Current Status of ~~SBRT~~ SABR & SRS

Alonso N. Gutiérrez, Ph.D.
gutierrezan@uthscsa.edu

Division of Medical Physics
Cancer Therapy & Research Center at
University of Texas Health Science Center San Antonio
San Antonio, TX 78229

Conflict of Interest Disclosure

- Ownership
  - VeriDos Solutions, LLC

Stereotactic Radiotherapy

- Guiding principal elements
  - Ablative doses: ≥ 8Gy
  - Focused dose distributions
  - Accurate geometrical radiation delivery
- Long standing success of SRS
  - >80-90% local control for benign, malignant tumors, AVM, trigeminal neuralgia*
  - Recent findings to pursue multiple brain metastases#
    - Treatment of multiple mets mono-isocentrically
- Newly, established success of SBRT
  - 1990's Karolinska Institute, Sweden⬩
  - Quick adoption for early-stage cancer and oligometastases

*Lippitz B, et al. Cancer Treat Rev. 2014. 40(1)
#Yamamoto M, et al. Lancet Oncol. 2014. 15(4)
⬩Blomgren H, et al. Acta Oncol. 1995. 43.

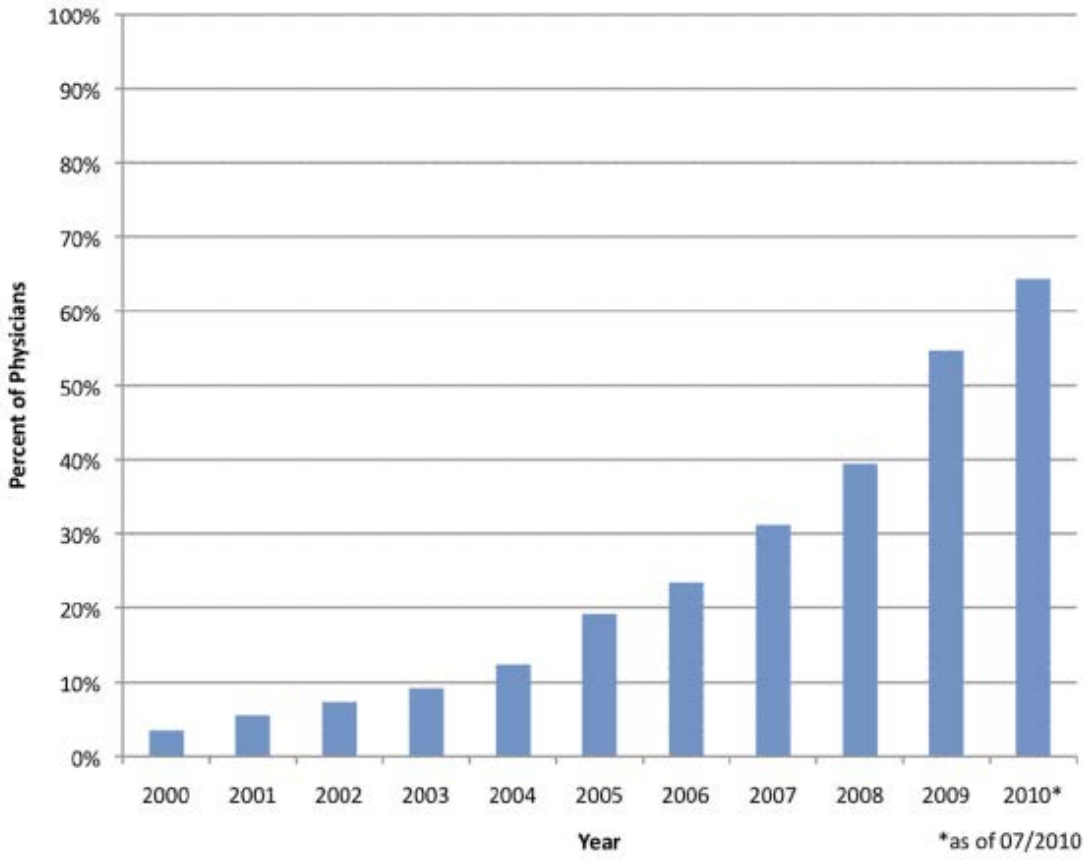
Increasing Use of SBRT

- More disease sites being pursued with SBRT techniques
  - Stage I NSCLC - RTOG 0618, 0236, 0915, 0813
  - Lung Metastases
  - Spinal Tumors – RTOG 0631
  - HCC/Liver Metastases
  - SCC H&N – U Pitt.
- Open clinical trials:
  - 253 w/SBRT keyword* (4/2/2014)
- Push for establishing stereotactic programs in both academic and private centers

*www.clinicaltrials.gov

SBRT Survey

- Sample: 1600 rad oncs.
  - 551 responses
  - 37.5% (A) / 62.5% (P)
  - 63.9% SBRT users
- >50% adopt after 2008
- 76.0% users plan to increase use
- 66.5% of non-users planned to adopt SBRT
- Common sites



*Pan H, et al. Cancer. 2011. 117(19)

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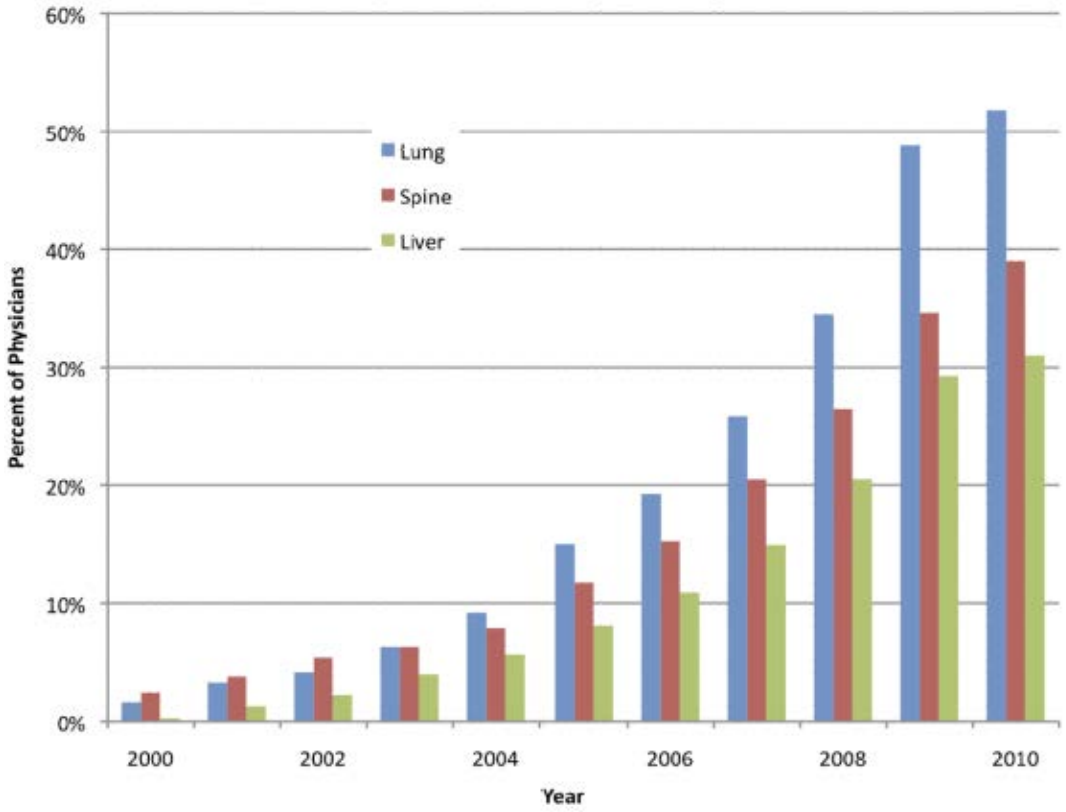


