IMAGING IN SBRT E ASPETTI TECNICO/DOSIMETRICI CORRELATI

IRCCS CROB
Stefania Clemente
SSD Fisica Sanitaria
IRCCS CROB Rionero in Vulture (PZ)

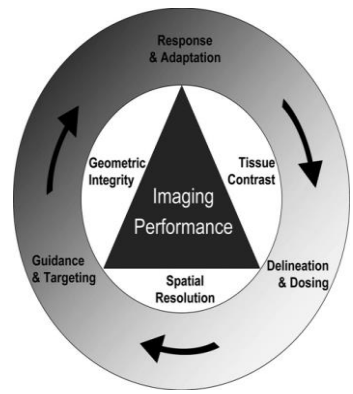
Aifm UNIVERSITÀ DEGLI STUDI DI MILANO

Stereotactic Body Radiation Therapy

Università di Milano
24/25 ottobre 2014

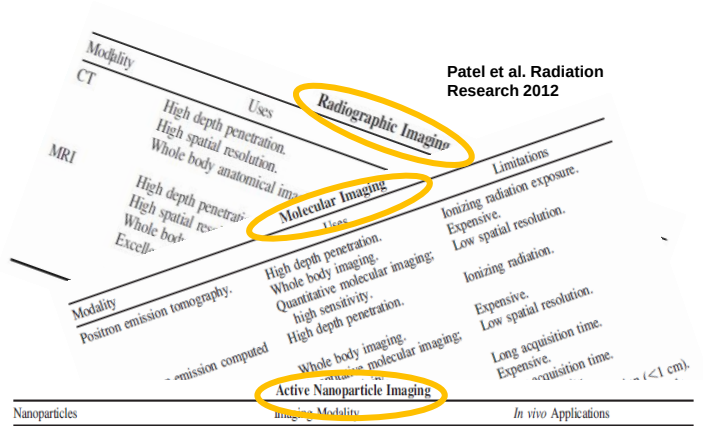
G.d.L. SBRT

Imaging accuracy in SBRT for Target Volume (TV) and OARs determination

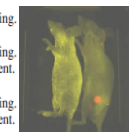


Dawson & Ménard. The Oncologist 2010

Multimodality imaging for TVD in SBRT

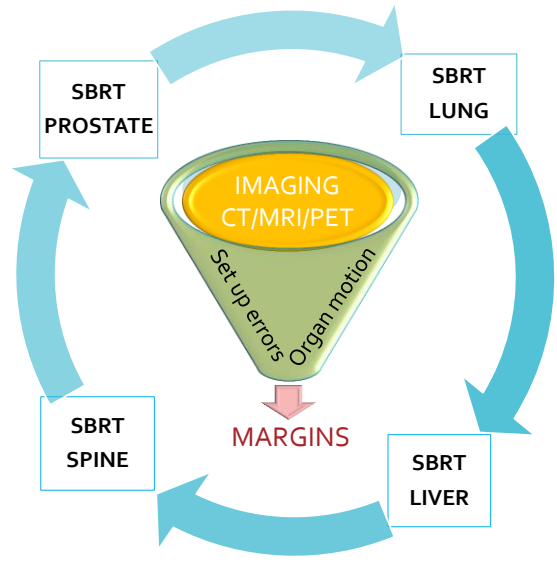


Nanoparticles	Imaging Modality	*In vivo* Applications
Liposomes	Gamma imaging, SPECT, PET	Clinically utilized to target tumor cells in breast, brain, head and neck, lung, and lymphoma
Iron oxide (Paramagnetic nanoparticles)	MRI, PET/CT, MRI/PET	Image tumor angiogenesis. Single and multimodal imaging.
Quantum dots	PET, optical imaging	Image tumor angiogenesis. Single and multimodal imaging. Study tumor microenvironment.
Dendrimers	MRI, CT, optical imaging, PET, SPECT	Image tumor angiogenesis. Single and multimodal imaging. Study tumor microenvironment.
Gold	SERS	Tumor imaging.



