Concepts of Plan evaluation in SRS / SRT

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Outline of the Presentation

• Introduction to SRS
• Brief History
• Radiobiological principles of SRS
• Workflow
• Different delivery systems of SRS
• Concept of Plan Evaluation
• Quality Assurance
BRIEF HISTORY OF RADIOSURGERY

- Termed “stereotactic radiosurgery” - 1951
- Used orthovoltage to treat Trigeminal neuralgia
- Leksell+ Borge Larsson- 1st SRS Gamma unit using 179 Cobalt 60 was installed at Sophiahemmet Hospital in 1968
- 2nd at Karolinska Hospital Stockholm in 1974
- Megavoltage x ray beams from isocentric linacs are used in radiosurgery since the mid 1980s.
- Ernest Spiegel and Henry Wycis created a stereotactic frame for human patients
Characteristics of SRS

• Highly conformal and High Precision
• High Accuracy - Positional (+/- 1mm)
• Focal irradiation - Lesion size <= 3cm
• Ablative doses: 12-24Gy margin dose
• Single Fraction (MF → SRT)
• Intracranial +/- Spine
• Minimally-invasive (Gamma knife)
• Multiple, converging beams
• Rapid dose fall off at the edge of target
Indications of SRS

- **Vascular lesions**: AVM, Acoustic neuroma
- **Functional disorders**: Trigeminal neuralgia, Parkinson’s disease, Intractable Epilepsy
- **Primary benign tumours**: Pituitary adenoma, Meningioma
- **Primary malignant tumours**: GBM, Pineal tumour
- **Metastatic tumours**: *SRS alone
  *WBRT f/b SRS
  *SRS f/b WBRT
  *fSRS / SRT
  *Re-RT setting
Does 4 R’s of Radiobiology hold significance in SRS?
Radiobiology of SRS

- Endothelial Cell Apoptosis Theory
- Vascular Damage
- Anti-tumour Immunity & Abscopal Effect
"We conclude that the available preclinical and clinical data do not support a need to change the LQ model or to invoke phenomena over and above the classic 5 Rs"

"Excellent results obtained from clinical studies are the result of the much larger BED that are delivered with SRS"
Invasive

Painful: Patient head is fitted with a localizer frame

Same day t/t: Can not be protracted

Non Invasive

Painless - May be claustrophobic

Can be protracted over time & fractions
Gamma Knife

Both Farmless and invasive frame is possible

Nonuniform dose distribution-Dose prescription (50%)-

LINAC

Both Farmless and invasive frame is possible

Uniform or non uniform Dose distribution- Prescription is at 80% or volumetric
We will restrict our discussion on dose evaluation in the LINAC based Stereotaxy: GK has limited application.
### Stereotactic Devices and Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Intracranial</th>
<th>Extracranial</th>
<th>Motion Management</th>
<th>Arc Therapy</th>
<th>Multifraction</th>
<th>Adaptive</th>
<th>Cone-Beam CT</th>
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<tbody>
<tr>
<td>Cyberknife</td>
<td>Yes</td>
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<td>Yes</td>
<td>No</td>
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<td>Gamma Knife</td>
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<td>No</td>
<td>No</td>
<td>Yes&lt;sup&gt;b&lt;/sup&gt;</td>
<td>No</td>
<td>Yes&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>TrueBeam/Trilogy</td>
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<td>Yes</td>
<td>Yes</td>
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<td>No</td>
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<td>Tomotherapy</td>
<td>Yes</td>
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<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<sup>a</sup>Can treat upper cervical spine.

<sup>b</sup>Gamma Knife Icon only.
Flowchart of a typical course of Radiotherapy

**PRE RT WORKUP**
- Diagnosis
- Patient history
- 3D imaging and staging
- Multi-Disciplinary Tumor Board

**RADIOTherapy Preparation**
- Immobilization
- 3D planning
- Delineation of volumes of interest (VOIs), e.g., GTV, CTV, OAR

**PlANNING**
- Planning aims
- Optimized treatment plan
- Prescription and technical data
- Accepted treatment plan

**DELIVERY**
- Setup patient with immobilization
- Image verification
- Adjust setup
- Treat

**PLAN ADAPTATION (if necessary)**
- Evaluate dose delivered
- Evaluate images and create new VOIs

**RECORD AND REPORT**
- Record
- Level 2 or 3 Reporting
CB-CHOP: A simple acronym for evaluating a radiation treatment plan