*Pan H, et al. Cancer. 2011. 117(19)

Radiobiology Challenges

- Normal tissue toxicity
  - Tolerance Tables
    - RTOG Study Updates – f/u time relatively short
    - AAPM TG 101: Dose/Volume constraints
- Radiobiological modeling
  - High dose models
    - Linear Quadratic-Linear (LQ-L)
    - Universal Survival Curve (USC)
  - Lack *in vivo* tumor dependencies
- Environmental/Molecular responses
  - Microvasculature endothelial apoptosis w/ 15-20Gy single fraction doses*
  - Induction in T-cell priming ➔ reduction of primary tumor in certain cell lines with 15-25Gy single fraction doses#

*Garcia-Barros M, et al. Science. 2003. 300
#Lee Y, et al. *Blood*. 2009. 114

Technical Challenges

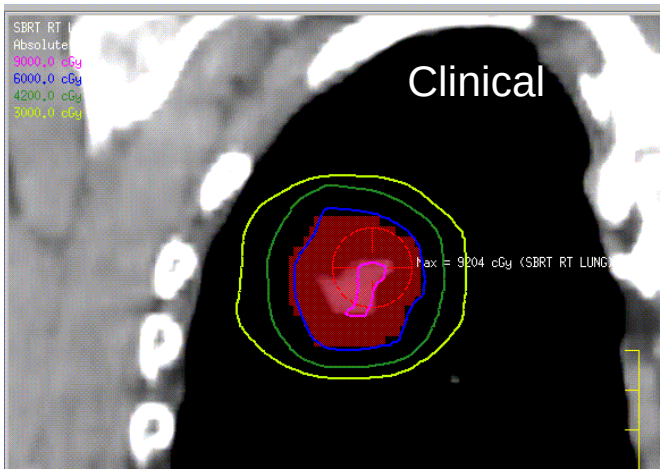
- Radiation delivery equipment
  - Machine accuracy – mechanical and imaging
  - Reduced localization residual errors - 6 DOF couch correct.
  - Real-time patient monitoring
  - Easier implementation motion management
    - Respiratory inhibition ➔ Gating/ABC & Tracking solutions
- Immobilization equipment
  - Improve patient setup reproducibility
  - Improve patient comfort
- Quality assurance equipment
  - Smaller and improved dosimeters
  - Improve phantom design – SRS/SBRT-specific

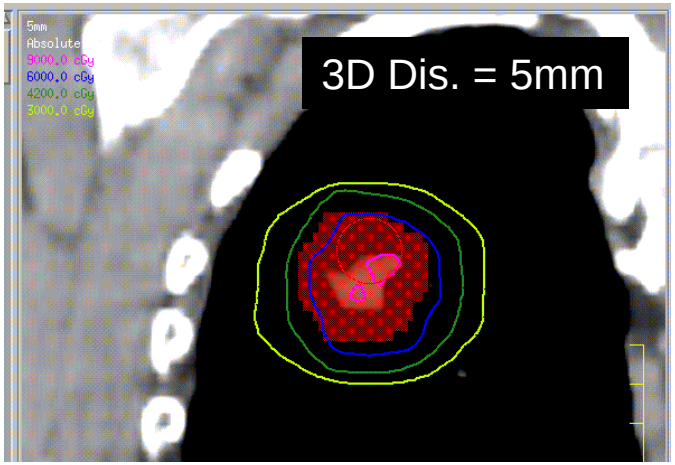
Safety Challenges

- Specialized training of staff
  - Role definition of staff in stereotactic programs
  - Formalize training requirements
- Quality assurance programs of equipment
  - Stereotactic Acceptance and Commissioning
  - Stereotactic Quality Assurance
- Establishment of safety programs
  - Patient/Process QA
  - Documentation
  - Ongoing Quality Improvements
  - Prevention of catastrophic failures

Solberg TD, et al. PRO. August. 2011.

