

Single and Hypo-fractionated Stereotactic Irradiation of Brain and Body Lesions

Curtis Miyamoto, M.D.

Professor and Chairperson

Department of Radiation Oncology



Temple University
Health System

Overview of SBRT

- Approximately 700 facilities in the United States report being capable of performing stereotactic radiosurgery.
- Almost 4500 abstracts and articles have been written on the subject.
- The principle site treated has been the lungs.

Radiobiology Overview

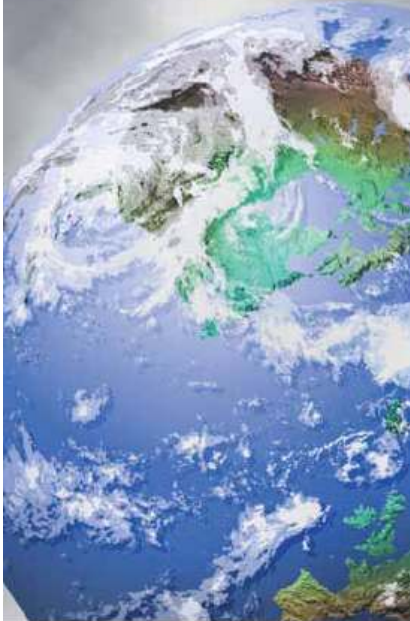
- Much of what we know comes from clinical experience.
- Linear quadratic model may not apply.
- Hypoxia may be overcome partially by large fractions.
- Endothelial apoptosis becomes significant above a ~8–10 Gy single dose (Fuks, et al) resulting in microvascular disruption and death of the tissue supplied by that vasculature (Garcia-Barros, et al).
- Immune response may be stimulated and stem cells depleted.

Radiobiology Overview

- SBRT is especially good in sparing parallel functioning (functional subunits are contiguous, discrete entities) normal tissues (kidneys, lung parenchyma, liver parenchyma, etc.) that abut or are involved by tumors.
- Serial functioning tissues (linear or branching organs, in which functional subunits are undefined) such as the spinal cord, esophagus, bronchi, hepatic ducts and bowel, may benefit from reduced high-dose volume exposure although radio-ablating these tissues may result in potentially devastating, irreversible downstream effects from damage to upstream portions of the organ.

SRS for Intracranial Disease GK Radiosurgery Worldwide

210 units out of 267
have reported per
December 2008



Vascular Disorders	
AVM	57,136
Aneurysm	278
Cavernous Angiomas	3,258
Other Vascular	4,412
Total	65,084

Benign Tumors	
Vestibular Schwannoma	46,835
Trigeminal Schwannoma	2,822
Other Schwannoma	1,590
Benign Glial Tumors (Grade I+II)	3,594
Meningioma	64,115
Pituitary Adenoma (Secreting)	24,273
Pituitary Adenoma (Non-secreting)	14,280
Pineal Region Tumor	3,540
Hemangioblastoma	2,056
Hemangiopericytoma	1,151
Craniopharyngioma	4,053
Chordoma	1,911
Glomus Tumor	1,483
Other Benign Tumors	4,616
Total	176,319

Malignant Tumors	
Malignant Glial Tumor (Grade III+IV)	26,437
Metastatic Tumor	185,070
Chondrosarcoma	775
NPH Carcinoma	1,454
Other Malignant Tumors	7,160
Total	220,896
Total Tumors	397,215

Functional Disorders	
Trigeminal Neuralgia	32,798
Parkinson's Disease	1,473
Intractable Pain	622
Epilepsy	2,399
OCD	154
Other Functional	1,015
Total	38,461

Ocular Disorders	
Uveal Melanoma	1,613
Glaucoma	263
Other Ocular Disorder	90
Total	1,966

Total Indications 502,726

ELEKTA Website

Brain Metastases

- The incidence of brain metastasis is rising with the increase in survival of cancer patients.
- 40% of intracranial neoplasms are metastatic.
- 98,000-170,000 cases occur each year.
- This is about 24-45% of all cancer patients.
- In 9%, the CNS is the only site of spread.
- 11% of patients with a solitary mass in the brain have lesions other than metastatic disease

RTOG Prognostic Classes

- Class 1: patients with KPS \geq 70, $<$ 60 years of age with controlled primary and no extracranial metastases.
Survival = 7.1 months
- Class 2: all others. Survival 4.2 months
- Class 3: KPS $<$ 70 Survival 2.3 months

Predicts for Gamma Knife and Linac based treatments

SRS/SRT-Brain Metastases

- With median minimum peripheral doses of 16.5-25 Gy a 70-95% local control rate can be expected
- Up to 3-5 lesions can be treated
- Usually whole brain irradiation (2 Gy fractions to 30-40 Gy) is given either before or after.
- SRS alone can be considered.

