be obtained and available for review ≥ 24 hours in advance of GK radiosurgery
**Imaging Protocol**
- The frame should be placed to allow optimal visualization of the optic apparatus in as planar a fashion as possible
- Post-frame placement, thin-slice (1 mm), multiplanar (axial, coronal, sagittal) MRI scan encompassing full tumor extent performed with 5 cc (reduced, 50% dose) Gadolinium, generally MPR/T1 FLASH
- Fat suppression technique is useful in cases of prior surgery
- CISS or T2 sequences may be considered and commonly aid in definition of the optic apparatus and require the use of insulated pins

**Target Definition and Dose Prescription**
- PTV = GTV = visualized tumor
  - Minimum dose is prescribed to the tumor margin (typically the 50% isodose line)
  - Non-functioning adenoma dose = 12-16 Gy
  - Doses required to control endocrine hyperactivity are higher than those required to control physical tumor growth
    - Minimum prescription dose of 20-25 Gy
    - Margin doses of 30-35 Gy should be considered if able to respect critical structure dose constraints

**Critical Structure Dose Constraints**
- Optic apparatus
  - Non-functioning adenoma ≤ 8 Gy
  - Significant endocrine abnormality ≤ 10-12 Gy
- Cranial nerves in the cavernous sinus ≤ 20-25 Gy

- For any case in which a patient has received prior radiosurgery to the same or similar area, a secondary Physics check should be undertaken

**Follow-Up**
- Follow-up Imaging should be performed at 6 months (with neuro-ophthalmology testing and endocrinological bloodwork), 12 months, and 24 months. This should be done using MPRAGE T1 and T2 fat saturation depending on prior surgery.
- All follow-up information should be copied to the Gamma Knife Center at Beaumont