The Gamma Knife Experience at Sacred Heart

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Lars Leksell

Pioneer stereotactic neurosurgeon
Creator of the Leksell stereotactic frame
Designer of the Gamma Knife
What is radiosurgery?*

- Radiation energy is focused into a small volume of soft tissue.
- This volume must be well defined regarding localization, size and shape.
- The energy is delivered in one single session, with patient immobilization required.

*Therefore the radiation energy must be delivered selectively to the volume and the radiosurgical procedure must be reproducible.*

* Prof. Lars Leksell and Prof. Börje Larsson
Schematic of Talairach based system

- Talaraich frame
- 10 MeV Linear accelerator
- Pnemoencephalograph chair
Collimator

- Lead lined
- Fits to linear accelerator
- Permits focus and narrows shape of emitted beam
Stereotactic ventriculogram

- Frame applied
- Ventricle cannulated
- Contrast injected
- Tele-radiograph obtained
Talairach atlas
Correlation to atlas ("Reperage")

- Stereotactic teleradiograph
- Talairach atlas overlay
- Dose planning by hand
Dose and arc planning

- Tracing made of teleradiographs
- Trajectories plotted (by hand) for arcs of radiation
- Vital anatomic structure location drawn from Talairach atlas
Talairach system (Buenos Aires)
Talairach system (Buenos Aires)

- Talairach frame
- Linear accelerator
- Pneumoencephalograph chair
Linac based SRS

- Standard stereotactic frame
- Horizontal couch mounted on turntable
Gamma Knife

- Leksell frame
- Helmet with 201 precisely milled collimators
- Radial arrangement
- Collimator width is changeable
The Gamma Knife

**Treatment Method**
Gamma Knife Surgery is a bloodless surgery for neurological diseases. The surgery does not require the skull to be opened for performance of the operation. The patient is treated in one session and can normally return home shortly after treatment.

The method facilitates treatment of very small targets deep within the brain.

The patient’s head is positioned by affixing a head frame. Then 201 radioactive beams are focused through a metal helmet toward the target treatment area of the brain.

*Gamma Knife Surgery*
Gamma Knife U.S. Installations
103 as of December 2005
Gamma Knife model 4C
Gamma Knife Model 4C
The Gamma Knife at Sacred Heart
The Gamma Knife at Sacred Heart
Clinical solutions / number of beams

Leksell Gamma Knife®
Multiple small isocenters
- High selectivity achieved
- Minimized risk for complications

Helmets
Collimator sizes:
4, 8, 14, & 18 mm
Clinical solutions / number of beams

Leksell Gamma Knife®
Multiple small isocenters
- High selectivity achieved
- Minimized risk for complications

Linac μMLC
One isocenter
- More healthy tissue irradiated gives a higher risk for complications
- Fractionation necessary
Selectivity in radiosurgery

[Se-lec-ti-vi-ty] describes how well a desired biological effect is achieved in a target volume without complications.
Filling the target with dose...

Target + “Shots” = Target “filled” with dose

Use of different collimators and weights

Use of different positions (i.e. Isocenters) of the shots
Selectivity in radiosurgery

- **Conformity** describes how well the prescription dose is fitted to the target volume.
- **Selectivity** also takes irradiation to normal tissue into account.
High Conformity - Low Selectivity
High Conformity - High Selectivity
Indications for Gamma Knife® surgery

Vascular Disorders
- AVM
- Aneurysm
- Cavernous Angiomas
- Other Vascular

Benign Tumors
- Vestibular Schwannoma
- Trigeminal Schwannoma
- Other Schwannoma
- Benign Glial Tumors (Grade I+II)
- Meningioma
- Pituitary Adenoma (Secreting)
- Pituitary Adenoma (Non-secreting)
- Pineal Region Tumor
- Hemangioblastoma
- Hemangiopericytoma
- Craniopharyngioma
- Chordoma

Malignant Tumors
- Malignant Glial Tumor (Grade III+IV)
- Metastatic Tumor
- Chondrosarcoma
- NPH Carcinoma
- Other Malignant Tumors

Functional Disorders
- Trigeminal Neuralgia
- Parkinson's Disease
- Intractable Pain
- Epilepsy
- OCD
- Other Functional

Ocular Disorders
- Uveal Melanoma
- Glaucoma
- Other Ocular Disorder

Source: Leksell Gamma Knife Society, June 2004
Scientific Validation of Gamma Knife Radiosurgery

- Clinical existence over 40 years with 20 years of rapidly expanding growth and validation
- 5 generations released to date
- Peer-review locally and internationally.
  - 18th meeting of Leksell Gamma Knife Society
- >340,000 patients treated worldwide
- >2,000 peer-reviewed publications to date
- 15 year follow-up shows clinical success, low morbidity
Trigeminal Neuralgia Treatment Paradigm