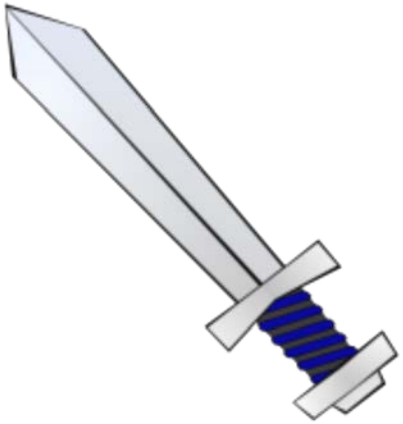
Detrimental Consequences - SBRT



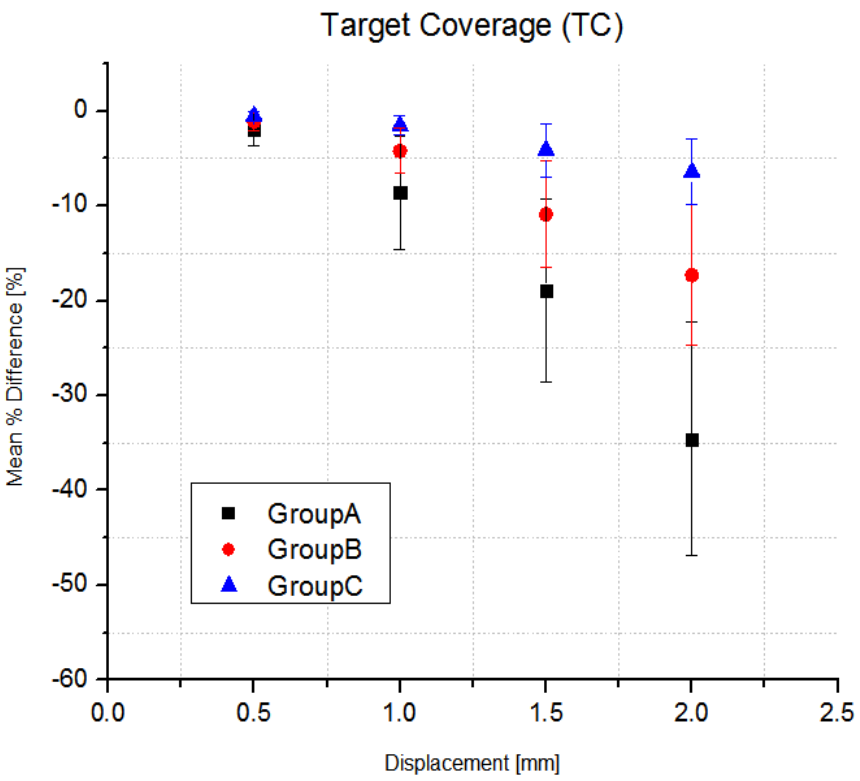


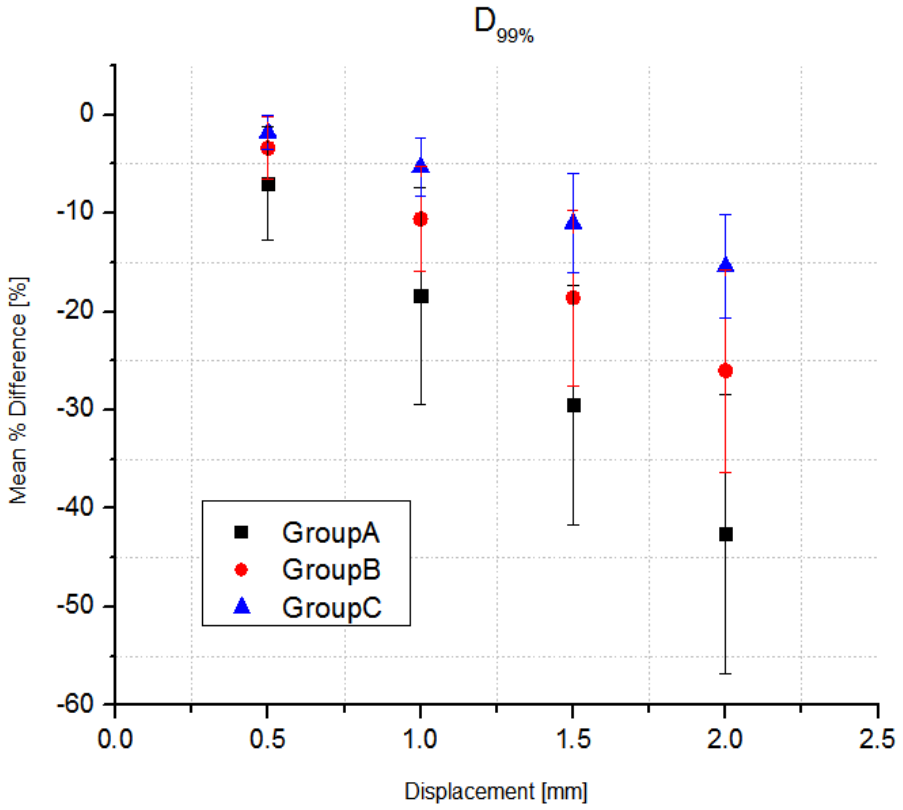
- PTV (Min Dose)
  - 1mm: -4.3%
  - 3mm: -12.2%
  - 5mm:-20.2%

- GTV
  - 1mm: -2.7%
  - 3mm: -10.3%
  - 5mm: -20.1%



Detrimental Consequences - SRS



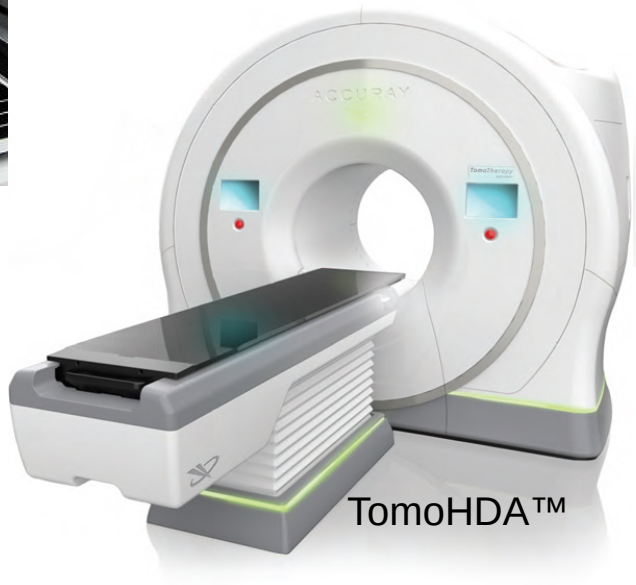


AJ Patel, et al. ISRS 2013. Toronto.

Ideal Rad Del. Equipment

- Accuracy/Stability
  - Tight machine specs (≤ 1.0mm)
- Precision via fine apertures
  - microMLC / IRIS collimator & MLC
- Image guidance
  - Accurate localization (≤ 1.0mm)
  - Volumetric image information
  - Real-time imaging
- Delivery efficiency
  - Higher dose rate
  - VMAT delivery
- Throughput
  - Fast, integrated workflow

Universal Functionality



Specialized Functionality

Vero™

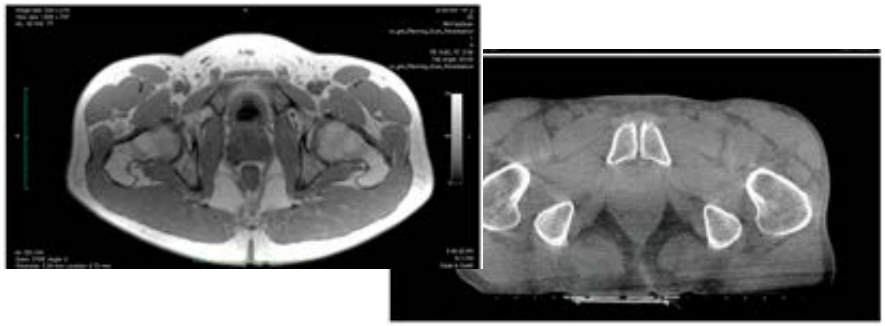
CyberKnife M6™

EDGE™

GK Perfexion™

Future Potential

- Real-time 4D volumetric imaging
- Non-ionizing, soft tissue contrast
- Design
  - Three ^{60}Co sources with DF-MLC
  - Split-magnet MRI (0.35T) system
- Automatic gating based on soft tissue detection
- Real-time adaptive tools



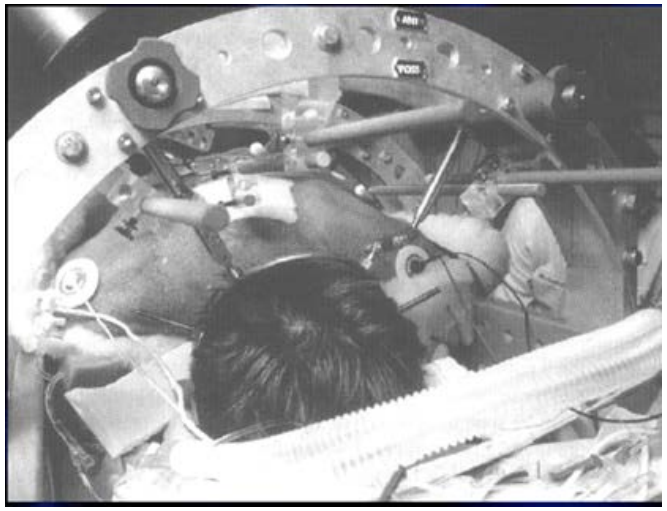
ViewRay™

MR-Guided/Real-time 3D-based (MRgRT)

Despite the nice equipment…..

Don’t forget the fundamentals!

