AAPM2015 REINVIGORATING SCIENTIFIC EXCELLENCE | 57th Annual Meeting & Exhibition • July 12–16 • Anaheim, CA

Stereotactic Body Radiation Therapy: QA, Safety, and Other Practical Aspects.

Tues, July 14, 2015: 7:30-8:30AM:
AAPM Therapy Educational SAM Session:
" Imaging, Treatment Planning, and QA for SBRT"

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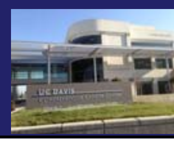
UCDAVIS COMPREHENSIVE CANCER CENTER
Radiation Oncology



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1. L. Potters, M. Steinberg, C. Rose, R. Timmerman, S. Ryu, J. M. Hevezi, J. Welsh, M. Mehta, D. A. Larson, and N. A. Janjan, "American Society for Therapeutic Radiology and Oncology and American College of Radiology practice guideline for the performance of stereotactic body radiation therapy," Int. J. Radiat. Oncol., Biol., Phys. **60**, 1026–1032, 2004

2. Potters L, Kavanagh B, Galvin JM, Hevezi JM, Janjan NA, Larson DA, Mehta MP, Ryu S, Steinberg M, Timmerman R, Welsh JS, Rosenthal SA; **American Society for Therapeutic Radiology and Oncology**; American College of Radiology, "American Society for Therapeutic Radiology and Oncology (ASTRO) and American College of Radiology (ACR) practice guideline for the performance of stereotactic body radiation therapy", Int J Radiat Oncol Biol Phys. 2010 Feb 1;76(2):326-32

3. Benedict SH (Chair), Yenice KM (Co-Chair), Followill D, Galvin J, Hinson W, Kavanagh B, Keall P, Lovelock M, Meeks S, Papiez L, Purdie T, Sadagopan R, Schell MC, Salter B, Schlesinger DJ, Shiu AS, Solberg T, Song D, Stieber V, Timmerman R, Tome WA, Verellen D, Wang L, Yin FF. Stereotactic Body Radiation Therapy (SBRT), the Report from the AAPM Task Group No. 101. *Med Phys* 37(8): 4078-4101, Aug 2010

4. Timothy D. Solberg, James M. Balter, Stanley H. Benedict, Benedick A. Fraass, Brian Kavanagh, Curtis Miyamoto,Todd Pawlicki, Louis Potters, Yoshiya Yamada, "Quality and safety considerations in stereotactic radiosurgery and stereotactic body radiation therapy: Executive summary (Supplemental Material On-Line: Full Text), *Practical Radiation Oncology* 2: 2–9, 2012

Disclosures

- The UC Davis Radiation Oncology Department receives research funding from NIH/National Cancer Institute, National Lung Cancer Partnerships, and RSNA
- The Radiation Oncology Department has research and development agreements with Varian Medical Technologies, Sun Nuclear, Elekta, AlignRT, and iRT Systems GmbH

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References (cont'd):

5. The Canadian Association of Radiation Oncology scope of practice guidelines for lung, liver and spine stereotactic body radiotherapy.
Sahgal A, Roberge D, Schellenberg D, Purdie TG, Swaminath A, Pantarotto J, Filion E, Gabos Z, Butler J, Letourneau D, Masucci GL, Mulroy L, Bezjak A, Dawson LA, Parliament M, The Canadian Association of Radiation Oncology-Stereotactic Body Radiotherapy Task Force. Clin Oncol (R Coll Radiol). 2012 Nov;24(9):629-39.

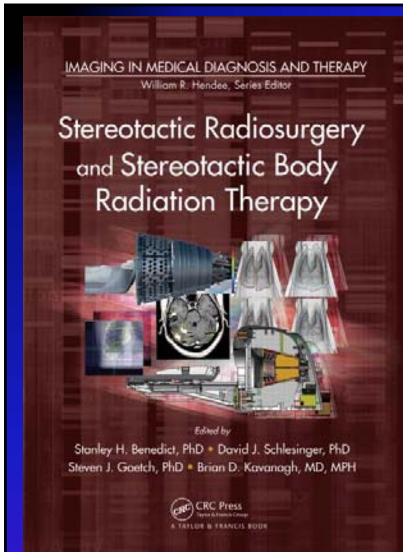
6. Radiosurgery scope of practice in Canada: a report of the Canadian association of radiation oncology (CARO) radiosurgery advisory committee. Roberge D, Ménard C, Bauman G, Chan A, Mulroy L, Sahgal A, Malone S, McKenzie M, Schroeder G, Fortin MA, Ebacher A, Milosevic M. Radiother Oncol. 2010 Apr;95(1):122-8.