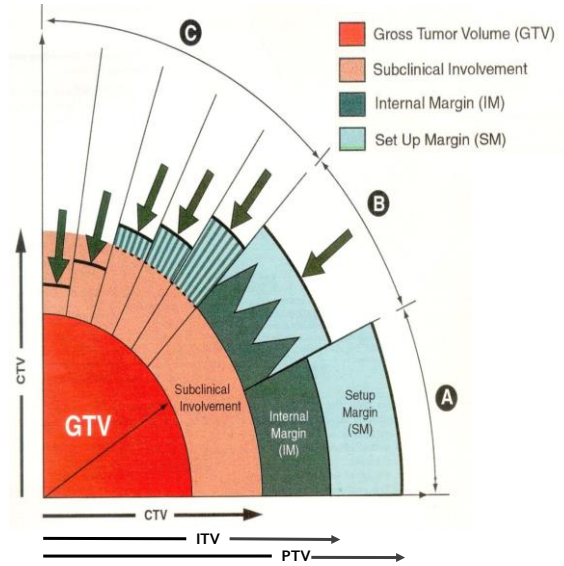
IRCCS CROB

From imaging to margins



IRCCS CROB

From imaging to margins in SBRT (ICRU 50-62)



IRCCS CROB

Setup-errors management in SBRT

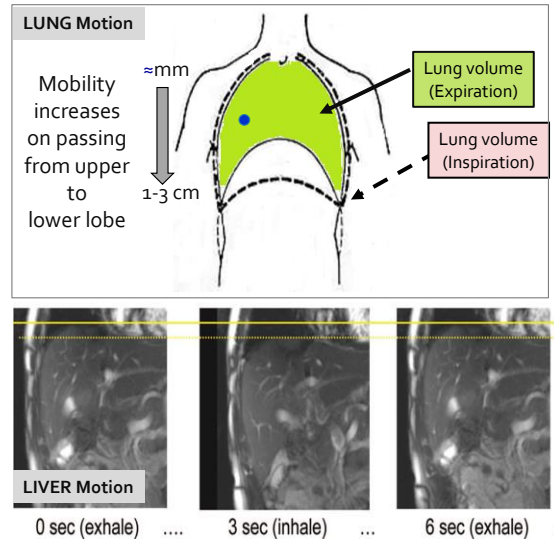
IRCCS CROB

TABLE IV. Achievable accuracies reported in the literature categorized by body site and immobilization/repositioning device.

