SRS/SBRT Errors and Causes

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Dallas, TX
Disclosures

• I receive research funding from the Cancer Prevention and Research Institute of Texas.
Outline of Presentation

• Introduction
• Summary of accidents and misadministrations
• Resources and guidance
• Conclusions
Learning Objectives

• To learn from previous accidents and misadministrations during SRS/SBRT
• To understand the types of errors that can occur
• To understand how to prevent these errors from happening to you!
What are the sources of errors?

Figure 4: Radiotherapy incidents (1976-2007) by the stages of treatment process

Adverse events N = 3125

WHO
Radiotherapy Risk Profile 2008
According to the WHO Radiotherapy Risk Profile, what are the two most common sources of actual adverse events in radiation therapy?

3%  1. Positioning/immobilization and commissioning
2%  2. Simulation/imaging and treatment planning
87% 3. Commissioning and treatment planning
4%  4. Planning and treatment information transfer
4%  5. Commissioning and treatment information transfer
3. Commissioning and treatment planning

Figure 4: Radiotherapy incidents (1976-2007) by the stages of treatment process

Adverse events N = 3125

WHO Radiotherapy Risk Profile 2008
Two Major Categories in SRS/SBRT Accidents

• Commissioning
  – Small field measurements
  – Absolute calibration

• Treatment parameter transfer
  – SRS Cones
  – Wrong side/site treatments
SUMMARY OF INCIDENTS
Stereotactic Output Factor Curve

FIGURE 7. 6-MV output factors at isocenter and at d_{max} for collimator diameters 12.5–40.0 mm.

The following data acquisition procedures are adequate for field diameters greater than or equal to 10 mm. Beam profiles require high spatial resolution and film has been shown to be the most efficient dosimeter. Film analysis can be performed by a scanning isodensitometer with an aperture of 1 mm or less or with a laser film digitizer. These approaches yield equivalent results to high-resolution TLDs. The uncertainty of the beam radius measurements can be greater than 1 mm. This uncertainty should be minimized. Tissue maximum ratios and output factors should be acquired with parallel plate or thimble ionization chambers that have small collecting volume diameters, e.g., 3 mm or less. The phantom material should be within the guidelines of the TG-21 Report of the AAPM.

- Off-Axis Ratios

Off-axis ratios (OAR) have been measured for 6-MV x-ray beams as a function of depth in a polystyrene phantom and in air. The variation of the scaled profile with depth (constant SDD) is less than 2% (Rice et al., 1987). Hence, some radiosurgery computer codes (Schell et al., 1991) use OAR tables for each collimator which scale with the geometric projection of the beam. Figures 4 and 5 illustrate the beam profiles for the 6-MV linac and gamma knife unit.

- Scatter Correction Factors

The total scatter correction factor, S_T, as a function of field size is a product of the collimator scatter, S_C, and the phantom scatter, S_p (Khan et al., 1980). Phantom scatter factors are inferred from the total scatter and collimator scatter factors.

- Collimator Scater

The dose in phantom is independent of collimator scatter from the tertiary collimator for a 6-MV x-ray beam (Bjarnagard et al., 1990). Collimator scatter is dependent on the secondary collimator setting and independent of the tertiary collimator diameter. S_C is illustrated in Figure 7 for the 6-MV beam. The data were obtained with a PTW Model N23342 parallel plate chamber. The chamber volume is 0.02 cm³ and a collecting volume diameter of 3 mm.

- Tissue-Maximum Ratios

The variation of tissue-maximum ratios (TMR) with collimator diameter at large depths is approximately 10% for 6 MV and 9 MV x rays (Arcovito et al., 1985; Rice et al., 1987; Houdek et al., 1983; Serago et al., 1992; and Jani, 1993) for field diameters in the interval between 0 cm and 4 cm. The principal diminution is from the lack of lateral electronic equilibrium. The TMR data in Figure 6 were acquired with the PTW parallel plate chamber.