SBRT Immobilization Devices

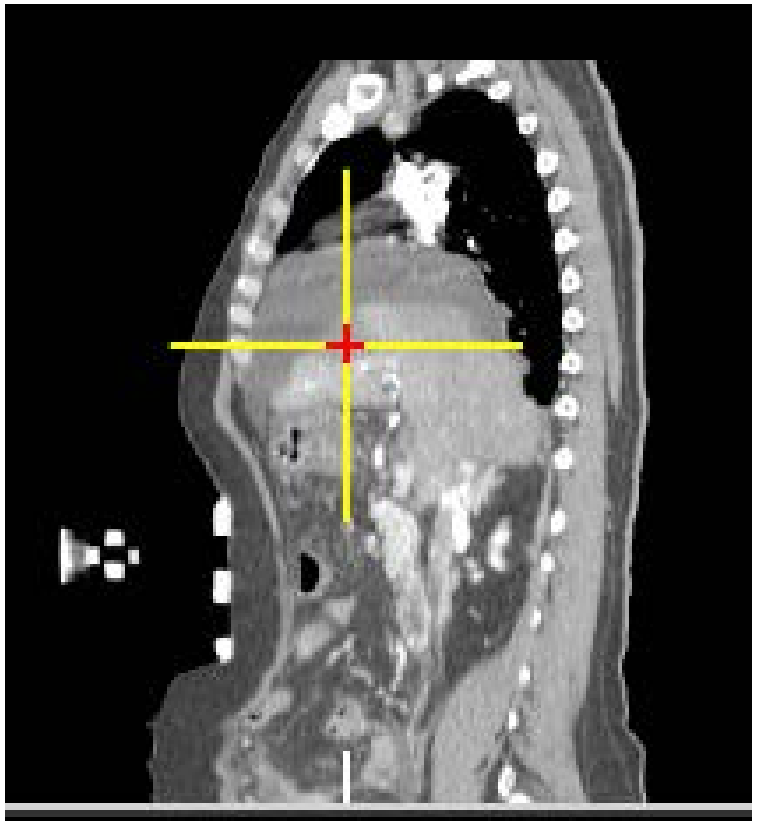


- No stereotactic coordinates
  - IG provides the stereotaxy
- Interfraction error: $\mu \leq$ 3-5mm*
- Improve patient comfort
- Respiratory inhibition devices

Hamilton, et al. Neurosurgery. 1995.

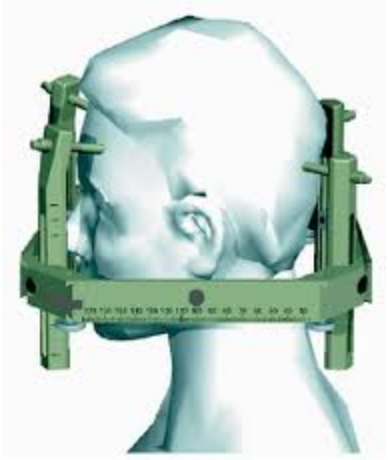
Abdominal Compression

- Basis: Limit diaphragm motion by inflating lungs with chest wall musculature
- Goal: Restrict cranial-caudal motion and reduce ITV volume
- SBRT Lung study*
  - Lower lobe
    - 3.5mm (amp) / 3.6cc (ITV)
  - Upper lobe
    - 0.8mm (amp) / 0.2cc (ITV)



Bouilhol G, et al. Phys Med. 2013

SRS Immobilization Devices



- Frameless IG-SRS
- Ease of workflow
- Setup accuracy studies
  - BrainLAB: 0.76 ± 0.46mm*

- SIG-SRS
- Initial study show comparable clinical outcomes for brain mets#
- Improved patient comfort

*Gevaert T, et al. IJROBP. 85(5). 2012
#Pan H, et al. Neurosurgery. 71(4). 2012

Quality Assurance Equipment

- Small/Narrow field geometry
  - New dosimeters for improved dosimetric characterization
- AAPM Rpt 54 – detector dimension < half field size (era ~ 1.0cm^2)
- AAPM TG 101 – spatial resolution ≤ 1.0mm (era ~ 5mm)

PTW MicroLion
- Liquid ion chamber
- Vol.: 0.0017cm^3

PTW E-Type Diode
- P-type Si
- Vol.: 0.002mm^3

IBA SFD
- P-type Si
- Vol.: 0.036mm^3

SN EDGE
- Vol.: 0.0019mm^3

Small Field Measurement Errors

LESSONS FROM RECENT ACCIDENTS IN RADIATION THERAPY IN FRANCE

S. Derreumaux*, C. Etard, C. Huet, F. Trompier, I. Clairand, J.-F. Bottollier-Depois, B. Aubert and P. Gourmelon
Institut de Radioprotection et de Sûreté Nucléaire, 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

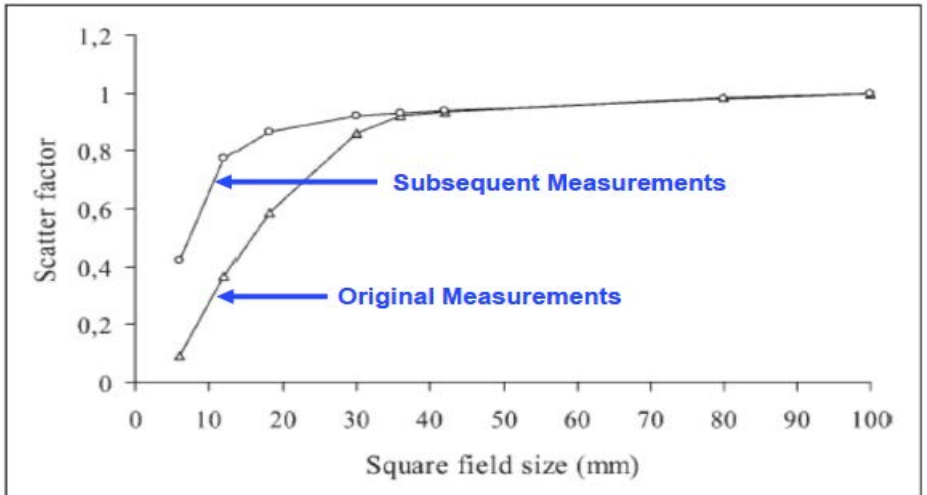


Figure 6. Scatter factors measured in 6 MV photon beams with a 0.65-cm^3 'Farmer' chamber (triangles) and a 0.03-cm^3 'Pinpoint' chamber (circles)

wnn world nuclear news

NUCLEAR EVENT REPORTS

Front Page

ENERGY & ENVIRONMENT

NEW NUCLEAR

REGULATION & SAFETY

Dose deviation during stereotactic radiosurgery treatments

18th June 2007

On 20 April 2007, the French Nuclear Safety Authority (ASN) was informed of a deviation between the delivered dose and the prescribed dose to 145 patients treated using stereotactic radiosurgery between 6 April 2006 and 17 April 2007.