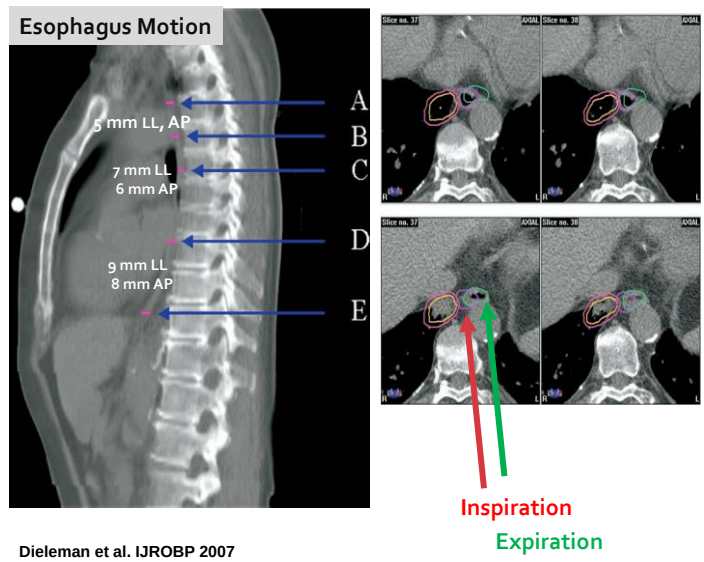
Author, year	Site	Immobilization/repositioning	Reported accuracy
Lax, 1994[a]	Abdomen	Wood frame/stereotactic coordinates on box to skin marks	3.7 mm Lat, 5.7 mm Long
Hamilton, 1995[b]	Spine	Screw fixation of spinous processes to box	2 mm
Murphy, 1997[c]	Spine	Frameless/implanted fiducial markers with real-time imaging and tracking	1.6 mm radial
Lohr, 1999[d]	Spine	Body cast with stereotactic coordinates	≤3.6 mm mean vector
Yenice, 2003[e]	Spine	Custom stereotactic frame and in-room CT guidance	1.5 mm system accuracy, 2–3 mm positioning accuracy
Chang, 2004[f]	Spine	MI™ BodyFix with stereotactic frame/linac/CT on rails with 6D robotic couch	1 mm system accuracy
Tokuuye, 1997	Liver	Prone position jaw and arm straps	5 mm
Nakagawa, 2000[g]	Thoracic	MVCT on linac	Not reported
Wulf, 2000[h]	Lung, liver	Elekta™ body frame	3.3mm lat,4.4 mm long
Fuss, 2004[i]	Lung, liver	MI™ BodyFix	Bony anatomy translation 0.4, 0.1, 1,6 mm (mean X,Y,Z); tumor translation before image guidance 2.9, 2.5, 3.2 mm (mean X,Y,Z)
Herfarth, 2001[j]	Liver	Leibinger body frame	1.8–4.4 mm
Nagata, 2002[k]	Lung	Elekta™ body frame	2 mm
Fukumoto, 2002[l]	Lung	Elekta™ body frame	Not reported
Hara, 2002[m]	Lung	Custom bed transferred to treatment unit after confirmatory scan	2 mm
Hof, 2003[n]	Lung	Leibinger body frame	1.8–4 mm
Timmerman, 2003[o]	Lung	Elekta™ body frame	Approx. 5 mm
Wang, 2006[p]	Lung	Medical Intelligence body frame stereotactic coordinates/CT on rails	0.3 ± 1.8 mm AP, -1.8 ± 3.2 mm Lat, 1.5 ± 3.7 mm SI