B. Measurement Summary

I. Linacs

- Measure beam profiles with film, diodes, plastic scintillators, thermoluminescent dosimeters or ionization chambers. Film is the dosimeter of choice. The detector dimensions must be 2 mm or less. Diodes must be used with caution, due to the angular response of the detector.
- Measure tissue-maximum ratios and total output factors (S) with ionization chambers with diameters less than or equal to 3 mm.
- Use phantom materials and calibrate in accordance with the AAPM Protocol: TG-21: a protocol for absorbed dose from high-energy beams.
- The PTW Model N23342 parallel plate chamber and the Capintec
Small field commissioning

This happened in France in 2007 and was reported in 2008!
Small field commissioning

Cox system settles 27 of 66 radiation lawsuits
Written by Jess Rollins
Feb. 18, 2012 |
news-leader.com

Safety measures in place

CoxHealth officials say “extensive” safety measures have been put into place following an error that overirradiated cancer patients. “We have taken this issue very seriously, and we are committed to doing everything we can to ensure a similar issue does not happen in the future,” said CoxHealth spokeswoman Stacy Fender. Fender said the measures include a system-wide safety initiative to check and double-check technology and equipment; independent, ongoing verification of radiation beam data and treatment plans; on-site, independent, annual physics audits; extensive additional training for staff; and other measures. Following the error, Fender said, CoxHealth adopted “safety” as the organization’s fourth value
How many patients in Missouri could have received the correct treatment if the incident in France had been more widely reported?
Small field measurement issues persist

detector. The response at different SSDs was within ±0.35% and ±0.26% with farmer chamber. For field sizes greater than 5x5cm², output factors measured with array chamber were within ±0.12% and ±0.17% with farmer chamber. However, for 2x2cm², the difference was 17.95% and 16.61%. In all the cases, array over-estimated the output factors. WFs measured with array were
The following text is not legible due to the quality of the image.
According to TG101, an appropriate measurement device for SRS/SBRT small fields would be a

0%  1. 0.6 cc Farmer chamber
1%  2. CC13 ion chamber
6%  3. Parallel plate chamber
31% 4. 0.015 cc pinpoint ion chamber
62% 5. Stereotactic diode
5. Stereotactic body radiation therapy: The report of AAPM Task Group 101

Recommendation: Due to the small dimensions and steep dose gradients of photon beams used in SRS/SRT and IMRT, an appropriate dosimeter with a spatial resolution of approximately 1 mm or better (stereotactic detectors) is required to measure the basic dosimetry data, e.g., the total scatter factor (or relative output factor), tissue-maximum ratio, and off-axis ratios. Even with stereotactic detectors, careful detector-
Much more detail coming in tomorrow’s presentations!
6 MV; Central Axis

A 1x1 cm² 6 MV output factor measured with a 0.6 cc Farmer chamber

92%
1. Would be 40% smaller than the true output factor
0% 2. Would be the true output factor
1% 3. Would be 5% smaller than the true factor
6% 4. Would be 50% larger than the true factor
1% 5. Would be 10% larger than the true factor
Answer

1. Would be 40% smaller than the true output factor.

How do you know if your data is good?
Compare with Other Institutions / Machines

<table>
<thead>
<tr>
<th>Field Size (cm × cm)</th>
<th>Varian 6 MV RPC Institution</th>
<th>Varian 10 MV RPC Institution</th>
<th>Varian 15 MV RPC Institution</th>
<th>Varian 18 MV RPC Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 × 10</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>6 × 6</td>
<td>0.938 ± 0.005 (0.945)</td>
<td>0.959 ± 0.002 (0.964)</td>
<td>0.963 ± 0.005 (0.964)</td>
<td>0.969 ± 0.003 (0.971)</td>
</tr>
<tr>
<td></td>
<td>[0.8%] (n=127)</td>
<td>[0.5%] (n=22)</td>
<td>[0.4%] (n=32)</td>
<td>[0.5%] (n=41)</td>
</tr>
<tr>
<td>4 × 4</td>
<td>0.886 ± 0.006 (0.900)</td>
<td>0.916 ± 0.006 (0.927)</td>
<td>0.927 ± 0.006 (0.928)</td>
<td>0.928 ± 0.002 (0.933)</td>
</tr>
<tr>
<td></td>
<td>[1.8%] (n=122)</td>
<td>[1.2%] (n=25)</td>
<td>[0.7%] (n=32)</td>
<td>[0.9%] (n=37)</td>
</tr>
<tr>
<td>3 × 3</td>
<td>0.851 ± 0.007 (0.870)</td>
<td>0.880 ± 0.006 (0.894)</td>
<td>0.892 ± 0.006 (0.894)</td>
<td>0.884 ± 0.005 (0.891)</td>
</tr>
<tr>
<td></td>
<td>[2.4%] (n=123)</td>
<td>[1.6%] (n=25)</td>
<td>[0.9%] (n=31)</td>
<td>[1.4%] (n=41)</td>
</tr>
<tr>
<td>2 × 2</td>
<td>0.804 ± 0.008 (0.825)</td>
<td>0.823 ± 0.005 (0.838)</td>
<td>0.824 ± 0.011 (0.823)</td>
<td>0.806 ± 0.007 (0.804)</td>
</tr>
<tr>
<td></td>
<td>[2.9%] (n=136)</td>
<td>[2.0%] (n=23)</td>
<td>[2.2%] (n=33)</td>
<td>[1.6%] (n=40)</td>
</tr>
</tbody>
</table>