- Medically refractory
- Age
- Percutaneous rhizotomy vs. SRS vs. microvascular decompression
- Options for treatment failure
- Repeat SRS
Trigeminal Neuralgia

Dose plan

6 months post

Courtesy: Douglas Kondziolka, MD, MSc, FRSC, University of Pittsburgh, USA
Results in Trigeminal Neuralgia

- Pain relief after GK @ 6 mo
  - Excellent 65%
  - Good/excellent 86%

- 5 yr FU
  - Excellent 40%
  - Good/excellent 55%
  - >50% relief 69%

- Recurrence 14% at 5 years

Lunsford, J NS, 2001
Acoustic Neuroma

Pre 6 months post 2 years post

Courtesy: Douglas Kondziolka, M.D., M.Sc., FRCS, University of Pittsburgh, USA
Treatment of Vestibular Schwannoma

- Observation
- Craniotomy
- Stereotactic radiosurgery
Appropriate Candidates: Microsurgery

- Large tumors in young patients
- Mass effect on the brainstem
- Patient choice
- Tumor recurrence after radiosurgery
Results of Surgery for VS

- Complete surgical removal: 97%
- CSF leakage: 30%
- Meningitis: 6%
- CVA: 1%
- Mortality: 1%
- Hearing preservation
- Facial motor preservation
<table>
<thead>
<tr>
<th>Tumor size</th>
<th>CN 7</th>
<th>CN 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 cm</td>
<td>95%</td>
<td>57%</td>
</tr>
<tr>
<td>1-2 cm</td>
<td>80-92%</td>
<td>33%</td>
</tr>
<tr>
<td>2 cm</td>
<td>50-75%</td>
<td>6%</td>
</tr>
</tbody>
</table>
Appropriate Candidates: Gamma Knife

• Size <3 cm extracanalicular diameter
• Elderly, medically infirm
• Hearing preservation
• Recurrent or residual after surgery
• Patient choice
Long Term Outcomes in Vestibular Schwannomas (w/ GK)

- Tumor control 98%
  - Previous surgery in 26%
- Surgery performed in 2%
- Normal facial function after 5 years 79%
- Unchanged hearing 51%
- No new deficits after 28 months

- Modification of doses
- Collimator selection and dose planning

Flickinger, NEJM, 1998
Treatment of choice

"Vestibular Schwannoma Management in the Next Century: A Radiosurgical Perspective"

Number of Cases

Arteriovenous Malformation (AVM)

- 37 year old female treated with Gamma Knife® surgery for 4.0cc AVM on Nov 11, 1995
- 23 Gy to the 50% isodose
- Follow-up Oct 25, 1999 with complete obliteration
- The patient remains well

Pre treatment

25 months post treatment

Courtesy: Aizik Wolf, M.D., Sam Coy, Ph.D., Miami Neuroscience Center, Coral Gables, Florida
Arteriovenous Malformation (AVM)

Pre Gamma Knife® surgery

2 years post Gamma Knife® surgery

Courtesy: Douglas Kondziolka, M.D., M.Sc., FRCS, University of Pittsburgh, USA
Metastasis

Pre

10 months post

Courtesy: Aizik Wolf, MD, Miami Neuroscience Center, USA
Metastasis

Pre 2 months post

Courtesy: Douglas Kondziolka, M.D., M.Sc., FRCS, University of Pittsburgh, USA
Cerebral metastases treatment paradigm

• Extent of disease
  – Solitary vs. single brain met

• Cranial radiation
  – WBXRT
  – SRS
  – Timing which goes first
  – Deciding which to exclude (if either)
Appropriate Candidates

- Size: generally <3 cm
- Number of lesions
- Mass effect
- Cerebellar mets?
- Brainstem mets?
- Randomized trial: WBRT vs. WBRT + GK
- Traditionally radioresistant mets: renal, melanoma, sarcoma are appropriate candidates for GK radiosurgery
Results in Metastatic Brain Lesions

- Local tumor control 85%
- Recurrence 5-15%

Larson et al., 1994

- Local control:
  - WBRT 100% (6 mo. MTTF)
  - +GK boost 8% (36 mo. MTF)

Flickinger et al., 1999
Functional disorder

Figure A
Handwriting sample from a 76 year old woman with longstanding essential tremor before Gamma Knife® surgery.

Figure B
The left Gamma Knife thalamotomy could be seen 4 months later after a max. dose of 140 Gy delivered with a single 4mm isocenter.