Brain Metastases-RTOG

9508

- WBRT With or Without SRS Boost for Patients With 1-3 Brain Metastases
- Phase III Results (Randomised Trial)
- 331 patients
- WBRT 37.5 Gy in 2.5-Gy/fx
- Tumors ≤ 2 cm received 24 G, >2 cm but ≤ 3 cm received 18 Gy, and >3 cm but ≤ 4 cm received 15 Gy

Brain Metastases-RTOG

9508

- Patients with a single brain metastasis had longer survivals if they received the stereotactic boost (6.5 vs 4.9 mos. $P=0.0393$)
- Patients with 2 or 3 brain metastases did not have any improvement in survival with the stereotactic boost
- Patients in the stereotactic boost group were more likely to have a stable or improved KPS score at 6 months than those not receiving a boost

Brain Metastases: Delayed SRS

- New metastases appear in 22-73% of the cases after whole brain radiotherapy.
- The percentage of reirradiated patients is 3-10% .
- Patients with Karnofsky performance status > 70, age < 65 years, controlled primary and no extracranial metastases are those with the best prognosis.
- The absence of extracranial disease was the most significant factor in conditioning survival, and maximum tumor diameter was the only variable associated with an increased risk of unacceptable acute and/or chronic neurotoxicity.

Gamma Knife radiosurgery for numerous brain metastases: is this a safe treatment?

Yamamoto, et al, Katsuta Hospital Mito Gamma House IJROB 2002

- 92 GK procedures have been performed for 80 patients with 10 or more brain metastases.
- The median lesion number was 17 (range: 10-43) and the median cumulative volume of all tumors was 8.02 cc (range: 0.46-81.41 cc).
- The median selected dose at the lesion periphery was 20 Gy (range: 12-25 Gy).
- The median cumulative irradiation dose to the WB was 4.71 (range: 2.16-8.51) Gy.
- The cumulative WB irradiation doses for patients with numerous radiosurgical targets were not considered to exceed the threshold level of normal brain necrosis.

Memory Function Before and After WBRT

- 44 pts treated with PCI (36Gy) or WBRT (40Gy) for metastases.
- Pts. underwent serial cognitive testing before, during and after XRT.
- WBRT causes cognitive dysfunction immediately after the beginning of RT in patients with brain metastases. At 6-8 weeks this is seen in pts. receiving both PCI and WBRT.
- Memory dysfunction was restricted to verbal memory and not visual memory or attention.

Memory Function Before and After Whole Brain Radiotherapy in Patients With and Without Brain Metastases. Welzel G, Fleckenstein K, Schaefer J, et al. IJROBP Vol. 72. No. 5, pp 1311-1318 2008



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Neurocognitive Function

- 58 patients
- RPA class 1-2
- 1-3 metastases
- SRS vs. SRS + WBRT (2.5 Gy x 12)
- SRS dose 19-20 Gy
- Neurocognitive function (decline in recall memory 52% vs. 24%) and survival better for SRS only (15.2 vs. 5.7 months).

Neurocognition in Patients With Brain Metastases Treated With Radiosurgery or Radiosurgery Plus Whole-Brain Irradiation: A Randomised Controlled Trial. Chang EL, Wefel JS, et al: *Lancet Oncol*; 2009; 10 (November): 1037-1044

Repeat SRS/SRT

- Retrospective review from the University of Pittsburgh
- 26 patients
- Mean follow-up was only 10 months
- Mean marginal dose for the first and second treatments was 16.2 Gy and 14.9 Gy, respectively

SRS/SRT-AVM

- For deep lesions (especially ≤ 15 cc)
- Need to treat the nidus only
- Dose = 1650-2000 cGy
- Complete occlusion occurs in 40% at one year
- Complete occlusion occurs in 80% at two years
- Vascular damage as a consequence of radiation effects primarily on endothelial cells and subendothelial connective tissue of capillaries and arterioles.
- Endothelial and subendothelial proliferation leads to narrowing or total occlusion of vascular lumina over a 4 month to 2-3 year period.

AVM

SIZE4-10CC	CR AT 2 YEARS
<4cc	88%
4-10cc	75%
11-25cc	67%
26-70cc	39%

- Following successful obliteration of the nidus the likelihood of hemorrhage is essentially 0%
- In 9 series (6 with GK and 3 with Linac) 3462 patients were treated with 67% of AVMs obliterated by 3 years.
- 4% incidence of radiation necrosis

Results and Complications

Series	Eqp't	N	% Oblit	% Nec
Karolinska	GK	945	56	5
Japan (11 sites)	GK	681	65	ns
Buenos Aries	GK	326	82	3
Mayo Clinic	GK	313	61	9
Sheffield	GK	160	76	4
U Pittsburgh	GK	112	71	3
U Florida	Linac	434	67	2
Heidelberg	Linac	311	48	ns
Vincenza	Linac	180	80	2
COMBINED	Both	3462	67	4

Pituitary Adenoma

- Best if tumor 3-5 mm from optic chiasm
- Dose = 1500-2500 cGy-SRS and 4500-5000 for SRT
- Good results in 50-100%
- Complications in 0-11%
- Decreased pituitary hormone production occurs in 20% of patients (0-55%). The percentage and time to response varies with tumor type.
- SRT is increasingly being employed with repeat localizer frames. Lower complication rate but slower response (9 vs. 18 mos.).
- Acromegaly responds better to higher fraction sizes (i.e. SRS).