7. AAPM TG132: Quality Assurance for Image Registration (K. Brock)

8. AAPM TG 155: Small Field Dosimetry (Indra Das)

9. AAPM WG-SBRT: Radiobiological Effects of Hypofractionation (J. Grimm)

*** TG132, TG155, and WGSBRT NOT PUBLISHED…Yet**



- Published in Aug 2014
- Most SRT books have chapters dedicated to clinical sites
- This book focuses on technology, biology, physics…. With only one summary chapter on clinical experience (and results of clincial trials)

Table of Normal Tissue Tolerances

TG 101: Table 3

Serial tissue	Max critical volume above threshold	One fraction: Threshold dose (Gy)	One fraction: Max point dose (Gy)[a]	Three fractions: Threshold dose (Gy)	Three fractions: Max point dose (Gy)[a]	Five fractions: Threshold dose (Gy)	Five fractions: Max point dose (Gy)[a]	End point (≥Grade3)
Optic pathway	<0.2 cc	8	10	15.3 (5.1 Gy/fx)	17.4 (5.8 Gy/fx)	23 (4.6 Gy/fx)	25 (5 Gy/fx)	Neuritis
Cochlea			9		[illegible]		25 (5 Gy/fx)	Hearing loss
Brainstem (not medulla)	<0.5 cc	10	15	18 (6 Gy/fx)	[illegible] (7.7 Gy/fx)	23 (4.6 Gy/fx)	31 (6.2 Gy/fx)	Cranial neuropathy
Spinal cord and medulla	<0.35 cc	10	14	18 [illegible]	[illegible] (7.3 Gy/fx)	23 (4.6 Gy/fx)	30 (6 Gy/fx)	Myelitis
	<1.2 cc	7		12.[illegible]		14.5 (2.9 Gy/fx)		
Spinal cord subvolume (5–6 mm above and below level treated per Rx)	<10% of subvolume	10	[illegible]	18 (6 Gy/fx)	21.9 (7.3 Gy/fx)	23 (4.6 Gy/fx)	30 (6 Gy/fx)	Myelitis
Cauda equina	<5 cc	14	16	21.9 (7.3 Gy/fx)	24 (8 Gy/fx)	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Neuritis
Sacral plexus	<5 cc	[illegible]	16	22.5 (7.5 Gy/fx)	24 (8 Gy/fx)	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Neuropathy
Esophagus[b]	<5 cc	[illegible]	15.4	17.7 (5.9 Gy/fx)	25.2 (8.4 Gy/fx)	19.5 (3.9 Gy/fx)	35 (7 Gy/fx)	Stenosis/fistula
Brachial plexus	<3 cc	[illegible]	17.5	20.4 (6.8 Gy/fx)	24 (8 Gy/fx)	27 (5.4 Gy/fx)	30.5 (6.1 Gy/fx)	Neuropathy
Heart/pericardium	<15 cc	[illegible]	22	24 (8 Gy/fx)	30 (10 Gy/fx)	32 (6.4 Gy/fx)	38 (7.6 Gy/fx)	Pericarditis
Great vessels	<10 cc	31	37	39 (13 Gy/fx)	45 (15 Gy/fx)	47 (9.4 Gy/fx)	53 (10.6 Gy/fx)	Aneurysm
Trachea and large bronchus[b]	<4 cc	10.5	20.2	15 (5 Gy/fx)	30 (10 Gy/fx)	16.5 (3.3 Gy/fx)	40 (8 Gy/fx)	Stenosis/fistula
Bronchus-smaller airways	<0.5 cc	12.4	13.3	18.9 (6.3 Gy/fx)	23.1 (7.7 Gy/fx)	21 (4.2 Gy/fx)	33 (6.6 Gy/fx)	Stenosis with atelectasis
Rib	<1 cc	22	30	28.8 (9.6 Gy/fx)	36.9 (12.3 Gy/fx)	35 (7 Gy/fx)	43 (8.6 Gy/fx)	Pain or fracture
	<30 cc			30.0 (10.0 Gy/fx)				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SOME CAVEATS!

AAPM Task Group No. 101 on SBRT *Medical Physics* 37(8): 4078-4101, Aug 2010

An Introduction to the Recommendations for Physicists and Physicians from the AAPM Task Group No. 101 on SBRT *Medical Physics* 37(8): 4078-4101, Aug 2010

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

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Table of Normal Tissue Tolerances

- There is sparse long-term follow-up for SBRT.
- Data in table 3 should be treated as a first approximation!
- Doses are mostly invalidated, and they are based mostly on observation and theory.
- There is some measure of educated guessing!