Followill et al. JACMP 2012 and Erratum, JACMP Vol 15, No 2, 2014
Miscalibration of SRS Linac

77 Moffitt patients get excess radiation

Errors in a machine's installation caused the patients to get radiation doses 50 percent more powerful than prescribed.

By MICHAEL VAN SICKLER, Times Staff Writer
Published April 2, 2005

Dozens of Moffitt Center Patients Received Radiation Overdoses

The Associated Press
Published: Sunday, April 3, 2005 at 3:27 a.m.

TAMPA -- Dozens of patients at a cancer treatment center were exposed to radiation levels 50 percent stronger than they were supposed to receive for nearly a year because a machine was improperly installed.
### RESULTS OF OSLD CHECK OF PHOTON BEAM OUTPUT

**v 0.2**

**Institution:**
**RTF Number:**
**Person irradiating dosimeters:**
**Radiation Machine:**
**Radiation Quality:**
**Distance from source to reference point:**

- **Primus:**
- **6 MV X-rays:**
- **100.0 cm**

**OUTPUT VERIFICATION:**

<table>
<thead>
<tr>
<th>Date of Irradiation</th>
<th>RPC measured dose at d(_{\text{max}})*</th>
<th>Institution reported dose at d(_{\text{max}})*</th>
<th>Ratio of absorbed dose determined by RPC to that stated by institution: OSLD/INST</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-Oct-2009</td>
<td>97 cGy to muscle</td>
<td>99 cGy to muscle</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Agreement within 5% is considered a satisfactory check.
Improper Jaw Size During SRS

In 2004, physicist told therapist to set a “40x40” for cone SRS treatment; therapist set 40x40 cm²

Some normal tissue received more dose than the target; developed “fibrosis and oeso-tracheal fistula” requiring surgery; patient died from “brutal haemorrhage” a few days after surgery

Figure 2. Stereotactic radiotherapy treatment delivery with successive beam entrance positions as a function of accelerator and table rotation angles (left). The plate used in the centre (Case 2) to hold the cylindrical additional collimator (right).

Improper Jaw Size During SRS

A Pinpoint Beam Strays Invisibly, Harming Instead of Healing
By WALT BOGDANICH and KRISTINA REBELO

Marci Faber was one of the three patients. She had gone to Evanston Hospital in Illinois seeking treatment for pain emanating from a nerve deep inside her head. Today, she is in a nursing home, nearly comatose, unable to speak, eat or walk, leaving her husband to care for their three young daughters.

This occurred in France in 2004!
I-8957 - Medical Event - [Redacted], Texas

On June 6, 2012, the licensee notified the Agency that a medical event had occurred at its facility on June 5, 2012. A technician failed to insert a conical collimator prior to a stereotactic surgery procedure which had resulted in a dose being delivered to a patient that varied greater than 10% from the prescribed dose. An investigation into this event is ongoing.

File open.
<table>
<thead>
<tr>
<th>Name</th>
<th>Type of Order</th>
<th>License #</th>
<th>Address</th>
<th>Action</th>
<th>Date of Issuance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varian Medical Systems, Inc.</td>
<td>Emergency Cease and Desist Order</td>
<td>R06706</td>
<td>911 Hansen Way, M/S: C-255, Palo Alto, CA 94304-1030</td>
<td>Cease and desist from all further assembly, installation or reinstallation of linear accelerators with stereotactic radiosurgery (SRS) components without all required interlocks or SRS components without all required interlocks; repair or install immediately all required interlocks on linear accelerators capable of performing SRS.</td>
<td>10/17/12</td>
</tr>
<tr>
<td>BrainLAB, Inc.</td>
<td>Emergency Cease and Desist Order</td>
<td>R31234</td>
<td>3 Westbrook Corporate Center, Suite 400, Westchester, IL 60154</td>
<td>Cease and desist from all further assembly, installation or reinstallation of linear accelerators with stereotactic radiosurgery (SRS) components without all required interlocks or SRS components without all required interlocks; repair or install immediately all required interlocks on linear accelerators capable of performing SRS.</td>
<td>10/17/12</td>
</tr>
</tbody>
</table>
Appendix 2—Institution 1: Spine SBRT Worklist example