SRS-Acromegaly

- Fractionated radiation is successful in up to 83% of cases but endocrine normalization after fractionated RT may take 5 to 15 years.
- Retrospective review of 50 patients treated with fractionated XRT from 1973 to 1992 (group 1), and 16 patients treated with SRS from 1994 to 1996 (group 2).
- Most of group 1 was treated with 40 Gy in 20 fractions
- Group 2 patients received a minimum of 25 Gy.
- The time to normalization of GH and IGF-I was 7.1 years in group 1 but only 1.4 years in group 2.
- In group 1, there was loss of normal endocrine functions in 16%, with no additional endocrine function loss noted (with shorter follow-up) in the radiosurgery group

Stereotactic Radiosurgery for Recurrent Surgically Treated Acromegaly: Comparison With Fractionated Radiotherapy. Landolt AM, Haller D, et al: J Neurosurg 1998;88 (June):

1002-1008



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Acoustic Schwannomas (Neuromas)

- Usually done for non-surgical candidates
- Dose ranges from 10-25 Gy
- 90% of patients get stability or regression of disease
- Hearing is preserved in 34-75%
- Preservation of VII nerve function in 83-96%

U of Pitt GK Experience

- Local control 95% with a 62% decrease in size, 33% stable and 5% larger)
- No dose response over 12 Gy
- Central necrosis occurred 6-12 months after treatment
- VII numbness and weakness in 8% each with MRI planning (50% permanent)
- VII damage did not occur with doses ≤ 14 Gy

U of Florida Linac Experience (Foote, et al)

- 149 patients treated over 10 years
- Mean dose 14 Gy to 70-80% isodose line with 2 isocenters
- Local control in 93%
- 2 year V/VII complication rate was 12%/10% (5%/2% after 1994)
- Best outcome with 12.5 Gy



Acoustic Schwannomas (Neuromas)

- Single-Fraction vs. Fractionated Linac-Based Stereotactic Radiosurgery
- 129 patients with tumor diameters <4 cms
- 80 patients treated with 20 Gy in 5-Gy fractions or after 1995, 25 Gy in 5-Gy daily fractions
- 49 edentulous patients treated with a single 10-Gy fraction; after 1995 a single 12.5-Gy fraction
- Edentulous patients were considerably older (63 vs 43 years old; $P < 0.0001$)

Meijer OWM, Vandertop WP, et al. *Int J Radiation Oncology Biol Phys*; 2003; 56 (5): 1390-1396

Acoustic Schwannomas (Neuromas)

- 5-year tumor control probability was 94% in the fractionated group and 100% in the single-fraction group, which was not statistically different ($P = 0.14$)
- 5-year probability for sparing the facial nerve was 97% for the fractionated arm versus 93% for the single-fraction group.
- The 5-year trigeminal nerve preservation probability was 98% for the fractionated patients versus 92% for the single-fraction patients ($P = 0.048$)
- Hearing preservation was 61% for the fractionated and 75% for the single-fraction group ($P = 0.42$)

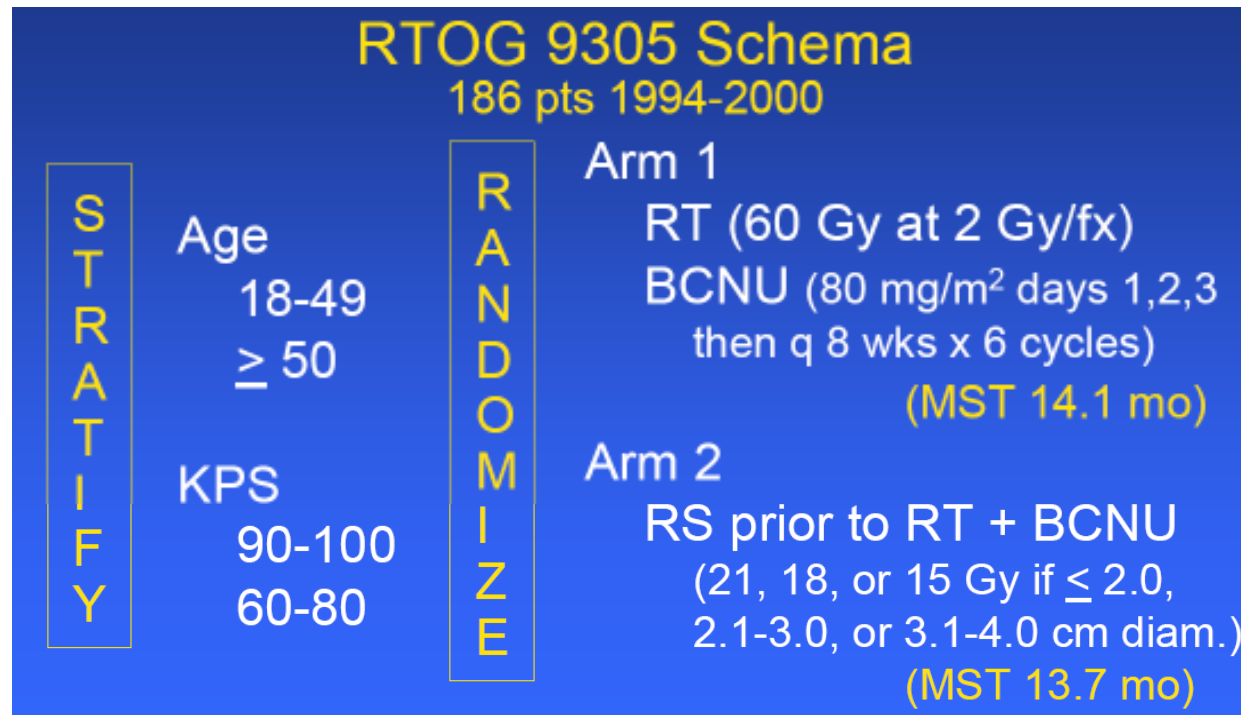
Meningioma

- 10-50 Gy yield local control rates of 95% at 3-4 years
- Of the responding lesions approximately 2/3 will stabilize and 1/3 will shrink
- Optic nerve and chiasm involvement are strong relative contraindications
- The dose to the optic apparatus should ideally be kept at 8 Gy or less