- Contours: Review target volumes and OARS
- Beam Arrangements/Fields: Appropriate and reasonable
- Coverage: Evaluate on graphic plan and DVH
- Heterogeneity/Hot Spots: Value and location
- Organs at Risk: Review specified constraints, corresponding isodose lines on plan, and DVH
- Prescription: Total dose, dose per fraction, and image guidance
Basic imaging requirements as pre-planning

CT Scan:

• Slice thickness- 1mm.

• Adequate planning CT scan.

• Minimum 10 cm beyond t/t borders (more for Non-coplanar)

• Vertex to Neck

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MRI

CT
Basic imaging requirements as pre-planning

MRI
• High resolution Imaging for target delineation - Planning MRI.
• (3DFSPGR with contrast.
• 1mm slice & continuous
• No Tilt
• DICOM format
Stereotactic Imaging-DSA (2D Imaging)

- Angio (DSA) – For Nidus delineation (for AVM only)
- MR-Angio - Nidus delineation
• Triple layered fine mesh thermoplastic mask used for rigid immobilization.

• Planning CT done with a localiser BOX to get a stereotactic co-ordinate.

• Localiser Box generates a stereotactic isocentre w.r.t patient anatomy and LINAC isocentre.
CT and MRI Fusion

- Aim to maximize *similarity* between the images.

- T1 contrast guides us an exact extent

- T2 FLAIR sequence gives us an idea about the edema.
CONTOURS

• Review the **delineated target volume**.

• Review if **OARs** are contoured accurately.

• Review if a structure is **forgotten / mistakenly not contoured**.

• Review **accuracy of expansions**.

  e.g., GTV may have been modified without appropriate re-expansion of the corresponding CTV and PTV not done.
OAR in Brain RT

- Optic Apparatus:
  - Optic Nerve
  - Optic Chiasma
  - Brainstem
  - Hippocampus
  - Eye (as a surrogate for retina)
  - Lens (replaceable)

- Name OAR and PRV separately
  - e.g. Left Optic Nerve, PRV

Dose constrains in brain

Organs at risk in the brain and their dose-constraints in adults and in children: A radiation oncologist’s guide for delineation in everyday practice

Scoccianti, 2014, R & O
Delivery Techniques

- MLC
- VMAT
- IMRT
- 3DCRT-Static F
- Cone

- Sharp fall off outside PTV
- Inhomogeneous dose inside PTV
- Multiple non co-planner beam or arc are needed to create conformal dose distributions.
How to choose the technique

Clinician/Physicist to decide:

- **VMAT**: Standard arcs, usually only 1 set of coplanar and 1 set of non-coplanar beams.
- **VMAT**: Easy and first delivery.
- **3DCRT/IMRT**: Multiple beams in non-coplanar geometry.
- **3DCRT**: Longer delivery time.
- Ease and comfort of patient is very important.
- Imaging like CBCT can’t be done in Non coplanar beams.

Dose Coverage

- Ideal GTV $V_{100\%} \geq 95\%$ and $V_{90\%} > 99\%$
- Dmax – Inside the GTV
- Prescription isodose: 50 to 90%

3DCRT / IMRT: Couch rotation isocentre have to be very accurate
Delivery Techniques: 3DCRT

All techniques are equally effective depending on the efficiency of the treatment planner.

3D CRT – Multiple Coplanar and Non coplanar beams- creates a very confirm dose distribution.
Similarly IMRT can be used effectively preferably having same beam arrangement that of 3DCRT for similar dose falloff characteristics.
3DCRT VS VMAT

- We shouldn’t get carried away on the techniques.
- Every technique is good to produce a desired dose fall off by efficient treatment planner.
To Remember: Something basic

- Try to confine the beams only to the ipsilateral hemisphere of the brain for lateralise tumour.
- Co-planar arcs may be better to avoid low dose spill to normal brain.
- More beams may mean more Monitor units (MUs).
- Avoid entry points in previously treated areas (In Re-RT settings)
**Prescription: Linac Based Stereotaxy**