R. Timmerman, 10/26/09, pers. comm.

AAPM Task Group No. 101 on SBRT *Medical Physics* 37(8): 4078-4101, Aug 2010

UCDAVIS

AAPM WGSBRT: Radiobiological Effects of Hypofractionation.

A WG with 74 Physicians, Physicists, and radiobiologists

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Soren Bentzen, PhD
Tithi Biswas, MD
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Planning Aspects for New SBRT Program

6 TD Solberg et al — *Practical Radiation Oncology: August 2011*

Table 1. Essential planning aspects for developing a new SBRT program and/or considering new disease sites.

Recommendation	Duration or Frequency	Reference
Establish clinical program goals, specify disease sites, identify program specialists, develop guidelines for treatment, follow-up and assessment.	Initially	33-34, 36
Identify required resources: expertise, personnel, technology, time.	Initially, and for each new technology and/or disease site	32-33
Perform technology assessment commensurate with clinical goals, identify equipment and processes for simulation, immobilization, image guidance, management of organ motion, treatment delivery.	Initially, and for each new technology and/or disease site	32-33
Perform assessment of staffing levels, develop processes for initial and ongoing training of all program staff.	Initially, and for each new technology and/or disease site	32-35
Develop and use checklists for all aspects of SRS/SBRT processes.	Initially, and for each new technology and/or disease site	34-36
Provide documentation for a culture and environment fostering clear and open communication.	Ongoing	32
Develop quality assurance processes that encompass all clinical and technical SBRT program aspects, clearly following available guidance, with regard to procedures and tolerances.	Initially, and for each new technology and/or disease site	32-36, 43
Conduct clinical SBRT patient conferences for pre-treatment planning and post-treatment review.	Ongoing	
Develop processes for documentation and reporting, peer review, regular review of processes and procedures, updating clinical guidelines and recommendations, ongoing needs assessment, and continuous quality improvement.	Ongoing	32-35

"Quality and Safety Considerations in SRS and SBRT", Solberg et al, *Practical Rad Onc*, 2011

QA and Safety in SRS / SBRT (Executive Summary and Supplemental Material)

SUPPLEMENTAL MATERIAL

Practical Radiation Oncology (2011)

pro

Quality and Safety Considerations in Stereotactic Radiosurgery and Stereotactic Body Radiation Therapy

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Reprint requests to:
Timothy D. Solberg, Ph.D.

This document was prepared by the SBRT experts invited by the Multidisciplinary Quality Assurance Subcommittee of the Clinical Affairs and Quality Committee of the American Society for Radiation Oncology (ASTRO) as a part of ASTRO's Target Safely Campaign.

Personnel Qualifications for an SRT Program

Table 2. Personnel qualifications of a stereotactic program

Recommendation	Duration or Frequency	Reference
All personnel must demonstrate initial attainment of knowledge and competence in their respective discipline through graduation from an approved educational program, board certification and licensure as appropriate.	Initially	32-33
All personnel must receive vendor provided equipment -specific training prior to involvement in an SBRT program.	16 hours per staff member	32, 34
All personnel must receive disease-site-specific training prior to involvement in a stereotactic program.	16 hours per staff member	32, 34
All personnel must maintain their skills by lifelong learning through continuing professional development. For physicians and physicists this is the ABR Maintenance of Certification process.	Ongoing	32, 34-35
There must be adequate resources in place to meet the demands of the stereotactic program with sufficient staff. Staff must have sufficient time to carry out the necessary tasks without undue pressure.	Ongoing	32-33, 37, 39
Job description and list of responsibilities should be clearly delineated in writing for all stereotactic program individuals.	Initially	32-33
Non-radiation oncology specialists can sometimes lend expertise in the area of target delineation for SBRT, given a deep fund of knowledge in the anatomy of various body sites. Examples of such specialists include neurosurgeons, pulmonologists, hepatologists, and oncologic surgeons.		

"Quality and Safety Considerations in SRS and SBRT", Solberg et al, Practical Rad Onc, 2011

Commissioning of a SRS Program

Table 3. Essential commissioning elements of a stereotactic program.