February 24, 2010

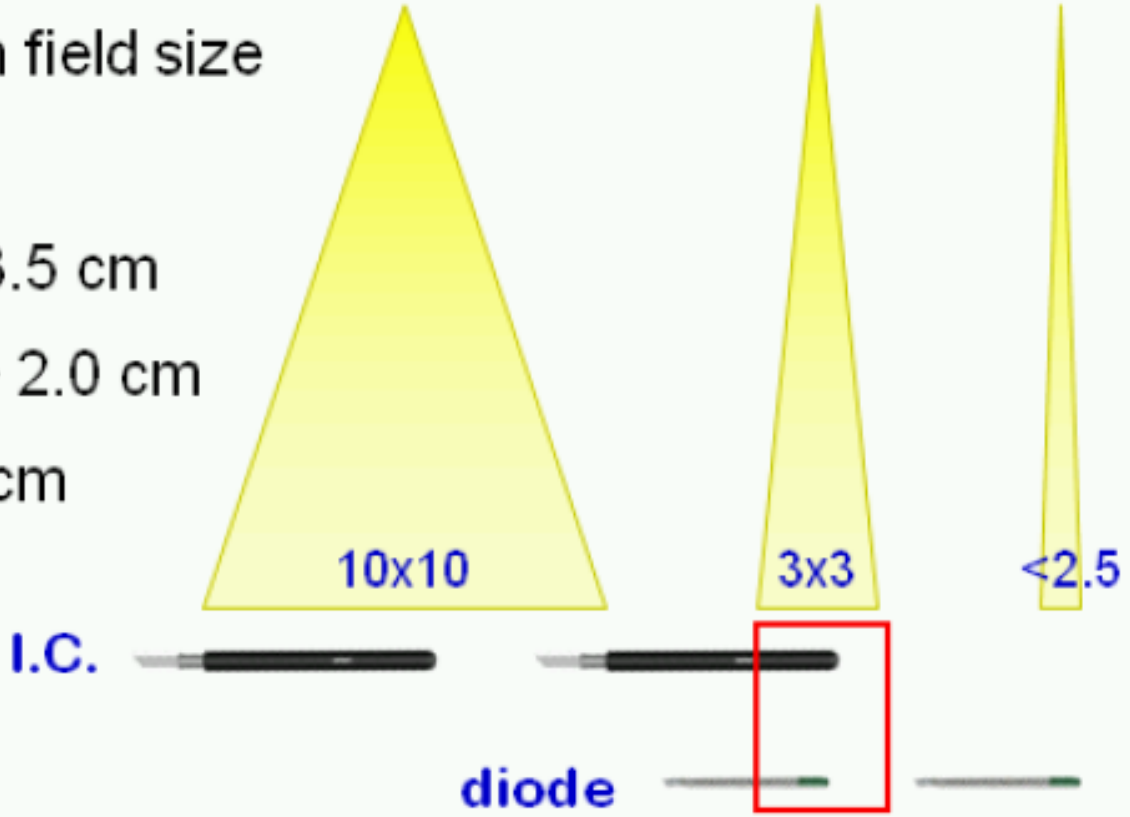
Radiation Errors Reported in Missouri

By WALT BOGDANICH and REBECCA R. RUIZ

A hospital in Missouri said Wednesday that it had overradiated 76 patients, the vast majority with brain cancer, during a five-year period because powerful new radiation equipment had been set up incorrectly even with a representative of the manufacturer watching as it was done.

Small Field Measurement - “Daisy chain”

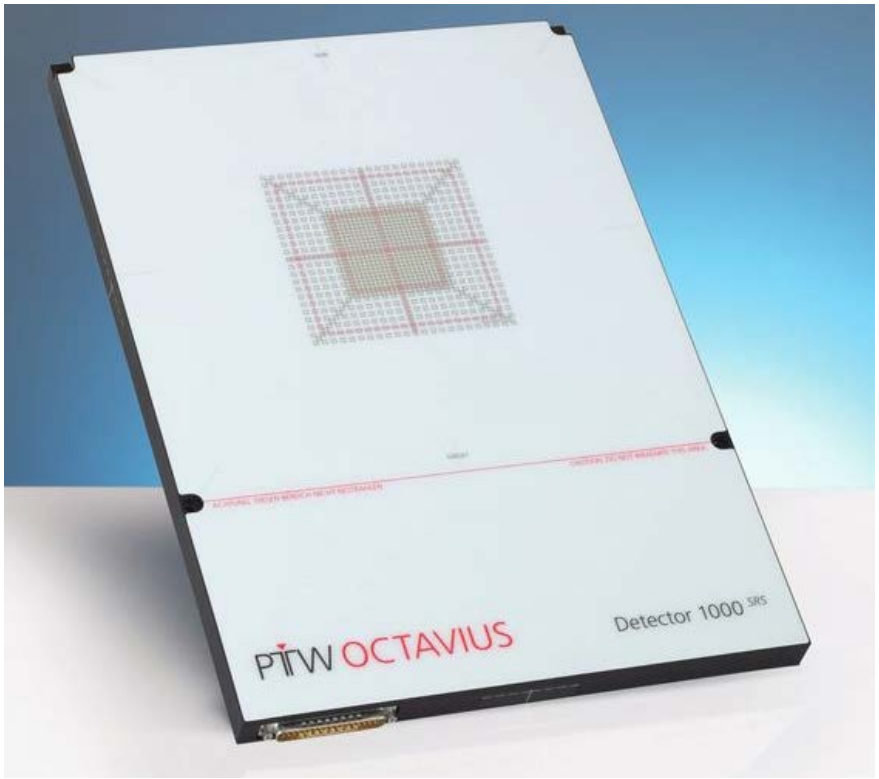
- Bridge at ~ 3-4 cm field size
- Farmer: for FS > 3.5 cm
- Pin-point: for FS > 2.0 cm
- Diode: for FS < 4 cm



*Dieterich S, et al. Med Phys. 2011. 38.
Slide courtesy of Min Leu

SBRT/SRT – Patient Specific QA

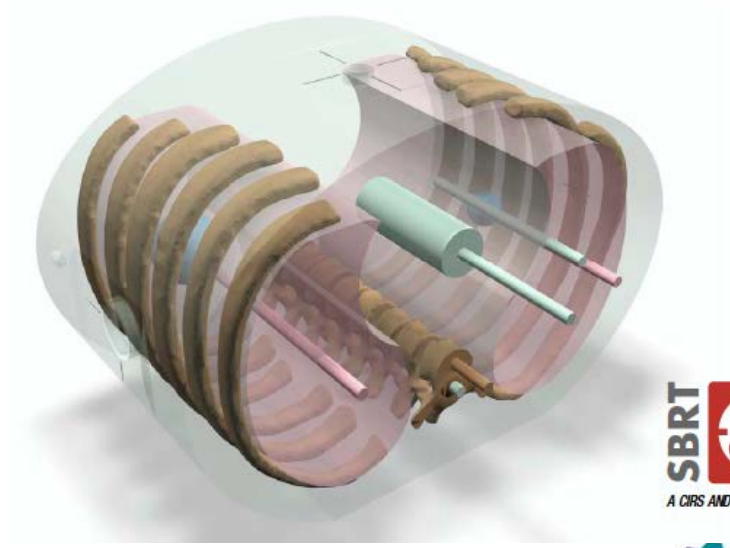
- OCTAVIUS 1000 SRS
  - High spatial resolution for small field IMRT plans
- microLion-based array
- 10x10cm^2 active area
- 977 liquid chambers
- (2.3mm x 2.3mm x 0.5mm)