**SBRT Spine Worklist:**

Patient Name: ___________________________ MRR:

Date of Implant: ___________________________ Target Area:

Rad Oncologist: ___________________________

**Preplan:**

Planned Dose/Fractions: ____________

Markers to Surgery (3 pre-loaded needles)

Load Pet, MRI, iPlan:

**Target Volume & Coverage:**

Review and approve Image Fusion:

PTV = 1-5 mm margin on GTV (per case)

%/ Dose %:

Table and External Are edited

35%/5%, 40%/0%

Patient localized to BB marks

%/ Dose %:

At least 7 beams, (or at least 340 Deg of arc)

40%/5%, 50%/0%

RX line is between 70-90% (100% is at center)

Hot spots is in the PTV

Rx isodose cover approximately 95% of PTV

99% of PTV gets at least 90% of RX dose

**IMRT Constraints Volume/Dose:**

PTV 18 Gy at 50%

Spinal Canal (listed below Volume)

100%/0%, 90%/25%, 55%/30%,

Esophagus (listed below Volume)

100%/0%, 90%/25%, 60%/35%,

Start 25 Step-n-Shoot segments

Adaptive Resolution

**Normal Tissue Constraints:**

Cord: (contoured as canal +/- 6 mm of PTV length)

< 10% of canal at 10 Gy (8Gy for Rx 14Gy)

Transcsection canal: < 8 Gy (6 Gy if RX is 14 Gy)

Lung: Both lungs as one structure (no dose limits)

Esophagus: +/-10 cm of PTV length: Max 10 Gy to > 2cc

Other: Heart, Brain, Liver, Kidney, Brochial plexus, Max Surface dose, stomach.
GammaKnife Misadministrations

U.S. NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Home > NRC Library > Document Collections > General Communications > Information Notices > 2000 > IN 2000-22

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
WASHINGTON, D.C. 20555-0001

December 18, 2000

NRC INFORMATION MEDICAL MISADMINISTRATION'S CAUSED BY HUMAN ERRORS
NOTICE 2000-22: INVOLVING GAMMA STEREOTACTIC RADIOSURGERY (GAMMA KNIFE)
GammaKnife Misadministrations

A patient received a dose of 3000 cGy (rad) to the intended site of his brain, instead of the prescribed dose of 2300 cGy (rad). This event was caused because the licensee did not follow the treatment plan and used an incorrect collimator helmet.

A patient received a dose 54.5 percent below the intended dose. The prescribed dose was 2200 cGy (rad) and the patient received a dose of 1000 cGy (rad). The treatment physician failed to enter the prescribed dose into the treatment planning system. This resulted in the system's default value (1000 cGy) (rad) being used for the treatment. The error was missed by all three team members involved in the treatment planning.

A patient was prescribed a treatment of 9000 cGy (rad) to the left trigeminal nerve of his brain. However, the treatment was actually administered to the right trigeminal nerve. The medical physicist had inadvertently prepared a treatment plan for the wrong side of the patient's head and the radiation oncologist (authorized user) signed the treatment plan without properly verifying the neurosurgeon's request identifying the correct site.

A patient being treated for an arteriovenous malformation in the left part of his brain received treatment to the right side of his brain. During the treatment planning process, the computer software refused several times to accept the "correct" orientation (as viewed by the planning team) of the patient's image. Eventually, the neurosurgeon and the medical physicist instructed the computer system to accept the image they believed to be correct. After initiating the treatment, the physicist noticed that the X coordinates indicated a definite right-side target and stopped the treatment. The physicist and the neurosurgeon were unaware that a different angiography room had been used to acquire the patient's X-ray images during the quality assurance (QA) runs. QA tests had been performed in what the physicist believed to be the only angiographic suite. This room was equipped in such a way that the lateral X-ray tube could only be on the patient's right side, with the patient in a supine position. The actual angiographs were performed in another room where the tube focus was on the patient's left side.
The consequences of human errors in radiosurgery are also very important. An early report by Flickinger et al. (27) found error rates of $\leq 8\%$ in setting coordinates, but these were reduced to $< 0.1\%$ for errors of $\geq 0.25$ mm if two observers independently verified the coordinates. An Information Notice published by the U.S. Nuclear Regulatory Commission in 2000 described 15 misadministrations reported by radioactive material users involving Gamma Knife radiosurgery (28). The errors described in that report were analyzed by Goetsch (29) who found that all but 1 of these 15 errors would have been prevented by use of the newer Gamma Knife Model C with the automatic positioning system and record and verify capability. Reported misadministrations have