Recommendation	Duration	Reference
Appropriate resources, specialized equipment, personnel, time, must be evaluated and available prior to initiation of acceptance and commissioning processes and procedures.	8-16 weeks	32-33
Independent assessment of measured beam data should be performed prior to initiating a clinical SBRT program.	1 week	
Independent verification of absolute calibration should be performed prior to initiating a clinical stereotactic program.	<1 week	
Comprehensive treatment planning system commissioning incorporating a full range of stereotactic delivery parameters and techniques, and specifically addressing use of inhomogeneity corrections with specific dose algorithm(s), must be performed prior to initiating a clinical stereotactic program.	4-8 weeks	33
Independent verification of system commissioning, utilizing appropriate specialized phantoms such as those from the Radiological Physics Center, should be performed prior to initiating a clinical stereotactic program and prior to initiating new clinical sites and/or treatment techniques.	2-4 weeks	
Thorough commissioning of simulation devices and processes, including 4D CT if used, must be performed prior to initiating a clinical stereotactic program.	2-4 weeks	33
Management of respiratory motion is an essential element of SBRT simulation, planning and delivery. Measures must be developed to ensure effective and safe operation of these technologies.	2-4 weeks	33-34, 40
Evaluation of individual and end-to-end localization capabilities of the image guidance system must be performed prior to initiating a clinical stereotactic program and prior to initiating new clinical sites and/or treatment techniques.	2 weeks	33-34
End-to-end commissioning procedures, incorporating simulation, treatment planning and dosimetry, image guidance, management of motion, and treatment management systems, must be performed prior to initiating a clinical stereotactic program and prior to initiating new clinical sites and/or treatment techniques. In addition, users may find it useful to deliberately introduce known errors, and evaluate the capabilities of the system and processes in detecting such errors.	2 weeks	33

"Quality and Safety Considerations in SRS and SBRT", Solberg et al, Practical Rad Onc, 2011

Sample Checklist for SRS Program: Lung

Practical Radiation Oncology: August 2011 — Safety Considerations for SRS and SBRT 21

Appendix 2 – Institution 1: Lung SBRT worklist example

SBRT Lung Worklist:

Patient Name: ______ MR#: ______

Date of Implant: ______ Target Area: ______

Rad Oncologist: ______

Preplan:

Planned Dose/ Fractions: _50 Gy in 4 fractions______

Other images needed for planning: ______

Markers to Implant (2 Visicoil 1 cm markers)

Superdimension CT ready for implant.

Target Volume & Coverage:

4D CT scan performed and loaded to iPlan ______

Review and approve Image Fusion (including PET/ Diag, etc): ______

Select exhale scan for planning ______

PTV = 3-7 mm margin on GTV (as determined by case) ______

Table and External Are edited. ______

Patient localized to BB marks ______

At least 7 beams (conformal beams only) ______

*Use Normalization point for RX (50Gy at 90% IDL) ______

Hot spots is in the PTV ______

Rx IDL (typically 90%) covers approx. 95% of PTV (or greater) ______

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

PITV (Near 2.0 or less) = ______

*Exceptions depending on case & physician

Normal Tissue Constraints:

Max Cord < 14 Gy ______ Max Esoph. < 17 Gy ______

Max Brach.l Plex. < 14 Gy ______ Heart <10% > 17Gy ______

Max Trach./Broncus < 17 Gy ______ Max Stom. < 17Gy ______

%Liver > 15Gy (< 20%) ______ %Lung > 10Gy (< 30%) ______

Plan Review / Finalization:

Collimator angles are all the same ______

Collisions have been checked (Table angles as necessary) ______

Planned on Correct Data set ______

Heterogeneity is turned on ______

Dose normalized to isocenter ______

Coverage of PTV ______

Sort Beam Angles into Treatment Order (CW, group table angles) ______

Export Exactrac (Only planning CT no other images) ______

Export Mosaiq (change dose, dose rate, time as necessary) ______

Print ______

Chart / Physics Check:

Approved RX ______

Document Shifts ______

Double check spreadsheet or IMRT QA ______

Import to Exactrac (identify markers) ______

Append Mosaiq Qual checklist for PR and HM ______

Billing ______

Check Shifts (iso coordinates) ______

Physics & Physician must be present for 1st Day of Treatment to approve alignments

______

Physicist Date

"Quality and Safety Considerations in SRS and SBRT", Solberg et al, *Practical Rad Onc*, 2011

Practical Radiation Oncology: August 2011 — Safety Considerations for SRS and SBRT 21

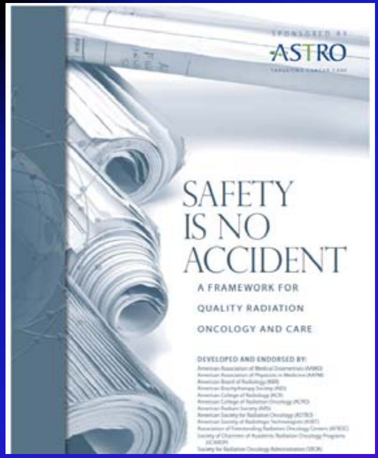
Appendix 1 – Recommendations to Guard Against Catastrophic Failures in SRS and SBRT