Classical X-Knife prescription is 80% coverage with 100% Hot spot

**What dose it mean?**

- Put beams to Create a dose distribution
- Find the covering isodose (it may be 93%) – re-normalised it to 80%RxD. So tumour covered by 80% and adjust the hot spot inside the tumour to 100% by altering beam/arc weights, angle etc

**Modern Equivalence**

- Tumour covered by 100% hot as 120%
- Why Shifted?
- As modern TPSes have shifted from relative to volumetric prescription.
High Dose Spillage

- $V_{105\%}$ should ideally be < 15% of GTV volume.
Intermediate Dose Spillage

- $R_{50\%} = V_{50\%}/GTV$ volume.

- *Dose gradient: Volume enclosed by 50% isodose*

  Ideal value < 4.6
What risks of tumor under dosage to accepted to avoid exceeding a certain level of toxicity, or what risks of toxicity to accept to ensure optimal treatment of the tumor?
Prescription: Linac Bases Steriotoaxy

Core Hot Or Cold or Uniform Plan?

Depends on the clinical scenario
(Volume of hypoxic cell, vicinity of OAR’s)

**CORE UNIFORM**

\[ D(100\%-98%) \rightarrow V(100\%-98\%) \]

\[ D_{\text{max}} \leq 110\% \]

or

**CORE HOT**

\[ D(100\%-98\%) \rightarrow V(100\%-98\%) \]

\[ D_{\text{max}} \leq 120\% \text{ at the core} \]
Prescription: Linac Bases

Steriotaxy

Core Hot Or Core Uniform?

D_{max} = 12 Gy

Prescription 12 Gy

D_{max} = 12 Gy

0% RxD
$D_{\text{max}} = 26 \text{ Gy}$

Prescription $= 25 \text{ Gy}$
Can we always get good dose distribution??
Yes : For isolated tumours
No : For OAR invaded tumours
What to do if PTV is abutting an OAR (Brainstem)?

1\textsuperscript{st} option: Compromise the PTV:
As you are not supposed to change the OAR.

2\textsuperscript{nd} option: Do not compromise the PTV:
Use PTV Under Dosing (\textit{in Selective areas}) to achieve OAR tolerance doses.

2\textsuperscript{nd} option is commonly opted.
Some Definitions: What is Coverage and Spillage?

**Target Coverage**

\[ C = \frac{V_D \times V_T}{V_T} \]

**Coverage**

**Plan Selectivity**

\[ S = \frac{V_D \times V_T}{V_D} \]

**Spillage**

- **VT** = Target volume
- **VD** = Volume receiving dose D (i.e. prescription volume)
- **D** = Prescription dose
Coverage versus Selectivity

- Excellent target coverage, poor selectivity
- Excellent selectivity, poor target coverage
In a conventional fractionated IMRT plan, the acceptable minimum dose in the PTV is often around 95% with maximum around 115% of the prescribed dose.

- A hot spot within the PTV is acceptable as opposed to its being within the critical organs.

- A cold spot at the edges of the PTV is preferred to it being within the GTV or CTV.
ICRU 83 - Homogeneity & Conformity

Homogeneity index is defined as,

$$HI = \frac{D_{2\%}}{D_{50\%}} - \frac{D_{98\%}}{D_{50\%}}$$

Dose homogeneity characterizes the uniformity of the absorbed-dose distribution within the target.

Dose-volume reporting:
- $D_{50\%}$ (Dmedian), Dose received by 50% of PTV
- $D_{98\%}$ : Dose received by 98% volume of PTV
- $D_{2\%}$ : Dose received by 2% volume of PTV
Conformity Index

RTOG conformity index*:

\[ C_s = \frac{V_D}{V_T} = \frac{C}{S} \]

Conformity Indices

RTOG conformity index*:

\[ C_s = \frac{V_D}{V_T} = \frac{c}{s} \]

Usually “1, but can be < 1 if coverage is sub-optimal.