Malignant Gliomas

- Over 80% of failures after conventional XRT are within 2 cm from original lesion
- Used as a boost or for salvage
- Most studies with excellent PS
- Can be given before or after conventional irradiation
- Usual dose is 12-17 Gy

RTOG 9305



- Upfront SRS followed by RT and BCNU does not lead to an improved survival nor changes patterns of failure in this group of selected pts with GBM. Furthermore, there was no difference in general QOL and cognitive functioning between the arms.

TRIGEMINAL NEURALGIA

Trigeminal Neuralgia is in most cases found to be caused by compression by a blood vessel (vascular compression) of the root entry zone of the trigeminal nerve. Toxic, nutritive and infectious factors are believed to be possible sources of the disorder, but usually the exact cause is still unknown.

Trigeminal Neuralgia is found usually to affect older patients of both sexes.

SRS/SRT-Trigeminal Neuralgia

- Need high doses - 70 Gy and above
- Target is the vasculature around the nerve
- Used generally after patients have failed other medical and surgical interventions
- Use small collimators 7.5-5 mm
- Invasive fixation (BRW)

SRS/SRT-Trigeminal Neuralgia

- In a few patients, the pain relief is immediate. Most take many months to achieve a complete response.
- 90% of patients will have a decrease in their pain and 60 % of patients that have failed other techniques will have a complete response.
- Low complication rate: 6% of all patients will develop numbness or parasthesias

Movement Disorders

- Thalamotomy
 - 120-180 Gy to produce a well circumscribed necrosis
 - Collimators usually 3-5 mm
- Pallidotomy
 - 66-92% patients show improvements in bradykinesia and rigidity.
 - Improvement in UPDRS (Unified Parkinson's Disease Rating Scale) scores as high as 64.7% of the time.
 - Results similar to radiofrequency lesioning methods
 - 4mm target
 - Targets are the thalamus or globus pallidus-rate of improvement are roughly equal (85-87%)
 - Dose 120-160 Gy.
 - Main complication is hemianopsia in <5%

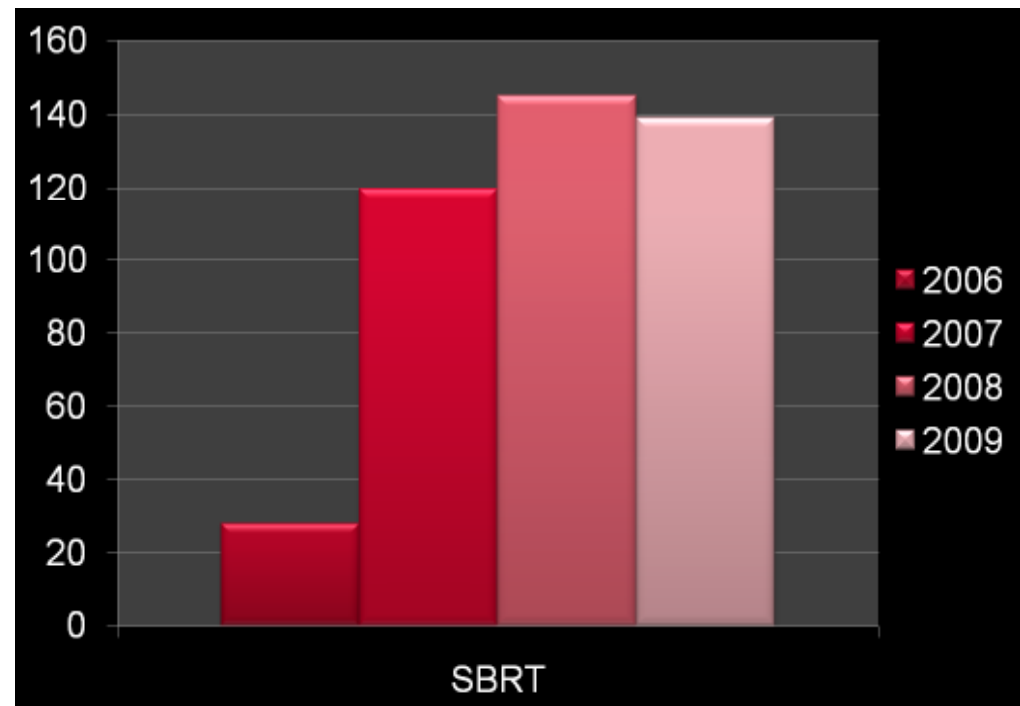
SRS/SRT Complications

- Increased T2 signal on MRI can occur from 1-24 months (generally 6-12 mos.) after treatment (30% incidence for AVMs).
- For benign tumors it is 5-10%. <50% of these patients are symptomatic.
- Resolution occurs at approximately 14 mos.
- The incidence and severity of complications tends to increase with increasing target volume and therefore the tendency to treat them with lower doses.