IMAGING IN SBRT LUNG AND LIVER

Tumor motion management



Organ motion management

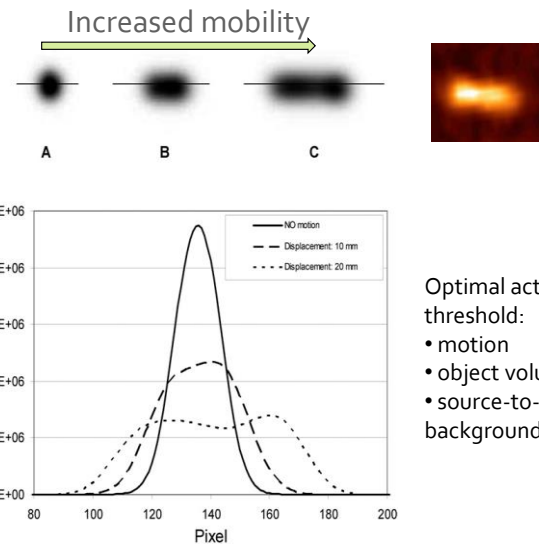


Dieleman et al. IJROBP 2007

Imaging CT for mobile tumors: artifacts

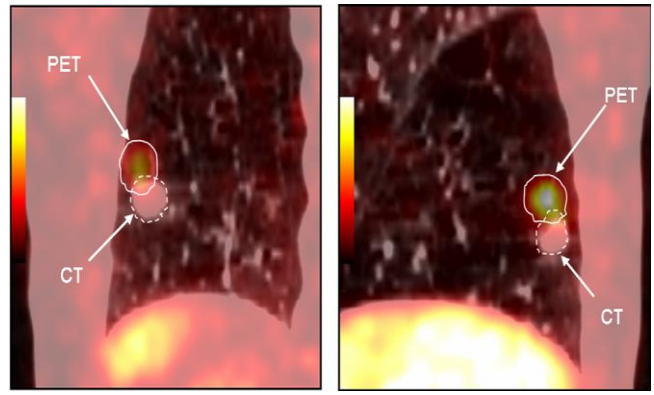
Bettinardi et al. Seminars in NM 2012

Imaging PET for mobile tumors: artifacts



Optimal activity threshold:
- motion
- object volume
- source-to-background

Imaging PET/CT for mobile tumors: artifacts



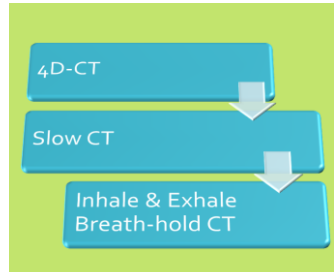
Bettinardi et al. Seminars in NM 2012

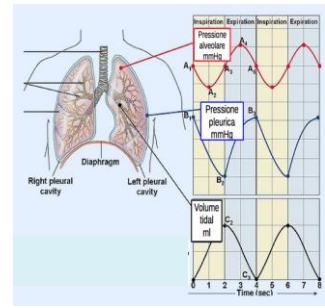
Tumor motion strategies in SBRT (AAPM TG 76)

1. Motion-encompassing
   - 4D-CT
   - Slow CT
   - Inhale/exhale breath-hold CT
2. Motion compensating
   - Respiratory gating
   - Respiration-synchronized (tracking)
3. Motion restrictive
   - Breath-hold
   - Forced shallow-breathing with AC

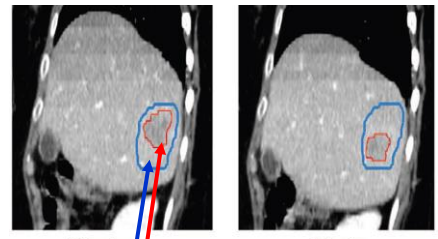
Tumor motion strategies in SBRT (AAPM TG 76)

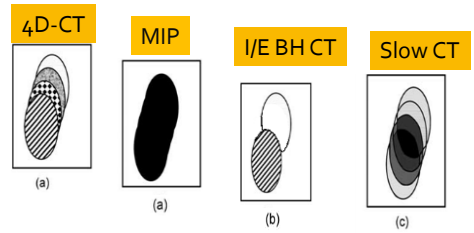
1. Motion- encompassing



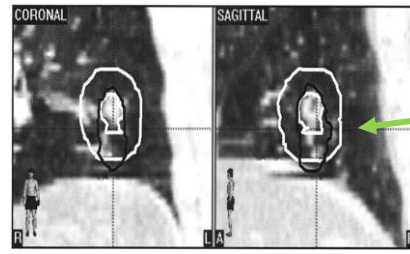


Motion encompassing strategies for TVD



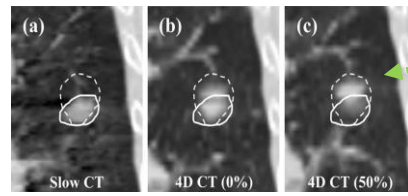


Motion encompassing strategies for TVD



4D-CT vs Fast CT

Underberg et al. R&O 2004



4D-CT vs Slow CT

Nakamura et al. Med. Phys 2008

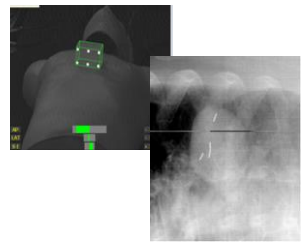
Motion encompassing strategies for TVD

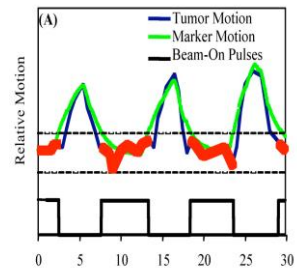
4D-PET/CT MIP VOLUMES CONSISTENT WITH 4D-CT MIP VOLUMES

Callahan et al. IJROBP 2013

Tumor motion strategies in SBRT: motion compensating (AAPM TG 76)