Beam data acquisition for SRS / SBRT is challenging and time consuming

• Small fields
• Sharp gradients
• Detector position-orientation effects
• Loss of lateral electron equilibrium
• Must get this right!
• Commissioning errors affect all patients treated with the device – not just a select few!
Dosimetric commissioning: Do your calculations agree with measurement?

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Planned Dose (Gy)</th>
<th>Measured Dose (Gy)</th>
<th>Diff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single 10x10 field AP, SAD</td>
<td>1.527</td>
<td>1.521</td>
<td>-0.39</td>
</tr>
<tr>
<td>AP-PA (same fs, same MU) 10x10</td>
<td>1.502</td>
<td>1.487</td>
<td>-1.00</td>
</tr>
<tr>
<td>AP-PA (same fs, same MU) 30x30</td>
<td>1.761</td>
<td>1.747</td>
<td>-0.80</td>
</tr>
<tr>
<td>4-field box</td>
<td>2.707</td>
<td>2.742</td>
<td>1.29</td>
</tr>
<tr>
<td>Whole Brain</td>
<td>2.012</td>
<td>2.017</td>
<td>0.25</td>
</tr>
<tr>
<td>3-D Pelvis</td>
<td>3.608</td>
<td>3.623</td>
<td>0.42</td>
</tr>
<tr>
<td>Breast</td>
<td>3.228</td>
<td>3.183</td>
<td>-1.39</td>
</tr>
<tr>
<td>SBRT Lung (course 10) IMT phantom</td>
<td>18.002</td>
<td>18.183</td>
<td>1.01</td>
</tr>
<tr>
<td>SBRT Lung (course 10) solid water</td>
<td>13.709</td>
<td>13.543</td>
<td>-1.21</td>
</tr>
<tr>
<td>SBRT Lung solid water (course 1)</td>
<td>20.996</td>
<td>20.604</td>
<td>-1.87</td>
</tr>
<tr>
<td>Prostate SBRT</td>
<td>11.311</td>
<td>11.388</td>
<td>0.68</td>
</tr>
<tr>
<td>Spine SBRT</td>
<td>5.573</td>
<td>5.463</td>
<td>-1.97</td>
</tr>
<tr>
<td>H&amp;N IMRT</td>
<td>1.666</td>
<td>1.646</td>
<td>-1.20</td>
</tr>
<tr>
<td>Brain IMRT</td>
<td>1.692</td>
<td>1.724</td>
<td>1.89</td>
</tr>
<tr>
<td>SmartArc H&amp;N</td>
<td>1.553</td>
<td>1.575</td>
<td>1.42</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>-0.19</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td><strong>1.27</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dosimetric commissioning: Do your calculation agree with measurement?
Patient Specific QA
What About Localization Accuracy?

Must perform end to end tests!
Report of Lung Phantom Irradiation

Date of Report: January 14, 2013
Institution: UTSW Med Ctr - St. Paul University Hospital
Physician: Ryan Foster
Radiation Machine: Varian, TrueBeam (1063) – 6 MV FFF
Collimator: MLC
Technique: 3D-CRT
Treatment Planning System: Phillips, Pinnacle (3D/IMRT) – CC Convolution
Date of Irradiation: December 17, 2012

Description of procedure:
An anthropomorphic lung phantom incorporating a cylindrical dosimetry insert that simulated the left lung was placed in the supine position in a CT scanner and imaged. The insert contained a spherical centered target. TLD capsules located near the center of the target provided point dose information and three sheets of GAFChromatic™ Dosimetry Media provided dose distributions in the axial, coronal, and sagittal planes. The phantom included heart and spinal cord structures, each one containing one TLD capsule. The right lung was also included. The phantom with the insert was irradiated to approximately 6 Gy using a 3D-CRT technique. The analyses of the results were based on dose calculation applying correction for tissue heterogeneity.