Stereotactic Body Radiotherapy

SBRT

SBRT treatments at Temple University Health System



SBRT

- Advantages

- Decreased overall length of treatment.
- Improved precision.
- Increased local control.
- Improved compliance.
- Improved accessibility.

- Disadvantages

- If the target volume is not in the field there is an increased risk for normal tissue damage.
- Specialized equipment required for target delineation and treatment delivery.
- Specialized training.
- Insurance issues.

SBRT

- Primary lung cancer and metastases.
- Primary hepatocellular carcinoma and liver metastases.
- Primary brain and spine tumors and metastases.
- Retreatment of spine, brain, prostate and lung cancers and other diseases.
- Pancreatic cancer.
- Etc.

SBRT Lung Indications

- Non-small cell lung carcinoma T1, T2 and lesions smaller than 4 cm.
- 30-70% incidence of cancer
- Unresectable patients with medical contraindications to surgery.
- Patients that refuse surgical resection

Solitary Pulmonary Nodules

- Local control rates reported between 60-90%
- Very well tolerated.
- Special concerns:
 - Tumors against or involving the chest wall.
 - Central tumors-against the esophagus or heart.
- Lung volume reduction may improve respiratory function.

SBRT vs. Wedge Resection

- 124 patients with T1/T2N0M0 NSCLC
- Retrospective review at William Beaumont - SBRT vs. wedge
- CTV = internal target volume + 4 mm with PTV = CTV + 5 mm
- 48 Gy in 4 fractions or 60 Gy in 5 fractions
- Overall survival was worse 72 vs 87%
- LR less with SRS 4% vs. 20%
- Grade 2 or worse radiation pneumonitis in 11%

Outcomes After Stereotactic Lung Radiotherapy or Wedge Resection for Stage I Non-Small-Cell Lung Cancer. Grills IS, Mangona VS, et al: *J Clin Oncol*; 2010; 28 (February 20): 928-935

Prospective Phase II RTOG trial 0236

- 55 eligible patients between May 2004 to October 2006
- Biopsy proven inoperable NSCLC
- T1, T2 T3 in the periphery
- 2000cGy x 3 prescribed at the edge of the PTV without heterogeneity correction.
- V20 <10% (Volume of lung receiving at least 20 Gy)
- 51% CR
- 3 year primary control rate of 97.6%
- SBRT had a survival rate of 55.8% at 3 years
- 27.4% grade 3 or 4 complications

SBRT for NSCLC Produces 97% Primary Tumor Control Rate at 3 Years
Stereotactic Body Radiation Therapy for Inoperable Early Stage Lung Cancer.
Timmerman R, Paulus R, et al: *JAMA*; 2010; 303 (March 17): 1070-1076

Princess Margaret JCO 2008

- Medically inoperable T1-T2 NSCLC
- 54-60Gy in 3 fractions for peripheral tumors (n=45)
- 48Gy in 4 fractions for tumors near risk organs (n=23)
- 50-60Gy in 8-10 fxs for central tumors (n=14)
- 76 patients-49 followed > months
- 4% local failure
- 22% distant failure rate
- 18% have died
- 2 year local control = 95%
- Overall survival 68% at 2 years.

J Clin Oncol 26: 2008 (May 20 suppl; abstr 7529)

Dose Response

- A retrospective review of the records of 152 patients with 261 NSCLC and liver lesions
- PTV was defined by a 5-mm expansion radially around GTV and 10-mm cranio-caudally
- SBRT dose to the PTV was 60 Gy in 3 fractions
- Constraints included limiting the following:
 - (1) the volume of uninvolved lung receiving ≥ 15 Gy to $< 30\%$
 - (2) the total cumulative maximum point dose to the:
 - spinal cord = 18Gy
 - trachea = 36Gy
 - Esophagus= 27Gy
 - brachial plexus = 24 Gy

Observation of a Dose-Control Relationship for Lung and Liver Tumors After Stereotactic Body Radiation Therapy. McCammon R, Scheffer TE, et al:
Int J Radiat Oncol Biol Phys; 2009; 73 (1): 112-118

Dose Response

- 165 assessable lesions in the lung and mediastinum and 81 in the liver
- A nominal dose of 54 to 60 Gy resulted in 1 and 3-year control rates of 100% and 89.3%, respectively
- Local control rates were 89.0% at 1 year for 36.1 to 53.9 Gy and 40.5% for <36.1 Gy.
- At 3 years, there was a further reduction in control rates to 59.0% (36.1 to 53.9 Gy) and 8.1% (<36.1 Gy) with a significant *P* value
- A nominal dose of ≥ 54 Gy or an equivalent uniform dose of >65.3 Gy results in a higher local control rate with stereotactic body radiotherapy.

Observation of a Dose-Control Relationship for Lung and Liver Tumors After Stereotactic Body Radiation Therapy. McCammon R, Scheffer TE, et al:
Int J Radiat Oncol Biol Phys; 2009; 73 (1): 112-118

Radiation Pneumonitis

- 128 patients retrospectively reviewed
- 2 patients were treated with a prescribed dose of 60 Gy in 5 fractions, 98 received 50 Gy in 5 fractions, 29 received 40 Gy in 5 fractions, and 4 received 50 Gy in 10 fractions.
 - Grade 0 = 27%
 - Grade 1 = 52%
 - Grade 2 = 16%
 - Grade 3 = 5%
- The latent period was the only significant factor associated with Grade ≥ 3 RP ($p < 0.01$). A latent period of 1 or 2 months indicated a 40% (6/15) risk for Grade 3. However, the risk for Grade 3 was 1.2% (1/82) 3 months after SBRT.

