

立体定向放射治疗 (SRT/SBRT)的生物学问题

胡逸民
教授首席专家
中国医学科学院协和医科大学
肿瘤医院肿瘤研究所
中国医学物理分会主任委员

基本要求 (Basic requirements)

- * 靶区精确定位
- * 患者治疗体位的有效固定
- * 精心的治疗计划设计
- * 准确的治疗实施

SRT/SBRT面临的挑战 (Challenges)

- * 高梯度的剂量分布
- * 照射中/分次间肿瘤及器官的运动控制

定义 (Definitions)

- SRS(SRT) 利用立体定向图像或体内植入标记引导的重定位、和射野空间集束照射技术，对精确确定的病变(肿瘤)实施手术式单次/分次大剂量照射

SRS(SRT) is the use of external beams to treat lesions in the body with "surgical" doses and high precision tumor identification and relocation employing "stereotactic" image guidance or implanted fiducials.

- 该技术通常称为 (It is often called):
- SRS with one radiation Stereotactic delivery (单次)
- SRT with fractionated Stereotactic delivery (分次)
- SBRT with fractionated Stereotactic delivery for Body

SBRT : Immobilization/Repositioning

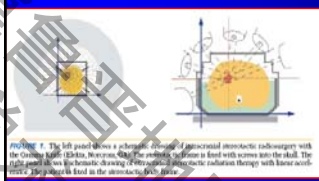




FIGURE 4. The left panel shows a schematic diagram of fractionated stereotactic radiotherapy with the Calypso™ (Elekta, Muncie, IN) fiducial markers to be fixed with screws into the skull. The right panel shows the robotic, dynamic, ultrasonically guided fractionated radiotherapy with laser accuracy. The fiducial markers are fixed in the stereotactic body frame.

FIGURE 5. A patient positioned in the stereotactic body frame, with the abdominal pressure device applied to reduce diaphragmatic motion with the respiration.

特征 (Characteristics)

- * 肿瘤精确定位
- * 图像或体内标记点引导的精确照射
- * 1-5次照射 (SRS 单次; SRT/SBRT 2-5次)
- * 分次剂量很高

- 因此, 该技术又称为 (It is called):
- 低分次大剂量照射 (Hypo-Fractionation)

CFRT vs SRT(SBRT)

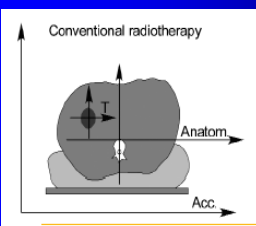
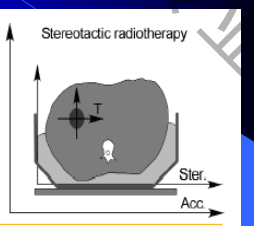
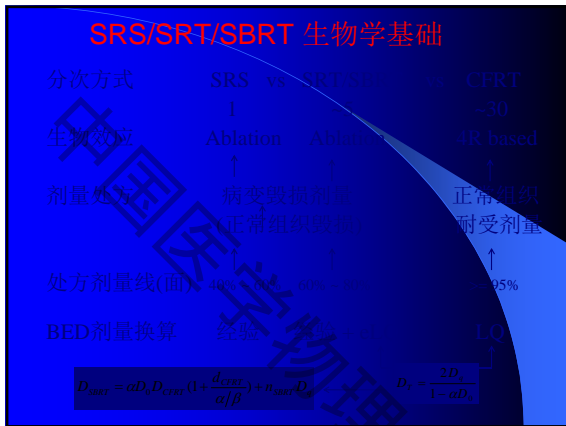



FIGURE 2. Illustration of coordinate systems used in conventional radiotherapy (left) and stereotactic body radiation therapy (right).

* Slide courtesy of Brian Kavanagh / University of Colorado



SRS/SRT/SBRT 生物学基础

分次方式	SRS vs	SRT/SBRT vs	CFRT
	1	~5	~30
生物效应	Ablation	Ablation	4R based
剂量处方	↑ 病变毁损剂量 (正常组织毁损)		↑ 正常组织耐受剂量
处方剂量线(面)	40% ~ 60%	60% ~ 80%	>= 95%
BED剂量换算	经验	经验 + eLQ	LQ

$$D_{SBRT} = \alpha D_0 D_{CFRT} \left(1 + \frac{d_{CFRT}}{\alpha/\beta}\right) + n_{SBRT} D_q$$

$$D_T = \frac{2D_q}{1 - \alpha D_q}$$

SRS/SRT/SBRT 生物学基础

分次方式	SRS vs	SRT/SBRT vs	CFRT
	1	~5	~30
生物效应	Ablation	Ablation	4R based
剂量处方	↑ 病变毁损剂量 (正常组织毁损)		↑ 正常组织耐受剂量
处方剂量线(面)	40% ~ 60%	60% ~ 80%	>= 95%
BED剂量换算	经验	经验 + eLQ	LQ

$$D_{SBRT} = \alpha D_0 D_{CFRT} \left(1 + \frac{d_{CFRT}}{\alpha/\beta}\right) + n_{SBRT} D_q$$

$$D_T = \frac{2D_q}{1 - \alpha D_q}$$

SRS/SRT/SBRT 生物学基础

分次方式	SRS vs	SRT/SBRT vs	CFRT
	1	~5	~30
生物效应	Ablation	Ablation	4R based
剂量处方	↑ 病变毁损剂量 (正常组织毁损)		↑ 正常组织耐受剂量
处方剂量线(面)	40% ~ 60%	60% ~ 80%	>= 95%
BED剂量换算	经验	经验 + eLQ	LQ

$$D_{SBRT} = \alpha D_0 D_{CFRT} \left(1 + \frac{d_{CFRT}}{\alpha/\beta}\right) + n_{SBRT} D_q$$