Paddick conformity index**:

\[ C_P = cxs \]

\[ S = \frac{V_D \times V_T}{V_D} \]

\[ C = \frac{V_D \times V_T}{V_T} \]

Always ≠ 1

\( C_P = 1 \) represents perfect conformity


Dose conformity

- **CI** – must be between 1 – 2,
- **CI** of 0.9 – 1 & 2 – 2.5 means minor violation
- **CI** of < 0.9 & > 2.5 means major violation
- Increasing availability & use of DVH formats for dose reporting, make these indices less relevant in IMRT.

**CI** = TV/PTV

It can be employed when the PTV is fully enclosed by the Treated Volume.

It can be used as a part of the optimization procedure.

Dose conformity characterizes the degree to which the high-dose region conforms to the target volume, usually the PTV.
<table>
<thead>
<tr>
<th>Isodose Plan</th>
<th>Parameters</th>
<th>$\text{PIV} / \text{TV}$</th>
<th>$TV_{PIV} / TV$</th>
<th>Proposed Index</th>
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<tbody>
<tr>
<td>1</td>
<td>TV = 5cm³</td>
<td>2.00</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>$TV_{PIV}$ = 5cm³</td>
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<td></td>
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<tr>
<td></td>
<td>PIV = 10cm³</td>
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</tr>
<tr>
<td>2</td>
<td>TV = 5cm³</td>
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<td>0.60</td>
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<td>$TV_{PIV}$ = 3cm³</td>
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<td></td>
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<tr>
<td></td>
<td>PIV = 3cm³</td>
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</tr>
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<td>TV = 5cm³</td>
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<tr>
<td></td>
<td>PIV = 5cm³</td>
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<tr>
<td>4</td>
<td>TV = 5cm³</td>
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<td>0.60</td>
<td>0.36</td>
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<td></td>
<td>$TV_{PIV}$ = 3cm³</td>
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<td></td>
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<tr>
<td></td>
<td>PIV = 3cm³</td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>TV = 5cm³</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td></td>
<td>$TV_{PIV}$ = 5cm³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PIV = 5cm³</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Relationship between Shaw (RTOG) and Paddick Conformity Indices

\[ C_P = \frac{C^2}{C_S} \]

- \( C_P \) is inversely proportional to \( C_S \), with proportionality constant equal to the square of the target coverage.
- \( C_P = 1/C_S \) if the target coverage is 100% (i.e., \( c = 1 \)).
- In GK SRS we seem to be moving towards using \( C_P \).
\[ GI = \frac{\text{Volume of 50\% of PIV}}{\text{PIV}} \]

(Provided Isodose Volume)

Ideal Value \(\sim 3\)
Schematic representation of the basic concept of the dose gradient curves (DGC).

https://doi.org/10.1371/journal.pone.0196664
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0196664
INTERMEDIATE DOSE SPILLAGE

• $R_{50\%} = V_{50\%}/\text{PTV volume}$.
  
  Ideal value < 4.6

• $D_{2\text{cm}}$ = maximum dose in % of prescribed dose at 2 cm beyond the PTV in any direction.
  
  Ideal value < 52.7%
CONFIRMITY

• Defined by the conformity index \( V_{100\%}/\text{PTV} \) volume.

• Ideal value \( \leq 1.2 \)
Delivery

• Setup

• Imaging

• Verification
• 3DCRT – Absorbed Dose in the PTV be confined within 95% - 107% of the prescribed absorbed dose.

• In IMRT these constraints should not be followed if avoidance of normal tissue is more important than target dose homogeneity.

• ICRU 83 – Extent of high & low dose regions are specified using Dose – Volume metrics like $D_{2\%}$ & $D_{98\%}$ respectively.

• In IMRT small regions of low or high dose can develop when avoidance of sensitive structure is of prime importance.
Evaluation of Dose distribution

- 100%
- 80%
- 50%
- 20%
**Evaluation of Dose distribution**

*Set your eye for the dose distribution*
See it only in absolute
→ Thoroughly pass through all the slices first only with the dose coverage (98%, 100% or as desired)
→ Only with **hot spot** 108% or 120%
→ Check the distance of hotspot with the OAR-
Check it is well distanced
- Otherwise re-optimize

→ **Now low dose**
Switch of 50% isodose and scroll through all sections
→ 20% and 5% (not much reviling)
Typical example: Dose Distribution: VMAT
Typical example: Dose Distribution: VMAT
OAR Doses