EARLY GRAPHICAL APPEARANCE OF RADIATION PNEUMONITIS CORRELATES WITH THE SEVERITY OF RADIATION PNEUMONITIS AFTER STEREOTACTIC BODY RADIOTHERAPY (SBRT) IN PATIENTS WITH LUNG TUMORS: ATSUYA TAKEDA, M.D, PH.D.TOSHIO OHASHI, M.D., PH.D., ETSUO KUNIEDA, M.D., PH.D.,TATSUJI ENOMOTO, M.D., PH.D., NAOKO SANUKI, M.D., TOSHIAKI. Int. J. Radiation Oncology Biol. Phys., Vol. 77, No. 3, pp. 685–690, 2010

Rib Fracture

- In a multi-institutional study, the risk of rib fracture from SBRT to peripheral lung lesions, ≤ 1.5 cm from chest wall, was a function of the absolute volume of chest wall receiving >30 Gy in 3–5 fractions.[Dunlap et al *Int J Radiat Oncol Biol Phys* 2008 , **72**:S36.] No rib fractures occurred with <35 ml of chest wall receiving >30 Gy; at >35 ml, half of the patients developed rib fracture.
- Princess Margaret Hospital reported a 48% 2-year risk of rib fracture, mostly asymptomatic or mildly symptomatic, a median of 17 months after delivery of 54–60 Gy in 18–20 Gy fractions for tumors close (0–1.8 cm, median 0.4 cm) to the chest wall.[Voroney, et al *Int J Radiat Oncol Biol Phys* 2008 , **72**:S35-S36] The median dose at the fracture site was 29–78 Gy (median 49).
- In a prospective Japanese study, 1 of 45 patients developed grade 2 chest wall pain after receiving a prescribed dose of 60 Gy in 7.5 Gy fractions to a peripheral tumor; the chest wall received a maximal dose of 48 Gy [Onimaru, et al. *Int J Radiat Oncol Biol Phys* 2003 , **56**:126-135]

Spinal Cord Tolerance

- Multi-institutional pooled analysis has shown that radiation myelopathy has only been documented to occur after exceeding a fractional dose maximum of 10 Gy to the spinal cord and/or a biologically effective dose of 60 Gy in 2 Gy fractions

Sahgal A, Gibbs I, Ryu S, Ma L, Gerszten P, Soltys S, Weinberg V, Fowler J, Chang E, Larson D: Preliminary guidelines for avoidance of radiation-induced myelopathy following spine stereotactic body radiosurgery (SBRS) [abstract].
Int J Radiat Oncol Biol Phys 2008 , 72:S220

Brachial Plexopathy

- In a recent study the 2-year risk of brachial plexopathy was 46% after the brachial plexus received a biologically effective dose maximum of >100 Gy versus 8% for <100 Gy ($p = 0.04$).

Forquer JA, Fakiris AJ, Timmerman RD, Lo SS, Perkins SM, McGarry RC, Johnstone PAS: Brachial plexopathy (BP) from stereotactic body radiotherapy (SBRT) in early-stage NSCLC: Dose-limiting toxicity in apical tumor sites. *Int J Radiat Oncol Biol Phys* 2008 , 72:S36-37

- Another study reported brachial plexopathy in 1 of 60 patients due to significant volume of brachial plexus receiving 40 Gy in 4 fractions.

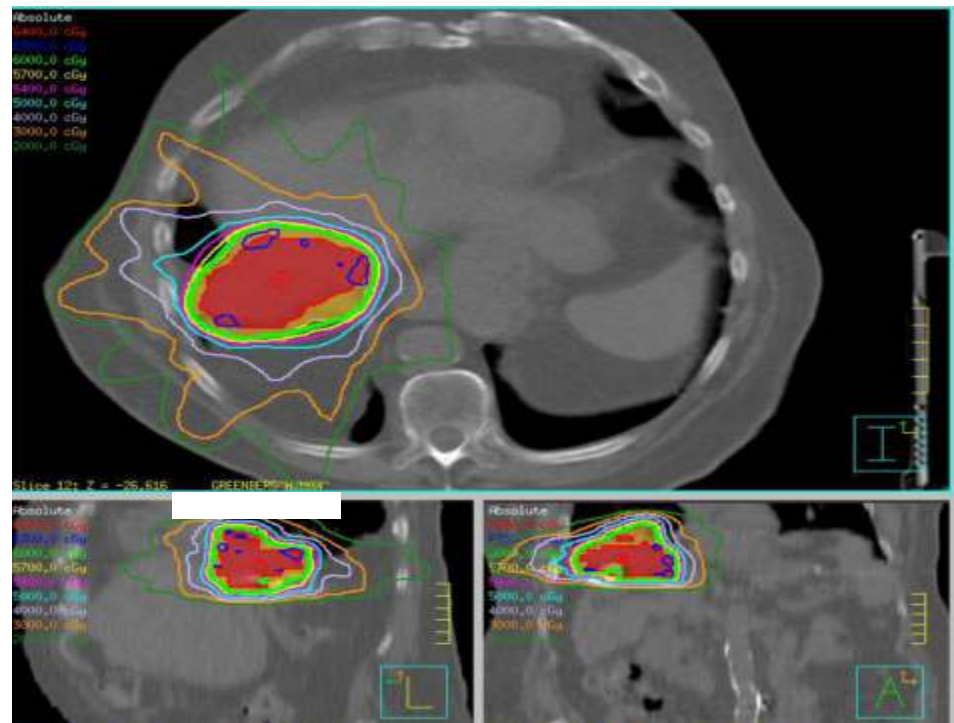
Chang JY, Balter P, Dong L, Bucci MK, Liao Z, Jeter MD, McAleer MF, Yang Q, Cox JD, Komaki R: Early results of stereotactic body radiation therapy (SBRT) in centrally/superiorly located stage I or isolated recurrent NSCLC [abstract]. *Int J Radiat Oncol Biol Phys* 2008 , 72:S463