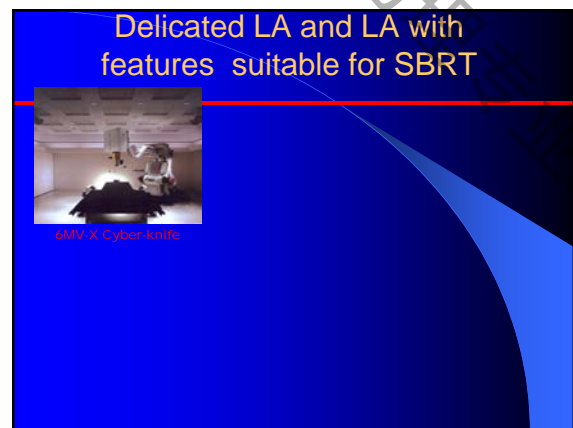
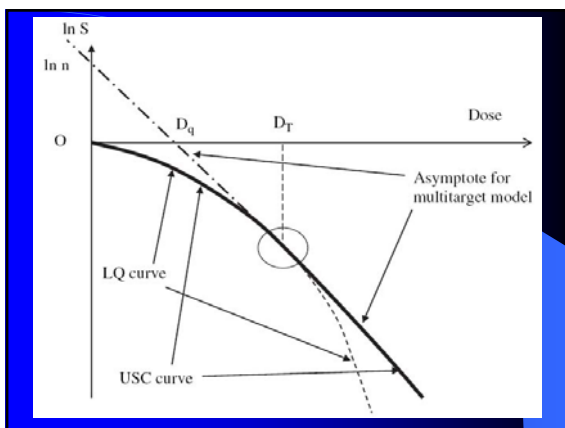
$$D_T = \frac{2D_q}{1 - \alpha D_q}$$

Total Dose	Reference	BED Gy10	NTD, Gy 2-Gy Fractions!	Estimated Progression-free Survival at 30 Mo. (Assuming No Hypoxia)
Conventional fractionation				
60 Gy, 30 fractions	—	(Fig. 1.1) 72	—	—
70 Gy, 35 fractions	—	84	70	24%
SBRT				
(Fig. 1.2)				
49 Gy, 4 fractions	(6)	106	63	34%
45 Gy, 3 fractions	(2)	113	94	95%
40 Gy, 3 fractions	(2)	125	104	99%
60 Gy, 3 fractions	(12)	132	110	>99%
60 Gy, 3 fractions	(3)	180	150	>99%
69 Gy, 3 fractions	(33)	228	190	>99%

BED, biologically equivalent dose; NTD, normalized total dose in 2-Gy fractions; SBRT, stereotactic body radiation therapy; NSCLC, non-small cell lung cancer; Tx, treatment; LQ, linear-quadratic.

Fowler JF, Tome WA, Welsh JS. Estimation of the Required Doses in Stereotactic Body Radiation Therapy. In *Stereotactic Body Radiation Therapy*. Kavanagh BD and Timmerman RD, eds. Lippincott Williams & Wilkins, 2005.

* Slide courtesy of Brian Kavanagh / University of Colorado



Delicated LA and LA with features suitable for SBRT

Varian CyberKnife Varian VERO 4DR1 SBRT

Delicated LA and LA with features suitable for SBRT

Varian CyberKnife Varian VERO 4DR1 SBRT Novus TX

Varian TrueBeam Elekta Access Super 7-knife

Delicated LA and LA with features suitable for SBRT

Varian CyberKnife Varian VERO 4DR1 SBRT Novus TX

Delicated LA and LA with features suitable for SBRT

Varian CyberKnife Varian VERO 4DR1 SBRT Novus TX

Varian TrueBeam Elekta Access Super 7-knife Tomo unit

Delicated LA and LA with features suitable for SBRT

Varian CyberKnife Varian VERO 4DR1 SBRT Novus TX

Varian TrueBeam Elekta Access

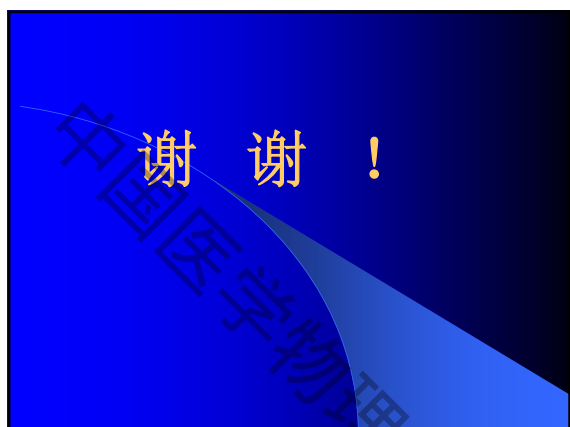
SRT(SBRT): When & where started it?

Organ	No. Tumors
Lungs	997
Medastinum	76
Liver	404
Pancreas	149
Suprarenal glands	30
Abdomen*	118
Skullion	25
Miscellaneous*	46

*Mainly kidneys and para-aortic regions.
 *Public area, muscles, and soft tissue.

Answer: Blomgren and Lax, Karolinska Institute, Stockholm, Sweden

* Slide courtesy of Brian Kavanagh / University of Colorado



中国医学物理分会京津冀鲁晋地区放射物理专业组
第十九次学术会议