2. Respiratory gating methods

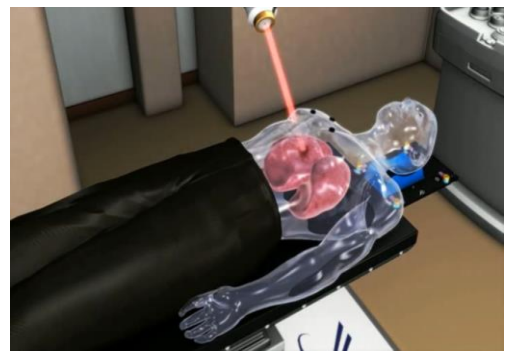




IRCCS CROB

Tumor motion strategies in SBRT: motion compensating (AAPM TG 76)

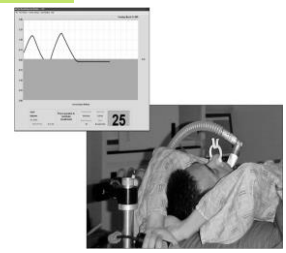
2. Respiratory tracking methods



IRCCS CROB

Tumor motion strategies in SBRT: motion restrictive (AAPM TG 76)

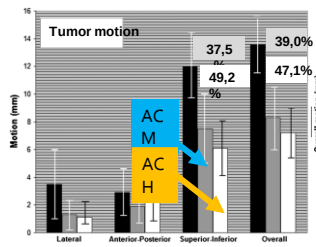
3. Breath-hold methods

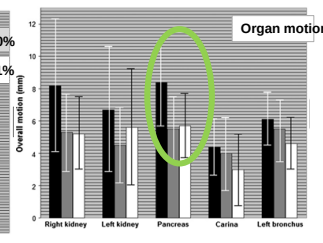


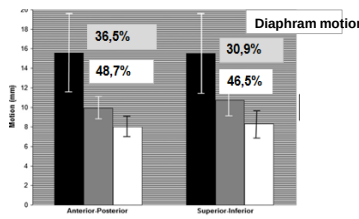
To maximize organ stabilty, reproducibility and comfort for the patient

Tumor motion strategies in SBRT: motion restrictive (AAPM TG 76)

3. Forced shallow breathing with AC



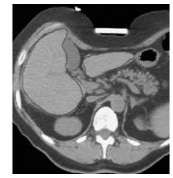




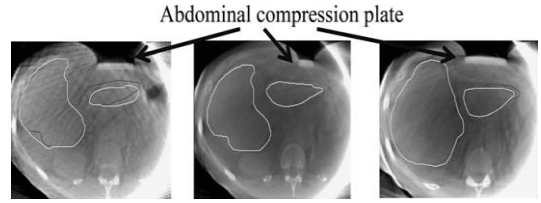
Heinzerling et al. IJROBP 2008

Tumor motion strategies in SBRT: motion restrictive (AAPM TG 76)

Liver deformations in patients undergoing SBRT under AC were small (< 5mm)