Locally Advanced Lung Carcinoma

- Standard fractionation for the mediastinum and hilum with hypofractionation for the primary
- Retreatment is possible with modern techniques.

Colon Adenocarcinoma Metastatic to the Liver

- SBRT.
- 2000cGy/fraction
- Total dose 6000cGy



RTOG 0438

A PHASE I TRIAL OF HIGHLY CONFORMAL RADIATION THERAPY FOR PATIENTS WITH LIVER METASTASES

- ≥ 1000 ml of tumor-free liver
- 70% of liver < 27 Gy and 50% of liver < 24 Gy
- $< 10\%$ of kidney(s), ≥ 10 Gy
(with 1 functioning kidney or creatinine > 2 mg/dl)
- $< 33\%$ of kidney(s), ≥ 18 Gy
(with 2 functioning kidney and creatinine ≤ 2 mg/dl)
- spinal cord maximum: 34 Gy
- small bowel and stomach: ≤ 37 Gy to ≤ 1 cc volume

Spinal Neoplasms

- Spinal tumors comprise 15% of all CNS neoplasms
- Spinal metastases are the most common and affect more than 100,000 annually.
- Potentially very dangerous.
- 85% arise from the vertebral column invading the epidural space through the bone or neural foramen.
- Spinal cord involvement occurs in 5-10% .
- 70% are in the thoracic spine. 20% in the lumbar spine.

Spinal Metastases

- After standard irradiation, the incidence of an "in-field" recurrence of spinal metastasis varies from 2.5-11% of cases and can occur at 2-40 months.
- Radiation-induced myelopathy can occur months or years (6 months-7 years) after radiotherapy.

Re-irradiation of brain metastases and metastatic spinal cord compression: clinical practice suggestions. Maranzano, et al: Tumori. 2005 Jul-Aug;91(4):325-30

Spinal Metastases

- Special challenges for irradiation of the spinal cord
 - Radiation sensitive (spinal cord injury occurs in 0.2% for a dose of 4500 cGy in 20-25 fractions).
 - Fraction size is important – tolerates larger doses per fraction poorly.
 - More difficult immobilize than the brain.
 - Total doses need to be decreased compromising tumor control.

ASTRO 2009

- UPMC and Georgetown
- 228 patients
- Cyberknife
- UPMC single mean dose of 16.31 Gy
- Georgetown-3 fractions with mean of 20.59Gy
- Single fraction dose superior for pain relief (100% vs. 88% $p=0.003$) but local control (96% vs 70% at up to 2 years- $p=0.001$) and need for retreatment less (1 vs 13% $p<0.001$) for 3 fractions.

Multifractionated image-guided and stereotactic intensity-modulated radiotherapy of paraspinal tumors: A preliminary report

- 35 patients
- Previously irradiated or prescribed doses beyond spinal cord tolerance (54 Gy in standard fractionation) and unresectable gross disease involving the spinal canal
- The median dose previously received was 3000 cGy in 10 fractions.
- The median dose prescribed for these patients was 2000 cGy/5 fractions (2000–3000 cGy), which provided a median PTV V100 of 88%.

Multifractionated image-guided and stereotactic intensity-modulated radiotherapy of paraspinal tumors: A preliminary report: Yamada, Y, Lovelock, M, et al. IJROBP Volume 62, Issue 1, Pages 53-61 (01 May 2005)

Multifractionated image-guided and stereotactic intensity-modulated radiotherapy of paraspinal tumors: A preliminary report

- In previously unirradiated patients, the median prescribed dose was 7000 cGy (5940–7000 cGy) with a median PTV V100 of 90%.
- The median Dmax to the cord was 34% and 68% for previously irradiated and never irradiated patients, respectively.
- More than 90% of patients experienced palliation from pain, weakness, or paresthesia; 75% of secondary and 81% of primary lesions had local control at the time of last follow-up.
- No cases of radiation-induced myelopathy or radiculopathy have thus far been encountered.