Two Main references – Both Published in 2010

MEDICAL PHYSICS
The International Journal of Medical Physics Research and Practice

Task group report: Free Access

Stereotactic body radiation therapy: The report of AAPM Task Group 101

International Journal of Radiation Oncology*Biology*Physics
Volume 76, Issue 3, Supplement, 1 March 2010, Pages S10-S19

Introductory Paper
Use of Normal Tissue Complication Probability Models in the Clinic

Lawrence B. Marks M.D. * & ▲, Ellen D. Yorke Ph.D. †, Andrew Jackson Ph.D. †, Randall K. Ten Haken Ph.D. ▲
## QUANTEC - OAR Doses

<table>
<thead>
<tr>
<th>Organ</th>
<th>Volume segmented</th>
<th>Irradiation type (partial organ unless otherwise stated)</th>
<th>Endpoint</th>
<th>Dose (Gy), or dose/volume parameters</th>
<th>Rate (%)</th>
<th>Notes on dose/volume parameters</th>
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</thead>
<tbody>
<tr>
<td>Brain</td>
<td>Whole organ</td>
<td>SRS (single fraction)</td>
<td>Symptomatic necrosis</td>
<td>V12 &lt; 5-10 cc</td>
<td>&lt;20</td>
<td>Rapid rise when V12 &gt; 5-10 cc</td>
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<tr>
<td>Brain stem</td>
<td>Whole organ</td>
<td>SRS (single fraction)</td>
<td>Permanent cranial neuropathy or necrosis</td>
<td>Dmax &lt; 12.5</td>
<td>&lt;5</td>
<td>For patients with acoustic tumors</td>
</tr>
<tr>
<td>Optic nerve / chiasma</td>
<td>Whole organ</td>
<td>SRS (single fraction)</td>
<td>Optic neuropathy</td>
<td>Dmax &lt; 12</td>
<td>&lt;10</td>
<td></td>
</tr>
<tr>
<td>Spinal cord</td>
<td>Partial organ</td>
<td>SRS (single fraction)</td>
<td>Myelopathy</td>
<td>Dmax = 13</td>
<td>1</td>
<td>Partial cord cross-section irradiated</td>
</tr>
<tr>
<td></td>
<td>Partial organ</td>
<td>SRS (hypofraction)</td>
<td>Myelopathy</td>
<td>Dmax = 20</td>
<td>1</td>
<td>3 fractions, partial cord cross-section irradiated</td>
</tr>
<tr>
<td>Cochlea</td>
<td>Whole organ</td>
<td>SRS (single fraction)</td>
<td>Sensory neural hearing loss</td>
<td>Prescription dose ≤ 14</td>
<td>&lt;25</td>
<td>Serviceable hearing</td>
</tr>
</tbody>
</table>
A dose equal to or greater than the indicated threshold dose for the given number of fractions used or a point dose, the volume-dose constraints are based on a critical minimum volume of tissue that should receive a dose equal to or less than the indicated threshold dose for the given number of fractions used.

<table>
<thead>
<tr>
<th>Serial tissue</th>
<th>Max critical volume above threshold</th>
<th>One fraction</th>
<th>Three fractions</th>
<th>Five fractions</th>
<th>End point</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Threshold dose (Gy)</td>
<td>Max point dose (Gy)</td>
<td>Threshold dose (Gy)</td>
<td>Max point dose (Gy)</td>
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<tr>
<td>Optic pathway</td>
<td>&lt;0.2 cc</td>
<td>8</td>
<td>10</td>
<td>15.3 (5.1 Gy/fx)</td>
<td>17.4 (5.8 Gy/fx)</td>
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<tr>
<td>Cochlea</td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>17.1 (5.7 Gy/fx)</td>
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<tr>
<td>Brainstem (not medulla)</td>
<td>&lt;0.5 cc</td>
<td>10</td>
<td>15</td>
<td>18 (6 Gy/fx)</td>
<td>23.1 (7.7 Gy/fx)</td>
</tr>
<tr>
<td>Spinal cord and medulla</td>
<td>&lt;0.35 cc</td>
<td>10</td>
<td>14</td>
<td>18 (6 Gy/fx)</td>
<td>21.9 (7.3 Gy/fx)</td>
</tr>
<tr>
<td>Spinal cord subvolume</td>
<td>&lt;1.2 cc</td>
<td>7</td>
<td></td>
<td>12.3 (4.1 Gy/fx)</td>
<td>14.5 (2.9 Gy/fx)</td>
</tr>
</tbody>
</table>
**QUANTEC- Issue**