Procedure and Tests	Principal	Primary Review	Secondary Review
1. Commissioning Treatment Devices and Planning Systems			
Machine output calibrations and factors in accordance with relevant guidelines (TG-51, TG-101, TG-142).	Physicist	2nd physicist	Independent assessment (RPC, etc.)
Treatment planning system commissioning should include test cases similar to those encountered in SBRT (TG-53).	Physicist	2nd Physicist	Physicists and Dosimetrists
2. Patient Selection			
Patient selection should be in accordance with an approved clinical protocol.	Physician	Physicians and Physicists	ALL
3. Patient Simulation			
Patient simulated in accordance with approved protocol (immobilization and respiratory management) and supervised by physician.	Simulation Therapist	Physician	Physicists and Dosimetrists
4. Patient Treatment Planning			
Verify the patient information, treatment site, and prescription.	Dosimetrist	Physician	All
Verify correct positioning of the high dose and intermediate regions of isodose plan relative to targets.	Dosimetrist	Physician	Physicist
Verify the reference images and any shift information - physician determines IGRT technique.	Dosimetrist	Physicist	ALL
5. Pre-Treatment Quality Assurance			
Verify that the correct version of the patient's treatment plan is approved, sent to treatment management system, and used for patient-specific QA.	Dosimetrist	Physicist	ALL
Perform a thorough chart review.	Therapist	Physicist	ALL
Perform a complete chart check including review of information in treatment management system, field apertures in treatment management system, and check of dose to verify TPS calculation.	Dosimetrist	Physicist	ALL
Before the first treatment or for any change in treatment, perform patient-specific QA to guarantee that data transfer between systems is correct before patient treatment begins.	Physicist	Physicist	ALL
6. Treatment Delivery			
Halt a procedure if the operator is unclear about what is being done.	ALL	ALL	ALL
Perform a check of treatment parameters before start of each treatment against a fixed version of the treatment plan.	Therapist	2nd Therapist	ALL
Perform a time out prior to treatment delivery.	Therapist	2nd Therapist	ALL
Assess patient clinically during course of SBRT to identify any acute effects.	Physician, Therapist, and Nurse	Physician, Therapist, and Nurse	
7. Quality Performance and Improvement			
Perform end-to-end testing to guarantee transfer of data among all systems involved in imaging, planning and dose delivery (annually and after any software or hardware changes).	Physicist	2nd Physicist	Physicists and Dosimetrists

Recommendations to guard against catastrophic failures:

- Principals
- Primary Reviews
- 2nd Reviews

"Quality and Safety Considerations in SRS and SBRT", Solberg et al, *Practical Rad Onc*, 2011



The 52-page document represents an intensive collaboration among 31 specialists from all of the major societies in the radiation oncology field, representing physicians, medical physicists, radiation therapists, medical dosimetrists, nurses and administrators to ensure safe and effective radiation therapy treatment for patients

ASTRO Publication 2012: The book is available online free as a PDF document

Staffing…from ASTRO, Safety is No Accident

A sample worksheet for calculating medical physics and dosimetry staffing in radiation oncology:

			Relative FTE Factor		Required FTE		Required Total FTE	
			Physicist	Dosimetrist	Physicist	Dosimetrist	Physicist	Dosimetrist
Equipment, Sources and Systems	Services -- # of Units or Licenses*	No. of systems*						
	Multi energy accelerators		0.25	0.05				
	Single energy accelerators		0.08	0.01				
	Tomotherapy, CyberKnife, GammaKnife		0.3	0.03				
	Cobalt Units, IMRT, PACS, EMR & Contouring		0.08	0.03				
	Orthovoltage and superficial units		0.02	0.01				
	Manual brachytherapy; LDR Seed Implants		0.2	0.03				
	HDR brachytherapy		0.2	0.02				
	Simulator, CT-Simulator, PET, MRI Fusion		0.05	0.02				
	Computer planning system (per 10 workstations)		0.05	0.02				
	HDR planning system		0.2	0.01				
						Subtotal		
No. Patient Procedures	Annual # of Patients undergoing Procedures**	No. of patients**						
	External Beam RT with 3D planning		0.0003	0.003				
	External Beam RT with conventional planning		0.0002	0.002				
	Sealed source Brachytherapy (LDR & HDR)		0.008	0.003				
	~~Unsealed source therapy~~		~~0.008~~	~~0.005~~				
	IMRT, IGRT, SRS, TBI, SBRT		0.008	0.005				
						Subtotal		
Nonclinical - Estimated Total FTE Effort	Estimated Total (Phys & Dosim) FTE Effort***	FTE Effort***						
	Education & Training (FTE)		0.667	0.333				
	Generation of Internal Reports (FTE)		0.667	0.333				
	Committees & Meetings inc. Rad. Safety (FTE)		0.667	0.333				
	Administration and Management (FTE)		0.667	0.333				
						Subtotal		
						Total		

* Enter the sum of the number of therapy units, imaging systems, workstations, support systems and technologies in each category (column 3).
** Enter the annual number of new patients that undergo each of the following planning and treatment deliver procedures; count each new patient one time (column 3).
***Enter the summed total medical physicist and medical dosimetrist estimated FTE effort in each of the following categories. See Component FTE table for typical FTE (column 3)

Doctors jailed in French radiation scandal

At least 24 people treated between May 2004 and August 2005 received 20 per cent more radiation than recommended due to a calibration error linked to the introduction of new machines in 2004.