Multifractionated image-guided and stereotactic intensity-modulated radiotherapy of paraspinal tumors: A preliminary report: Yamada, Y, Lovelock, M, et al. IJROBP Volume 62, Issue 1, Pages 53-61 (01 May 2005)

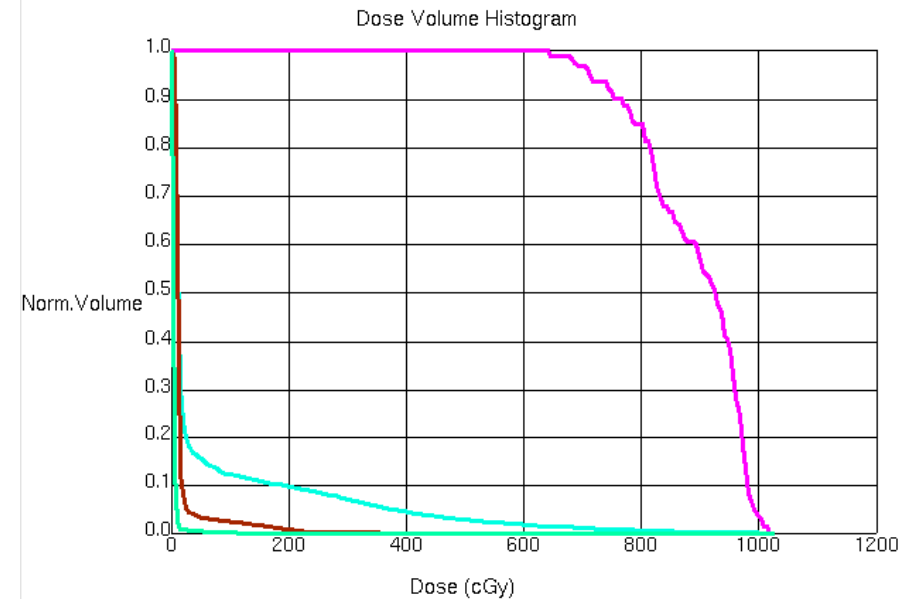
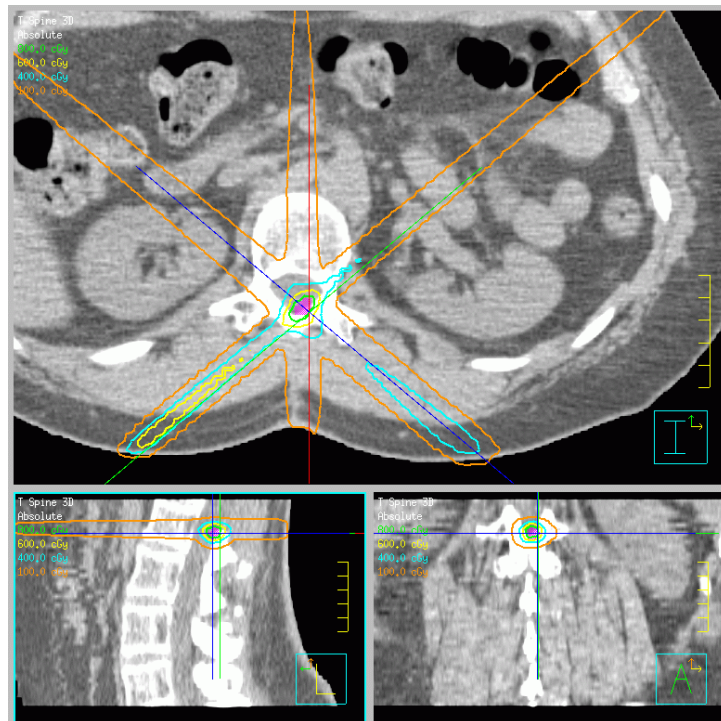
Bone Metastases-SRS as a Boost

- Prospective non-randomized study.
- 500 patients with vertebral metastases (73 cervical, 212 thoracic, 112 lumbar, and 103 sacral). 344 had prior XRT.
- 12.5 – 25cGy boost with radiosurgery after prior fractionated irradiation of 3 Gy x 10 to 2.5 Gy x 14 (7 as immediate boost). Majority had fiducial tracking. Main indication was pain.
- 86% had long term pain reduction.
- Long term tumor control in 90% as part of initial treatment and in 88% after recurrence. 84% of neurological symptoms improved.

Radiosurgery for Spinal Metastases: Clinical Experience in 500 Cases From a Single Institution. Peter C. Gerszten, MD, MPH; Steven A. Burton, MD; Cihat Ozhasoglu, PhD; William C. Welch, MD, FACS. Spine. 2007;32(2):193-199. 2007 Lippincott Williams & Wilkins

Schwannoma

Thoracic Spine Nerve Root



ROI Statistics								
Line Type	ROI	Trial	Min.	Max.	Mean	Std. Dev.	% O	
◇	Cord	T Spine 3D	1.2	1002.2	26.5	96.8	53.	
◇	GTV2	T Spine 3D	642.3	1015.9	891.1	89.7	0.1	
◇	Kidneys	T Spine 3D	3.7	352.7	15.6	26.6	0.1	
◇	Liver	T Spine 3D	--	111.2	2.6	5.2	0.1	

Conclusions

- There are many new techniques that have expanding indications
- Treatments need to be individualized.
- There is an improved tolerance with stereotactic radiation.
- The results may ultimately be better than for standard radiation therapy.
- Improved patient compliance.
- Possibly more economical.
- Arcs may have a lower integral dose than IMRT?
- More convenient
- Insurance companies, and the federal government may influence its application.