Table 1. QUANTEC Summary: Approximate Dose/Volume/Outcome Data for Several Organs Following Conventional Fractionation, Otherwise Noted

<table>
<thead>
<tr>
<th>Organ</th>
<th>Volume segmented</th>
<th>Irradiation type (partial organ unless otherwise stated)</th>
<th>Endpoint</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td></td>
<td>SRS (single fraction) or Hypofraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain stem</td>
<td>Whole organ</td>
<td>SRS (single fraction) or Hypofraction</td>
<td>V12 &gt; 5-10 cc</td>
<td></td>
</tr>
</tbody>
</table>

For patients with acoustic tumors

| Optic nerve/chiasma    |                  | Sensory neural hearing loss                             | Prescription dose ≤14 |
|                       |                  |                                                          | ≤25 Serviceable hearing |

Consider only non-intensity modulated dose distribution –

Consider only 1#SRS → No Solution for >3# and 5# prescription
## TG101 - Issues

<table>
<thead>
<tr>
<th>Serial tissue</th>
<th>One fraction</th>
<th>Three fractions</th>
<th>Five fractions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Threshold dose</td>
<td>Max point dose</td>
<td>'d dose</td>
</tr>
<tr>
<td></td>
<td>(Gy)</td>
<td>(Gy)</td>
<td>(Gy)</td>
</tr>
<tr>
<td>Optic pathway</td>
<td>&lt;0.7</td>
<td></td>
<td>25 (5 Gy/fx)</td>
</tr>
<tr>
<td>Cochlea</td>
<td></td>
<td></td>
<td>25 (5 Gy/fx)</td>
</tr>
<tr>
<td>Brainstem (not medulla)</td>
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<td></td>
<td>7</td>
<td>12.3 (4.1 Gy/fx)</td>
<td>14.5 (2.9 Gy/fx)</td>
</tr>
</tbody>
</table>

Not biased to intensity modulated or unmodulated techniques.

Have a solution for both 1# and 1-5# as well.
Necrosis is undesirable but unavoidable phenomenon.
### Take Home Msg: OAR doses

<table>
<thead>
<tr>
<th>OAR Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OAR Unchallenged Category</strong></td>
<td>Around 50% cases SRS tumour will be isolated at a 2 cm distance from Optic pathway, Brainstem and cochlea – Only OAR normal Brain</td>
</tr>
<tr>
<td><strong>OAR Challenged Category (not touched)</strong></td>
<td>Possible to achieve the desired dose to OAR with a little try. No Dose compromise to the PTV required.</td>
</tr>
<tr>
<td><strong>OAR Invaded Category</strong></td>
<td>Difficult to achieve the desired dose to OAR, often required coverage compromise to PTV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OAR s</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brainstem</td>
<td>A Must Save (if they are working)</td>
</tr>
<tr>
<td>Optic pathway</td>
<td></td>
</tr>
<tr>
<td>Cochlea(s)</td>
<td></td>
</tr>
<tr>
<td>Mastoid</td>
<td>Essential but absolute- Can be reduce as much as possible</td>
</tr>
<tr>
<td>Eyes</td>
<td></td>
</tr>
<tr>
<td>Lenses</td>
<td></td>
</tr>
<tr>
<td>Temporal lobes</td>
<td></td>
</tr>
<tr>
<td>Uninvolved Brain</td>
<td></td>
</tr>
</tbody>
</table>
Dose fall-off characteristics

Take Home Msg on Dose fall off

Max fall off ≈ 12%/ mm
Mean fall off between 100%-80%= 8%/mm
Mean fall off between 100%-50%= 5.5%/mm
Mean fall off between 100%-20%= 4.4%/mm

Fixed beam 3DCRT/IMRT Shows slightly higher dose fall off than VMAT plans*

Remember- You may not be able change the plan for getting a better gradient -
• Thanks a lot.