Figure C
Handwriting sample four months after Gamma Knife® surgery showed that her tremor had resolved.

Courtesy: L. Dade Lunsford, M.D., and Douglas Kondziolka M.D., University of Pittsburgh, USA
Examples of treated indications

**Vascular**
- Arteriovenous malformations
- AV fistulas

**Tumors**
- Meningioma
- Pituitary
- Acoustic Neuroma
- Metastases
- Gliomas

**Functional**
- Trigeminal neuralgia

**Research areas**
- Movement disorders
- Intractable pain
- Cluster headache
- Epilepsy
- Glaucoma
- Uveal melanoma
- OCD
Patient Experience
Treatment by Diagnosis

Procedure by Diagnosis

- Metastasis: 54%
- Trigeminal Neuralgia: 26%
- Meningioma: 8%
- Acoustic Neuroma: 5%
- Glioma: 3%
- AVM: 2%
- Other: 2%
Quality Measures

- Patient Satisfaction
- Significant Complication at 1st day post op & 30 days post op
- Significant Complications & Pain Scores on 30 day post op
- No Mortality or tumor reduction/elimination data available
Survey Questions

- Were the written discharge instructions helpful to you? 0% N 100% Y
- Any fever? 0% N 100% Y
- Pin site redness? 1% N 99% Y
- Pin site swelling? 17% N 83% Y
- Pin site drainage? 12% N 88% Y
- Any problem you would like us to know about? 11% N 89% Y
- Has your pain medication been effective in controlling any discomfort? 11% N 89% Y
- Are you having any nausea or vomiting? 5% N 95% Y

% Yes or No Answers
### 30 Day Post Op Complications & Pain Scores

<table>
<thead>
<tr>
<th>Survey Questions</th>
<th>% Yes</th>
<th>% No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any concerns you would like us to know about?</td>
<td></td>
<td>82%</td>
</tr>
<tr>
<td>Have you had your Post-Op appointment with the Neurosurgeon and/or Rad Onc?</td>
<td></td>
<td>64%</td>
</tr>
<tr>
<td>Are you taking any steroids now?</td>
<td></td>
<td>78%</td>
</tr>
<tr>
<td>Are you having any problems with your pin sites?</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Has your pain medication been effective in controlling your discomfort?</td>
<td></td>
<td>67%</td>
</tr>
<tr>
<td>Are you having any facial pain?</td>
<td></td>
<td>64%</td>
</tr>
<tr>
<td>Are you having any headache pain?</td>
<td></td>
<td>81%</td>
</tr>
<tr>
<td>Are you having any pain related to your GK surgery?</td>
<td>11%</td>
<td></td>
</tr>
</tbody>
</table>

*Note: The chart shows the percentage of yes and no answers for each question.*
Patient Satisfaction

Gamma Knife Center
Patient Satisfaction - Question-by-Question PMAS Scores
2008

Percent Maximum Achievable Score (%MAS)

<table>
<thead>
<tr>
<th>Question</th>
<th>2008 Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting Time</td>
<td>100.0%</td>
</tr>
<tr>
<td>Courtesy of Staff</td>
<td>99.4%</td>
</tr>
<tr>
<td>Willing to Discuss</td>
<td>99.4%</td>
</tr>
<tr>
<td>Genuineness</td>
<td>100.0%</td>
</tr>
<tr>
<td>Attitude</td>
<td>99.4%</td>
</tr>
<tr>
<td>Explain/Clearly</td>
<td>99.4%</td>
</tr>
<tr>
<td>Coordination</td>
<td>100.0%</td>
</tr>
<tr>
<td>Emotional Need</td>
<td>100.0%</td>
</tr>
<tr>
<td>Privacy Need</td>
<td>99.4%</td>
</tr>
<tr>
<td>Communication</td>
<td>100.0%</td>
</tr>
<tr>
<td>Marketing Themselves</td>
<td>99.4%</td>
</tr>
<tr>
<td>Overall</td>
<td>99.4%</td>
</tr>
<tr>
<td>Recommend</td>
<td>97.6%</td>
</tr>
</tbody>
</table>
What’s Gone Well

- Trigeminal Neuralgia cases more than expected
- High patient and physician satisfaction
- Efficient Expense management
- Physician champions
- Successful Multi Disciplinary Model with Neurosurgery and Oncology
Challenges

- Despite Gamma’s “Gold Standard” status for treating brain mets,
  - not embraced by oncologists over whole brain radiation in many communities
  - Locally placed technologies continue to prevail as only available treatment option in many communities
  - Many patients remain unaware of Gamma Knife as a treatment option for a variety of conditions