Planning CT

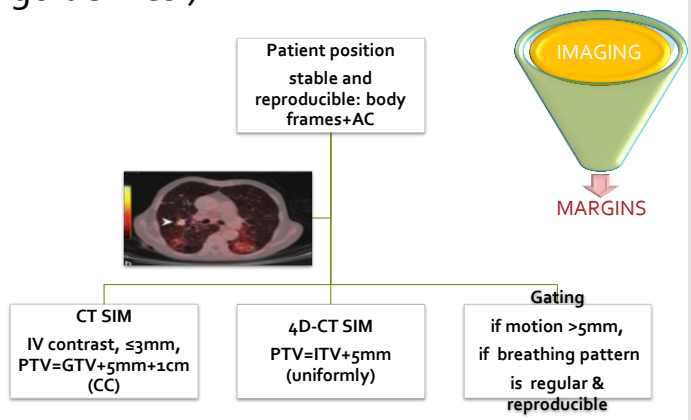


CBCT 1 | CBCT 5 | CBCT 6

Eccles et al. IJROBP 2010

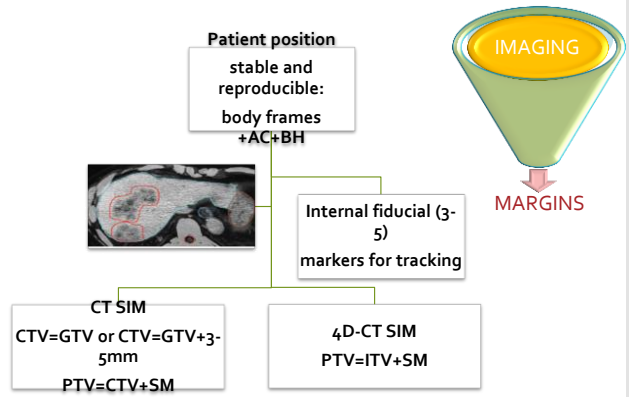
Imaging protocol for TVD in SBRT Lung

LUNG (RTOG 813 and 915-EORTC as guidelines)



Imaging protocol for TVD in SBRT Liver

LIVER (RTOG 438 as guidelines)



IRCCS CROB

IMAGING IN SBRT SPINE

Imaging SBRT Spine

NIH Public Access
Author Manuscript
Int J Radiat Oncol Biol Phys. Author manuscript; available in PMC 2013 July 15.
Published in final edited form as:
Int J Radiat Oncol Biol Phys. 2011 October 1; 81(2): S131–S132. doi:10.1016/j.prro.2013.05.001.

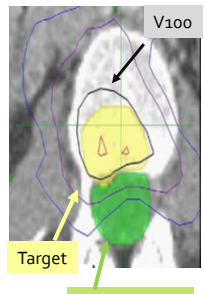
RTOG 0631 Phase II/III Study of Image-Guided Stereotactic Radiosurgery for Localized (1-3) Spine Metastases: Phase II Results

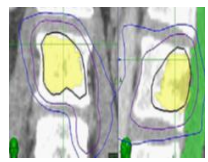
Samuel Ryu, M.D.[1], Stephanie L Pugh, Ph.D[2], Peter C. Gerszten, M.D., MPH[3], Fang-Fang Yin, Ph.D.[4], Robert D. Timmerman, M.D.[5], Ying J. Hitchcock, M.D.[6], Benjamin Movsas, M.D.[1], Andrew A. Kanner, M.D.[7], Lawrence B. Berk, M.D.[8], David S. Followill, Ph.D.[9], and Lisa A. Kachnic, M.D.[10]

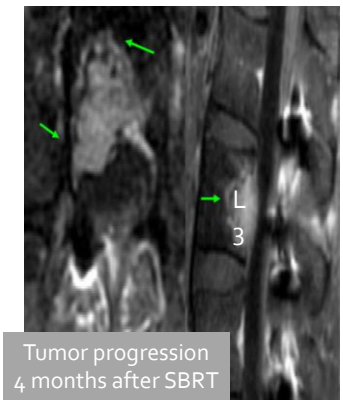
Single fraction dose of 16 Gy

Feasibility and accurate use of SRS to treat spinal metastases, with rigorous quality control