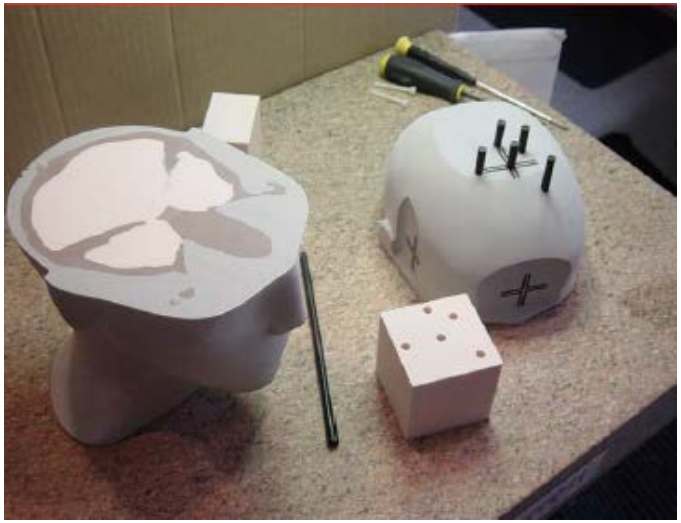


Overall Geometrical Accuracy

Newer QA Phantoms

- Specialized SBRT/ SRS phantoms
  - End-to-end testing **crucial**
    - Spatial accuracy (Hidden target)
    - Dosimetric accuracy
  - E2E needs to incorporate imaging
  - Tolerance: ≤ 1.0mm*





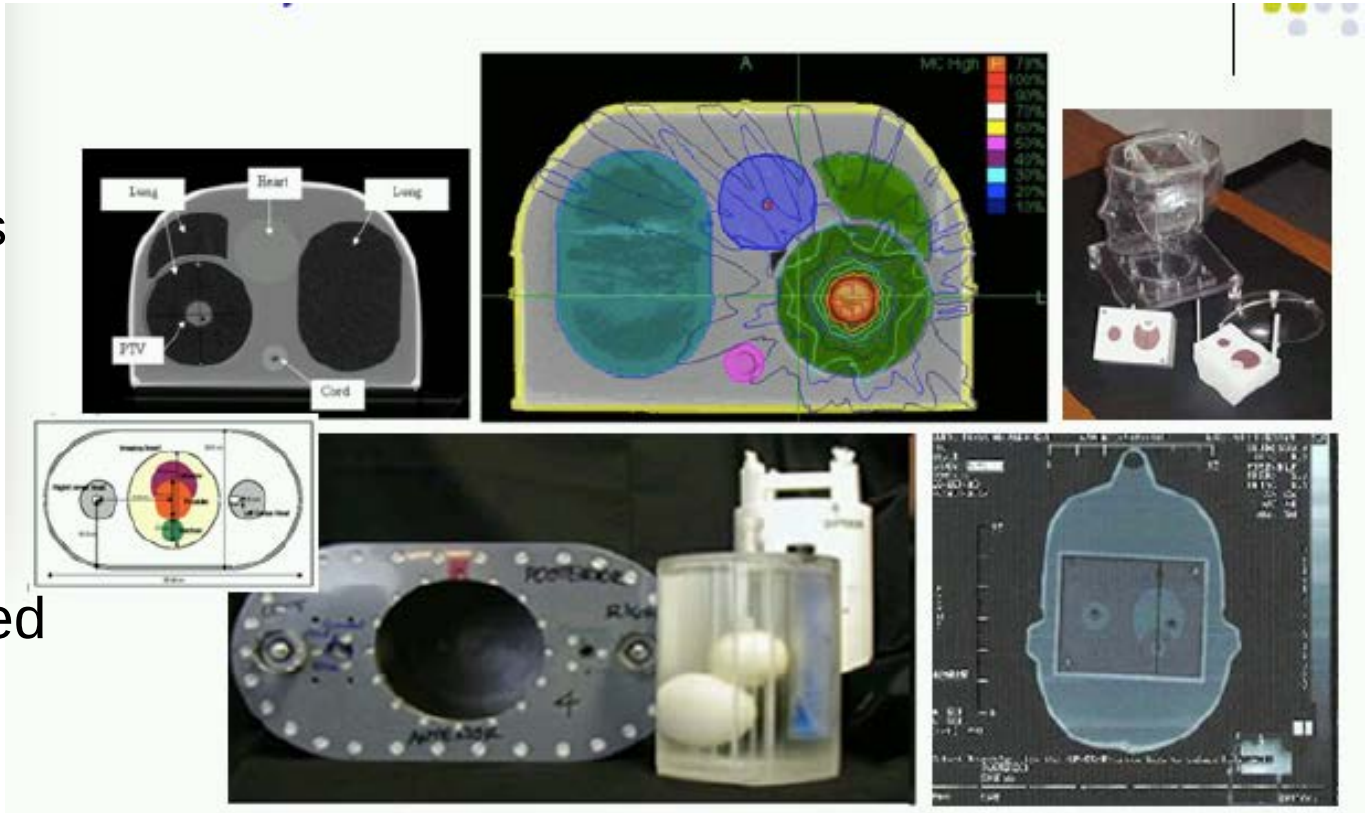
SBRT e2e SCAN PLAN LOCALIZE TREAT
A CIRS AND IMT JOINT DEVELOPMENT PROJECT

UT HEALTH SCIENCE CENTER™ SAN ANTONIO

*Solberg TD, et al. PRO. August. 2011.

Ind. Verification – IROC Phantoms

- Ind. E2E test
  - Var. phantoms
    - Lung
    - H&N
    - Liver
    - Pelvis
- **Required** for newly established programs*
- Clinical trials



*Solberg TD, et al. PRO. August. 2011.

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Report of
Liver Phantom Irradiation

Date of Report:	March 25, 2014
Institution:	UT Health Science Ctr at CTRC-Grossman
Physicist:	Alonso Gutierrez, Ph.D.
Radiation Machine:	Novalis, Novalis (4302) – 6 MV
Collimator:	MLC
IMRT Technique:	Segmental (step and shoot) MLC
Treatment Planning System:	Philips, Pinnacle (3D/IMRT) – Adaptive Convolve
Date of Irradiation:	February 3, 2014

Description of procedure:

An anthropomorphic liver phantom incorporating a liver structure with two targets and two normal tissue structures (NTS) was placed in the supine position in a CT scanner and imaged. TLD capsules located near the center of each target provided point dose information and two sheets of GAFChromic™ Dosimetry Media provided dose distributions in the coronal and sagittal planes of each target. The phantom NTSs contain TLD dosimeters. Each target within the liver phantom was irradiated to approximately 6 Gy using an IMRT 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:

Location	IROC-H vs. Inst.	Criteria	Acceptable
PTV1_TLD	0.99	0.93 – 1.07	Yes
PTV2_TLD	0.98	0.93 – 1.07	Yes

Film Plane	Gamma Index*	Criteria	Acceptable
PTV 1 Coronal	100%	≥ 85%	Yes
PTV 1 Sagittal	100%	≥ 85%	Yes
PTV 2 Coronal	100%	≥ 85%	Yes
PTV 2 Sagittal	96%	≥ 85%	Yes

*Percentage of points meeting gamma-index criteria of 7% and 4 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. and Carrie Amador

Report Checked by:

David S. Followill, Ph.D.
Director, IROC Houston QA Center

Let’s not forget about safety….