The Telegraph

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Monday 11 March 2013

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French doctors and radiologist jailed for radiation overdoses

Two doctors and a radiologist have been sentenced to 18 months in prison for their role in radiation overdoses that killed at least 12 people in France and left dozens seriously ill.

Doctor Michel Aubertel waits for the verdict in Paris Photo: AFP/GETTY

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Learning Lessons from SRS/SBRT Accidents and Administrations

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Department of Radiation Oncology
UT Southwestern Medical Center
Dallas, TX

Courtesy of Ryan Foster, Ph.D/UTSW

Improper Jaw Size During SRS

- Location : France
- Year : 2004
- Issue : Physicist told therapist to set a "40x40" for cone SRS treatment; therapist set 40x40 cm^2

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).

- Consequences : 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
- Lesson : Have clear procedures/checklists in place

FROM RECENT ACCIDENTS IN RADIATION THERAPY IN FRANCE
S. Derreumaux*, C. Etard, C. Huet, et al.
Institut de Radioprotection et de Su^ rete´ Nucle´aire, Direction de la Radioprotection de l'Homme, IRSN, BP 17, F-92262 Fontenay-aux-Roses Cedex, France
Radiation Protection Dosimetry (2008), Vol. 131, No. 1, pp. 130–135

Courtesy of Ryan Foster, Ph.D/UTSW

SRS Cone Left Out

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.

Improper Jaw Size During SRS

The New York Times

A Pinpoint Beam Strays Invisibly, Harming Instead of Healing

- Location : United States

This occurred in France in 2004!

- Issue : Collimator jaws for SRS treatment using cones were left open during treatment
- Consequences : Patient "is in a nursing home, nearly comatose…"
- Lesson : Interlocks needed, better communication, standardized procedures

Commissioning

- Location : France
- Year : 2007
- Issue : Large chamber used to make small field SRS measurements of output factors
- Consequences : Up to 200% overdose for some patients
- Lesson : Compare commissioning values with other institutions, look for guidance

Courtesy of Ryan Foster, Ph.D/UTSW

Same mistakes keep happening


Radiation Errors Reported in Missouri

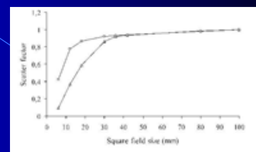


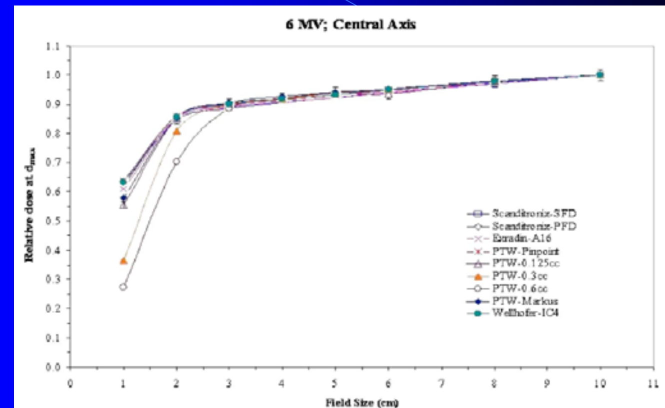
Figure 6. Scatter factors measured in 6 MV photon beams with a 0.65-cm³ 'Farmer' chamber (triangles) and a 0.03-cm³ 'Pinpoint' chamber (circles) (A. Lisbona, personal

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

This happened in France in 2007!

Courtesy of Ryan Foster, Ph.D/UTSW

Small Field Output Factors



Courtesy of Ryan Foster, Ph.D/UTSW

Das, Ding and Ahnesjo. Med Phys Vol. 35, No.1, 2008.