The dosimetric precision of the TLD is 3%, and the spatial precision of the film and densitometer system is 1 mm.

Summary of TLD and film results:

<table>
<thead>
<tr>
<th>Location</th>
<th>RPC vs. Inst</th>
<th>Criteria</th>
<th>Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV_TLD_sup</td>
<td>0.98</td>
<td>±0.2 – 1.2</td>
<td>Yes</td>
</tr>
<tr>
<td>PTV_TLD_inf</td>
<td>0.90</td>
<td>±0.2 – 1.2</td>
<td>Yes</td>
</tr>
<tr>
<td>Film Plane</td>
<td>Gamma Index*</td>
<td>Criteria</td>
<td>Acceptable</td>
</tr>
<tr>
<td>Axial</td>
<td>100%</td>
<td>≥80%</td>
<td>Yes</td>
</tr>
<tr>
<td>Coronal</td>
<td>100%</td>
<td>≥80%</td>
<td>Yes</td>
</tr>
<tr>
<td>Sagittal</td>
<td>100%</td>
<td>≥80%</td>
<td>Yes</td>
</tr>
<tr>
<td>Average over 3 planes</td>
<td>100%</td>
<td>≥86%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Percentage of points meeting gamma-index criteria of 3% and 5 mm

The phantom irradiation results listed in the table above do meet the criteria established by the RPC in collaboration with the cooperative study groups. Therefore, your institution has satisfied the phantom irradiation component of the credentialing process to enter patients onto clinical trials.

TLD and Film Analysis by: Paola Alvarez, M.S.
Report Checked by: [Signature]
RPC Spine Phantom

Date of Report: September 12, 2013
Institution: UTSW Med Ctr-Moncrief
Physicist: Brian Hrycakho
Radiation Machine: Elekta, Agility S (1245) – 10 MV
IMRT Technique: Segmented (step and shoot) MLC
Treatment Planning System: Philips, Pinnacle (3D/IMRT) – CCC
Date of Irradiation: July 29, 2013

Description of procedure:

An anthropomorphic thorax phantom incorporating a dosimetry system, lung-equivalent structures, and a spine structure was placed in the supine position in a CT simulator and imaged. The spine structure contained a target simulating a spine metastasis. TLD capsules located near the center of the target provided point dose information. Sheets of radiochromic film provided dose distributions in the axial and sagittal plane in the spine. The phantom included a heart structure containing one TLD capsule. A treatment plan with correction for tissue heterogeneity was performed. The phantom with the inserts was irradiated to approximately 6 Gy using an IMRT technique.

The dosimetric precision of the TLD is 3%, and the spatial precision of the film and densitometer system is 1 mm.

Summary Results:

<table>
<thead>
<tr>
<th>Location</th>
<th>RPC vs. Inst.</th>
<th>Criteria</th>
<th>Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV TLD sup ant</td>
<td>1.00</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
</tr>
<tr>
<td>PTV TLD inf ant</td>
<td>1.00</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
</tr>
<tr>
<td>PTV TLD sup post</td>
<td>1.02</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
</tr>
<tr>
<td>PTV TLD inf post</td>
<td>1.03</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Film Plane</th>
<th>Gamma Index*</th>
<th>Criteria</th>
<th>Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial</td>
<td>99%</td>
<td>≥85%</td>
<td>Yes</td>
</tr>
<tr>
<td>Sagittal</td>
<td>95%</td>
<td>≥85%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Percentage of points meeting gamma-index criteria of 5% and 3 mm.

Your plan does meet the protocol criteria.

The phantom irradiation results above do meet the criteria established by the RPC in collaboration with the cooperative study groups. Therefore, your institution has satisfied the phantom irradiation component of the credentialing process for spine radiotherapy protocols.

TLT and Film Analysis by: Nadia Hernandez and Andrea Molinir, M.S.