SBRT guidelines

ELSEVIER

Int. J. Radiation Oncology Biol. Phys., Vol. 76, No. 2, pp. 326–332, 2010

0360-3016/10/$–see front matter

doi: 10.1016/j.ijrobp.2009.09.042

REPORT

AMERICAN SOCIETY FOR THERAPEUTIC RADIOLOGY AND ONCOLOGY (ASTRO) AND AMERICAN COLLEGE OF RADIOLOGY (ACR) PRACTICE GUIDELINE FOR THE PERFORMANCE OF STEREOTACTIC BODY RADIATION THERAPY

LOUIS POTTERS, M.D.,* BRIAN KAVANAGH, M.D.,† JAMES M. GALVIN, D.SC.,‡ JAMES M. HEVEZI, PH.D.,§ NORA A. JANJAN, M.D.,¶ DAVID A. LARSON, M.D., PH.D.,** MINESH P. MEHTA, M.D.,†† SAMUEL RYU, M.D.,‡‡ MICHAEL STEINBERG, M.D.,§§ ROBERT TIMMERMAN, M.D.,¶¶ JAMES S. WELSH, M.D.,*** AND SETH A. ROSENTHAL, M.D.†††

*Department of Radiation Medicine, Long Island Jewish Medical Center, New Hyde Park, New York; †Department of Radiation Oncology, University of Colorado, Denver, Aurora, Colorado; ‡Department of Radiation Oncology, Thomas Jefferson University, Philadelphia, Pennsylvania; §Methodist Cancer Center, San Antonio, Texas; ¶Department of Radiation Oncology, MD Anderson Cancer Center, Houston, Texas; **Department of Radiation Oncology, University of California, San Francisco, San Francisco, California; ††Department of Radiation Oncology, University of Wisconsin, Madison, Wisconsin; ‡‡Department of Radiation Oncology, Henry Ford Health System, Detroit, Michigan; §§Department of Radiation Oncology, University of California, Los Angeles, Los Angeles, California; ¶¶Department of Radiation Oncology, University of Texas Southwestern Medical Center, Dallas, Texas; ***Department of Radiation Oncology, Riverview Hospital, Wisconsin Rapids, Wisconsin; and †††Radiation Oncology Center, Radiological Associates of Sacramento, Sacramento, California

Required read

- Technical recommendations
- Normal tissue tolerance tables
- Touched on program development and personnel roles

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

Stanley H. Benedict, Chairman[a)]
University of Virginia Health System, Charlottesville, Virginia 22908

Kamil M. Yenice, Co-Chairman
University of Chicago, Chicago, Illinois 60637

David Followill
University of Texas MD Anderson Cancer Center, Houston, Texas 77030

James M. Galvin
Thomas Jefferson University Hospital, Philadelphia, Pennsylvania 19107

William Hinson
Wake Forest University, Winston Salem, North Carolina 27157

Brian Kavanagh
University of Colorado School of Medicine, Aurora, Colorado 80045

Paul Keall
Stanford University, Palo Alto, California 94305

Michael Lovelock
Memorial Sloan–Kettering Cancer Center, New York, New York 10021

Sanford Meeks
M.D. Anderson Cancer Center Orlando, Orlando, Florida 32806

Lech Papiez
University of Texas Southwestern Medical Center, Dallas, Texas 75390

Thomas Purdie
University of Toronto, Princess Margaret Hospital, Toronto, Ontario M5G 2M9, Canada

Ramaswamy Sadagopan
University of Texas MD Anderson Cancer Center, Houston, Texas 77030

Michael C. Schell
University of Rochester Medical Center, Rochester, New York 14642

Bill Salter
University of Utah, Salt Lake City, Utah 84112

David J. Schlesinger
University of Virginia Health System, Charlottesville, Virginia 22908

Almon S. Shiu
University of Texas MD Anderson Cancer Center, Houston, Texas 77030

Timothy Solberg
University of Texas Southwestern Medical Center, Dallas, Texas 75390

Danny Y. Song
Johns Hopkins University, Baltimore, Maryland 21231

Volker Stieber
Forsyth Regional Cancer Center, Winston Salem, North Carolina 27103

Robert Timmerman
University of Texas Southwestern Medical Center, Dallas, Texas 75390

Wolfgang A. Tomé
University of Wisconsin, Madison, Wisconsin 53792

Dirk Verellen
UV Brussel, Vrije Universiteit Brussel (VUB), Brussels B-1090, Belgium

Lu Wang
Fox Chase Cancer Center, Philadelphia, Pennsylvania 19111

Fang-Fang Yin
Duke University Medical Center, Durham, North Carolina 27710

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0094-2405/2010/37(8)/4078/24/$30.00

Practical Program Guidelines

Practical Radiation Oncology (2011)

practical radiation oncology
pro

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

Timothy D. Solberg, Ph.D.[1], James M. Balter, Ph.D.[2], Stanley H. Benedict, Ph.D.[3], Benedick A. Fraass, Ph.D.2, Brian Kavanagh, M.D.[4], Curtis Miyamoto, M.D.[5], Todd Pawlicki, Ph.D.[6], Louis Potters, M.D.[7], Yoshiya Yamada, M.D.[8]

[1]*Department of Radiation Oncology, University of Texas Southwestern Medical Center, Dallas, Texas;*
[2]*Department of Radiation Oncology, University of Michigan Health System, Ann Arbor, Michigan;*
[3]*Department of Radiation Oncology, University of Virginia Health System, Charlottesville, Virginia;*
[4]*Department of Radiation Oncology, University of Colorado, Denver, Aurora, Colorado;*
[5]*Department of Radiation Oncology, Temple University, Philadelphia, Pennsylvania;*
[6]*Department of Radiation Oncology, University of California, San Diego, California;*
[7]*Department of Radiation Medicine, Long Island Jewish Medical Center, New Hyde Park, New York;*
[8]*Department of Radiation Oncology, Memorial Sloan Kettering Cancer Center, New York, New York*

Program Goals

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

- Establish program goals with clinical and admin team – disease sites
- Identify resources needed for successful program
- Ensure equipment will satisfy program goals

*Solberg TD, et al. PRO. August. 2011.

Personnel Qualifications

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.		

*Solberg TD, et al. PRO. August. 2011.

Patient-specific QA

Table 7. Patient-specific quality assurance activities.

Recommendation	Reference
The course of treatment, including dose schedule, normal tissue constraints, CTV/ITV and PTV margins, should follow established national guidelines, with careful consideration of the setup accuracy of the particular system in place at the given institution. Examples of dose constraints used at one institution are provided Reference 61.	33-34, 63
Treatment protocols that spell out responsibilities and detailed procedures ,must be available for all personnel, including therapists, medical physicists and radiation oncologists.	
One or more comprehensive checklists should be used to guide all aspects of the treatment process. Examples of checklists used at several institutions are provided in Appendix 2 and 3. Note: these checklists intended to serve as a template, and should not be adopted in whole or in part. They are institution and technology specific are meant solely for illustration.	34-36
Appropriate program team members, including radiation oncologist(s), medical physicist(s) and radiation therapist(s) must be present as described by their responsibilities during the various aspects of the treatment process.	33-34

Patient Specific QA – Process Checklists

CANCER THERAPY & RESEARCH CENTER
UT HEALTH SCIENCE CENTER
SAN ANTONIO

Treatment Planning Checklist: Frameless Radiosurgery

Please ensure the following is completed:

