Not for the Faint of Heart: Functional Radiosurgery
Functional radiosurgery with Gamma Knife
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Conflicts of interest

No conflicts
Learning Objectives (for this section)

1. Review some less common functional indications treated with Gamma Knife Radiosurgery
2. Understand how the design of the Gamma Knife supports its use for functional SRS
3. Summarize some important techniques that can help mitigate treatment risk when treating functional SRS on the Gamma Knife platform

Part 1: Indications
Glossopharyngeal neuralgia max dose: 75-90 Gy

Obsessive-compulsive disorder max dose: 120-180 Gy

Movement disorders max dose: 120-140 Gy

Glossopharyngeal (CN IX) neuralgia

Stabbing pain similar to trigeminal neuralgia, but affects ear, tongue, and throat.

Target is the glossopharyngeal nerve at the level of the glossopharyngeal meatus of the jugular foramen.

Difficult to visualize so CT/MR fusion often used.

Single 4mm isocenter used for treatment.

~80 Gy maximum dose (similar to trigeminal neuralgia SRS)
Movement disorders (essential tremor, Parkinson’s disease)

Goal is to modulate motor fibers running from the thalamus to the motor cortex (radiosurgical thalamotomy)

nucleus ventralis intermedius (Vim) of thalamus

FGATIR MR – coronal view

Targeting the VIM nucleus

VIM nucleus difficult to visualize. Targeting performed using Talairach atlas-derived rules:

1. Define AC-PC line and interhemispheric fissure

2. Lateral (X): 50% of 3rd ventricle width + 11 mm

3. Anterior (Y): 25% of the distance from PC to AC

4. Superior(Z) : 2mm superior of AC/PC line

5. Single 4mm isocenter Max dose = 120-150 Gy

Obsessive Compulsive Disorder

Goal is to modulate sensory fibers running from the thalamus to the orbitofrontal cortex (radiosurgical capsulotomy)

Lesions are targeted at the anterior limb of the internal capsule

Usually single 4mm isocenter each side

Max dose = 120-180 Gy (IRRF multicenter study median 135 Gy¹)

Image from: https://psychology.wikia.org/ ¹A. Gupta et al., Neurosurgery 85(6), 2019

Part 2: Gamma Knife and functional SRS
Functional radiosurgery is the **original** radiosurgery!

Lars Leksell with arc-centered stereotactic frame

Gamma Knife with external collimator helmet (with Lars Leksell and Ladislau Steiner at the Karolinska Institute)

Close-up view of rectangular collimator apertures

Designed to create radio-lesions similar to proton experiments


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Spreading out energy is the key to SRS

Technical requirement to create many individual small beams led directly to the use of $^{60}$Co

Spreading the energy out generates steep dose gradients that concentrates dose on the target

**Perfexion/Icon**: 192 beams / isocenter

Total # beams in plan = # isocenters * 192 (if no blocking)
Patient positioning accuracy and precision

Planned – achieved PPS position (µm)

X drive
Y drive
Z drive

n=53833 shots (8.3 years)

Mean PPS difference: 32.7 µm

97.5% of all shots within 70.1 µm

Human hair ~75 µm


Stereotactic frames provide immobilization

SRS frames provide for low setup uncertainty and robust immobilization.
Practically limits treatment to single fraction.
Looks more invasive than it really is.

Li, et al., IJROBP 2016.
Part 3: Imaging for functional SRS

**Steady-state sequences (CISS/SPACE/FIESTA-C)**

CISS: Constructive Interference in Steady State

SPACE: Sampling Perfection with Application-optimized Contrasts by using different flip-angle Evolutions

FIESTA: Fast Imaging Employing Steady-state Acquisition

Use RF-pulses to refocus echoes and maintain a steady-state net magnetization

Creates bright CSF signal, dark tissue

Good for visualizing fine structures in CSF

Image courtesy of University of Virginia

S. Stuckey, et al., AJNR 18, 1996
Specialized sequences: FGATIR

FGATIR: Fast Gray Matter Acquisition T1 Inversion Recovery

Similar in idea to MP-RAGE, but selected inversion time (TI) nullifies white matter signal

Allows better visualization of deep grey matter structures

FGATIR image used for an OCD treatment

Image courtesy of University of Virginia


Part 4: How to be safe
Stereotactic frame QA with onboard CBCT

Icon CBCT scans are acquired in stereotactic space.

Can be used as an independent measure of spatial localization.

We use it as a last-chance QA that all is well with the frame placement.

Don’t forget imaging QA!

Regular QA of imaging systems is critical for SRS!
This includes after hardware/software upgrades.
Make sure distortion correction is applied!

MRI is subject to system-level and patient-specific distortions.
Manufacturers have corrections for some system-level causes (gradient nonlinearities).
Make sure they are commissioned and applied!

We find it useful to compare to CT.

Learn from collective experience

Data is sparse for many functional indications.
Multi-center studies may provide helpful guidance.
If you experiment, formalize as an approved clinical trial!
Follow consensus recommendations

Require credentialing and training

"If the radiation oncologist's formal training did not include SRS/SBRT, then specific training in SRS/SBRT, including a minimum of 5 CME credit hours and direct observation of treatment of at least 3 different patients, should be obtained prior to performing any SRS or SBRT procedures"

Even more critical for functional SRS!
Summary: Functional radiosurgery really is different!

Treating “normal” brain
Targets are very small
Doses are very high
Safety first!

Max dose (Gy)

- Brain metastasis
- Trigeminal neuralgia
- Vestibular schwannoma
- Arteriovenous malformation
- Movement disorders
- Obsessive-compulsive disorder

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NOT safety first! Don’t do this!
(unless the unit is unloaded)