Report Checked by:

David S. Followill, Ph.D.
Director, Radiological Physics Center
Report of IMRT Head and Neck Phantom Irradiation

Date of Report: October 24, 2012
Institution: UTSW Med Ctr - Radiation Oncology West
Physician: Ryan Foster
Radiation Machine: Mitsubishi, Vero (201902) – 6 MV
Intensity Modulation Device: Multileaf Collimator
IMRT Technique: Segmental (step and shoot) MLC
Treatment Planning System: BrainLab, iPlan (3D/IMRT) – Pencil Beam
Date of Irradiation: August 21, 2012

Description of Procedure
An anthropomorphic head phantom incorporating a rectangular dosimetry insert was imaged and irradiated to approximately 6.6 Gy using an IMRT technique. The dosimetry insert consisted of one primary PTV containing four TLD capsules, a secondary PTV and an organ at risk (OAR), each containing two TLD capsules. The TLD capsules provided point dose information. Three sheets of GAFChromatic Dosimetry Media provided dose profiles through the center of primary PTV.

The dosimetric precision of the TLD is 3%, and the spatial precision of the film and densitometer system is 1 mm.

<table>
<thead>
<tr>
<th>Location</th>
<th>RPC vs. Inst.</th>
<th>Criteria</th>
<th>Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary PTV sup. ant.</td>
<td>0.96</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
</tr>
<tr>
<td>Primary PTV inf. ant.</td>
<td>0.97</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
</tr>
<tr>
<td>Primary PTV sup. post.</td>
<td>0.99</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
</tr>
<tr>
<td>Primary PTV inf. post.</td>
<td>0.98</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
</tr>
<tr>
<td>Secondary PTV sup.</td>
<td>0.96</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
</tr>
<tr>
<td>Secondary PTV inf.</td>
<td>0.96</td>
<td>0.93 – 1.07</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Film Plane</th>
<th>Gamma Index*</th>
<th>Criteria</th>
<th>Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial</td>
<td>100%</td>
<td>≥85%</td>
<td>Yes</td>
</tr>
<tr>
<td>Sagittal</td>
<td>99%</td>
<td>≥85%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Percentage of points meeting gamma index criterion of 7% and 2 mm.

The phantom irradiation results listed in the table above do meet the criteria established by the RPC in collaboration with the cooperative study groups. Therefore, your institution has satisfied the phantom irradiation component of the credentialing process to enter patients into certain protocols that allow the use of IMRT.

TLD and Film Analysis by: Nadia Hernandez and Andrea Molineu, M.S.

Report Checked by:

David S. Follin
Ph.D.
Director, Radiological Physics Center
Planning

Are your electronic systems configured correctly?

R/V

Do all of your commissioning in clinical mode and through your R/V system

Tx Unit
AAPM/ASTRO Resources

• AAPM Task Group 101
• Target Safely – IMRT Safety White Paper
• Target Safely – SBRT/SRS Safety White Paper
• ASTRO – Safety is no accident – A framework for quality radiation oncology and care
• Solberg et al. Quality and safety considerations in stereotactic radiosurgery and stereotactic body radiation therapy. PRO 2012.

Safety Considerations for SRS and SBRT

1. Introduction
1.1 Scope of this Document on Patient Safety for SRS and SBRT
1.2 Nomenclature
1.3 Safety Concerns
2. Elements of Successful SRS / SBRT Quality Assurance
2.1 Establishing Program Goals
2.2 Technology Requirements
2.3 Personnel Requirements
3. SRS / SBRT Systems Acceptance and Commissioning
4. SRS / SBRT Quality Assurance
4.1 General QA Concepts
4.2 Equipment QA
4.3 Patient / Process QA
5. Processes for Ongoing Quality Improvement
6. Documentation
7. Other Recommendations
8. Summary
SRS/ SBRT White Paper Key Points

- Focus on personnel qualifications and technology requirements
- Commissioning/credentialing/QA
- SRS and SBRT are SPECIALIZED procedures and should be treated as such!
International Resources

RADIOThERAPY RISK PROFILE
Technical Manual

Towards Safer Radiotherapy

British Institute of Radiology
Institute of Physics and Engineering in Medicine
National Patient Safety Agency
Society and College of Radiographers
The Royal College of Radiologists
Specific Lessons Learned from Accidents and Overexposures

• Get an independent check of machine calibration and commissioning
• Perform end to end commissioning tests, including the R&V system
• Use an independent method to check MU/time calculations
• Evaluate changes in TPS, R&V and other software thoroughly before implementation
• Carefully plan your program
Summary | Conclusion

• SRS and SBRT are ABLATIVE treatments!
• Care must be taken during commissioning
• Plan your program carefully!
Thank you!