- ☐ Patient Name: _____ CTRC#_____
- ☐ Import & verify images
  - ☐ CT
  - ☐ MR
    - ☐ Hi-resolution (<1.5mm slice thickness)
    - ☐ Correct pulse sequence (i.e. T1-weighted, post contrast)
- ☐ CT Images Localized (Use H&N Localizer for Frameless-based SRS)
- ☐ Fusion approved by radiation oncologist **AND** physicist
- ☐ Target segmentation approved by radiation oncologist **AND** neurosurgeon
- ☐ Apply correct CT Density table
- ☐ Check the box to verify that the localizer box was used.
- ☐ Check the box to insert treatment table model to CT dataset
- ☐ Surface rendering accurate
- ☐ Treatment prescription verified for ALL lesions
- ☐ Verify gantry and couch not in collision position
- ☐ Compute PITV ratio for each lesion—to be included in medical physics consultation
- ☐ Ensure "Check Mark" is present in top right corner of iPlan software
- ☐ Approve plan
- ☐ Complete all steps outlined in SR.1.1 - SRS Planning Documentation Policy
- ☐ Export treatment plan to ExacTrac and notify therapist

Responsible Physicist: _____ Date: _____

By my signature above, I am certifying that the SRS set-up meets the specification for SRS treatment plans

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Therapist Checklist: Frameless Radiosurgery

Please complete and initial the following:

- ☐ _____ Winston Lutz test completed and passed - Verified by physicist_____
- ☐ _____ Printed treatment plan received
- ☐ _____ TaPos placed on Localizer Box correctly
  - ☐ Verified by physicist _____
- ☐ _____ Beams verified for any couch collisions and MLC verified for differences with TaPos patterns
- ☐ _____ Completed Therapist column on "RadOnc Chart Check"
- ☐ _____ Prescription AND Electronic documents (Plan/2nd Check) approved by radiation oncologist and physicist
- ☐ _____ If applicable, IMRT QA approved by physicist
- ☐ _____ Patient data loaded up on Exac Trac system
- ☐ _____ Patient ID confirmed as required by Policy RTT 16.0 (Patient Time Out)
- ☐ Patient Name: _____ CTRC#_____
- ☐ Patient aligned to correct stereotactic coordinate using Exac Trac system
  - ☐ _____ Each coordinate to be double checked by both physicist AND physician/therapist
- ☐ If cone-based, fill out **Cone Interlock Verification Checklist**
- ☐ Acquire ExacTrac images, fuse, apply shifts, and acquire verification images
- ☐ _____ Physicists AND physician approve fusion
- ☐ _____ Disable Varian couch movement motors (Vert, Lat, Long)

Record couch position for each site below

Coordinates	Iso. #1	Iso. #2	Iso. #3	Iso. #4
Vert.				
Long.				
Lat.				

- ☐ Verify beam parameters with physicist prior to delivering radiation

Responsible Therapist*: _____ Date: _____

Responsible Rad Onc Physicist: _____ Date: _____

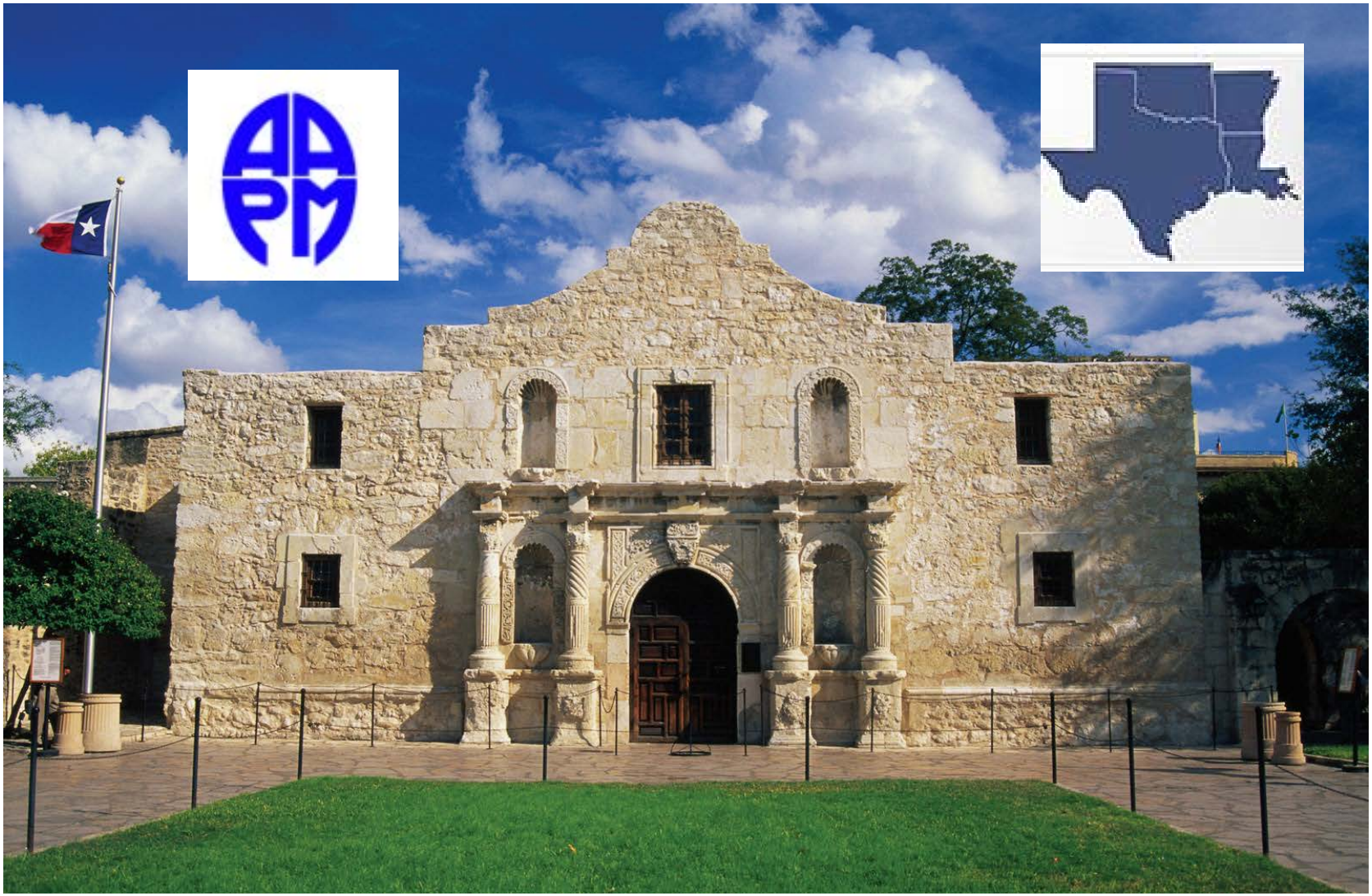
By my signature above, I am certifying that the SRS set-up meets the specification in the treatment plan

- ☐ Repeat last 5 steps for each isocenter (*if applicable*)

**Please turn completed form to radiation oncology physicist*

Summary

- Increasing demand for SBRT/SRS to be implemented due to clinical success
- Novel radiation delivery system and equipment is facilitating the implementation of SBRT/SRS programs
- New programs must be aware of guidelines and place strict emphasis on quality assurance of entire process
- All personnel must be trained and aware of their role and commitment to the process



Thank you for your time and attention!

Department of Radiation Oncology
School of Medicine

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Respiratory Inhibition