Miscalibration

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

- Location : Florida
- Year : 2004-2005
- Issue : Miscalibration of SRS linac
- Consequences : 77 patients received a 50% overdose
- Lesson : Get independent/second check of the output (RPC)

Courtesy of Ryan Foster, Ph.D/UTSW

Small Field Dosimetry

- SBRT often uses small fields and beamlets (< 1cm) in diameter
- This can cause a variety of dosimetric effects:
  - Loss of lateral electronic equilibrium
  - Volume averaging
  - Detector interface artifacts
  - Colllimator effects
  - Detector positioning and orientation effects

Small Field Dosimetry

- Use detectors with a spatial resolution of 1mm or better (stereotactic detectors) for basic dosimetry measurements
- Be VERY careful with setup and detector positioning
- Remember that MLC-shaped fields have more uncertainty than circular cones
- When detector diameter is close to the FWHM of the field, the detector volume effect becomes significant

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!

Courtesy of Ryan Foster, Ph.D/UTSW

Detectors for small fields

Recommendation: the maximum inner diameter of a detector should be less than half the FWHM of the smallest beam measured in order for the deconvolution of the detector-size effect to work properly.

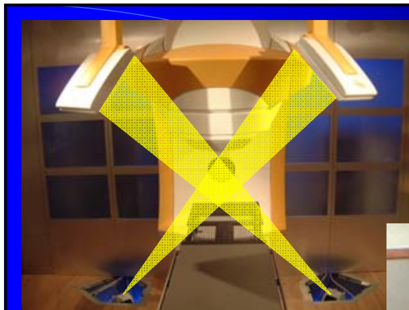
How do you know if your data is good? Compare with Other Institutions / Machines

TABLE 1. The RPC-measured and institution treatment planning system-calculated small field size dependence output factor values for Varian machines. The values in square brackets and parentheses beneath each energy for each field size value are the average absolute percent differences and standard deviations of the values, respectively. For each energy and field size, the number of measurements (accelerators) is also shown.

Field Size (cm × cm)	*Varian 6 MV RPC*	*Varian 6 MV Institution*	*Varian 10 MV RPC*	*Varian 10 MV Institution*	*Varian 15 MV RPC*	*Varian 15 MV Institution*	*Varian 18 MV RPC*	*Varian 18 MV Institution*
10 × 10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6 × 6	**0.921** (0.013) [0.9%] (n=64)	0.929 (0.004)	**0.946** (0.017) [0.7%] (n=9)	0.953 (0.016)	**0.951** (0.008) [0.5%] (n=14)	0.950 (0.008)	**0.949** (0.011) [0.5%] (n=16)	0.950 (0.014)
4 × 4	**0.865** (0.018) [1.3%] (n=64)	0.874 (0.021)	**0.900** (0.024) [1.3%] (n=9)	0.912 (0.030)	**0.909** (0.013) [1.1%] (n=14)	0.909 (0.017)	**0.902** (0.014) [1.1%] (n=16)	0.900 (0.024)
3 × 3	**0.828** (0.017) [1.7%] (n=62)	0.841 (0.025)	**0.867** (0.020) [1.2%] (n=9)	0.875 (0.025)	**0.874** (0.014) [1.3%] (n=12)	0.877 (0.019)	**0.861** (0.014) [1.7%] (n=16)	0.856 (0.027)
2 × 2	**0.786** (0.019) [2.3%] (n=55)	0.796 (0.031)	**0.817** (0.015) [1.8%] (n=11)	0.828 (0.019)	**0.803** (0.016) [2.8%] (n=10)	0.813 (0.038)	**0.784** (0.015) [3.5%] (n=15)	0.782 (0.034)

Followill et al. JACMP 2012

Courtesy of Ryan Foster, Ph.D/UTSW

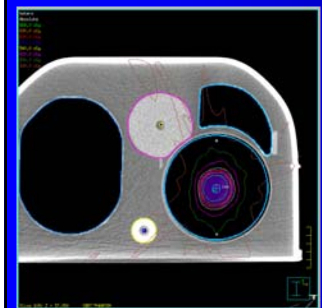


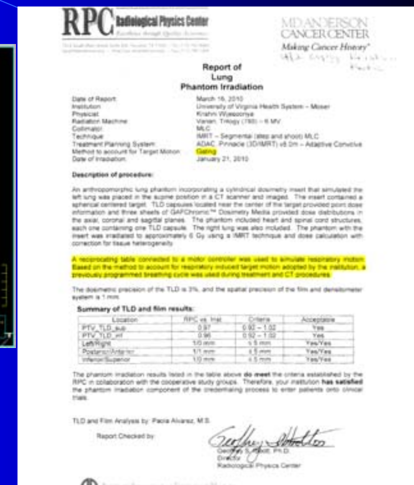
What About Localization Accuracy?

IGRT Accuracy

Must perform end to end tests!

RPC Lung Motion Phantom Benchmark





Summary of Published QA Recommendations for SBRT (TG 101)

TABLE V. Summary of published QA recommendations for SBRT and SBRT-related techniques.

Source	Purpose	Proposed test	Reported achievable tolerance	Proposed frequency
Ryu *et al.*, 2001[a]	End-to-end localization accuracy	Stereo x ray/DRR fusion	1.0 to 1.2 mm root mean square	Initial commissioning and annually thereafter
Ryu *et al.*, 2001[a]	Intrafraction targeting variability	Stereo x ray/DRR fusion	0.2 mm average, 1.5 mm maximum	Daily (during treatment)
Verellen *et al.*, 2003[b]	End-to-end localization accuracy	Hidden target (using stereo x ray/DRR fusion)	0.41 ± 0.92 mm	Initial commissioning and annually thereafter
Verellen *et al.*, 2003[b]	End-to-end localization accuracy	Hidden target (using implanted fiducials)	0.28 ± 0.36 mm	Initial commissioning and annually thereafter
Yu *et al.*, 2004[c]	End-to-end localization accuracy	Dosimetric assessment of hidden target (using implanted fiducials)	0.68 ± 0.29 mm	Initial commissioning and annually thereafter
Sharpe *et al.*, 2006[d]	CBCT mechanical stability	Constancy comparison to MV imaging isocenter (using hidden targets)	0.50 ± 0.5 mm	Baseline at commissioning and monthly thereafter
Galvin *et al.*, 2008[e]	Overall positioning accuracy, including image registration (frame-based systems)	Winston-Lutz test modified to make use of the in-room imaging systems	≈2 mm for multiple couch angles	Initial commissioning and monthly thereafter
Palta *et al.*, 2008[f]	MLC accuracy	Light field, radiographic film, or EPID	<0.5 mm (especially for IMRT delivery)	Annually
Solberg *et al.*, 2008[g]	End-to-end localization accuracy	Hidden target in anthropomorphic phantom	1.10 ± 0.42 mm	Initial commissioning and annually thereafter
Jiang *et al.*, 2008[h]	Respiratory motion tracking and gating in 4D CT	Phantoms with cyclical motion	N/A	N/A
Bissonnette *et al.*, 2008[i]	CBCT geometric accuracy	Portal image vs CBCT image isocenter coincidence	±2 mm	daily

Recommends End-to-End localization accuracy at initial commissioning and annually thereafter.

… learning from our mistakes by maintaining data on our experience… lots of experience…

lots of data!

UCDAVIS COMPREHENSIVE CANCER CENTER

ASTRO-NCI-AAPM Big Data Workshop: Aug 13-14, 2015

SAMS Question

ANSWER QUESTION #1

D. Checklists used prior to daily treatment must be customized to the particular treatment planning and delivery systems.

Checklists should be used, and they should be customized to match the technology and treatment site. These checklists should also be updated regularly to reflect any changes in procedures or technological updates in the SBRT program.

Reference:

Timothy D. Solberg, et al, "Quality and safety considerations in stereotactic radiosurgery and stereotactic body radiation therapy" *Practical Radiation Oncology* (2011)

SAMS Question

Question #1: The use of procedural checklists can be particularly effective at ensuring compliance and minimizing error. Which of the following best describes the use of checklists for treatments:

A. Checklists are only helpful for the initial stages of an SBRT program

B. The adoption of the same site specific checklists from other institutions will usually suffice for initiating SBRT

C. Checklists are exclusively for the therapists to review and ensure that the patient has been set-up correctly.

D. Checklists used prior to daily treatment must be customized to the particular treatment planning and delivery systems.

SAMS Question

Question #2: When target and/or critical structures cannot be localized accurately due to motion or metal artifacts which of the following applies…

A. Utilize the deformable image registration features of the treatment planning system to develop a treatment plan

B. Contour the target and critical structures as best you can and increase the margins on the target to a level that is necessary to account for the motion

C. Reduce the dose and/or fractionation from the standard protocol to account for the errors in localization

D. Use orthogonal (AP and lateral) kV planar imaging to develop a 2D plan for treatment and set-up.

E. Do not pursue SBRT as a treatment option.

SAMS Question

ANSWER QUESTION #2

E. Do not pursue SBRT as a treatment option.

- If one is unable to localize the target and adjacent critical structures due to motion or metal artifacts SBRT should not be a treatment option.
- Deformation registration and other imaging tools may be instructive for targeting, but if the target and/or adjacent critical structures are not localizable than SBRT is not an appropriate delivery.
- **Reference**:

- Benedict SH, Yenice KM, Followill D, et al., "**Stereotactic Body Radiation Therapy: The Report of AAPM Task Group 101"** *Med Phys*. 2010;37:4078–4101

Thank You