Imaging for TVD in SBRT Spine

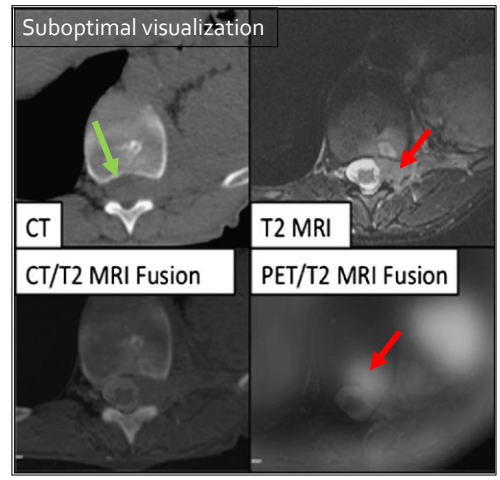




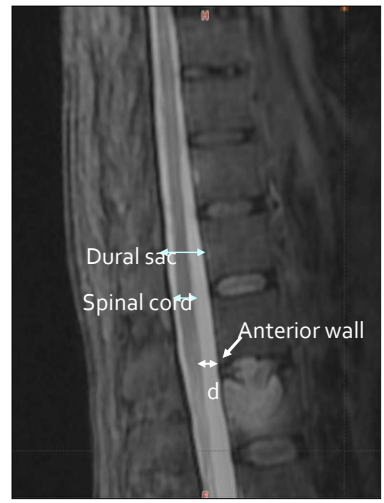


Tumor progression
4 months after SBRT

Imaging for TVD in SBRT Spine



Imaging for TVD in SBRT Spine



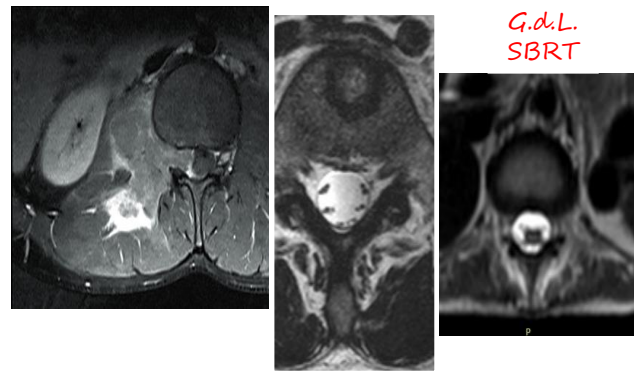
Variable location (d) of the spinal cord/cauda equina relative to the anterior wall of the spinal canal

Imaging MRI 3T for TVD in SBRT Spine

MR IMAGING OF THE SPINE AT HIGH FIELD

Table 1. Solutions for 3D FSE MRI

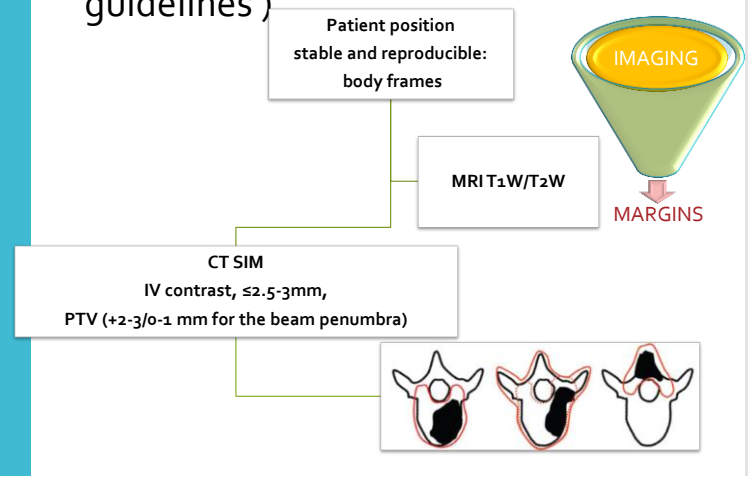
Problems	Old solutions	New problems	New solutions
Long acquisition time	Decreased TR Increase ETL or TF	Decreased CSF signal Increase blurring	Driven equilibrium pulse SPACE readout
CSF pulsation artifact	Decreased no. of phase-encoded steps	Decreased spatial resolution	Parallel imaging



IRCCS CROB

Imaging protocol for TVD in SBRT Spine

SPINE cases (RTOG 613 as guidelines)

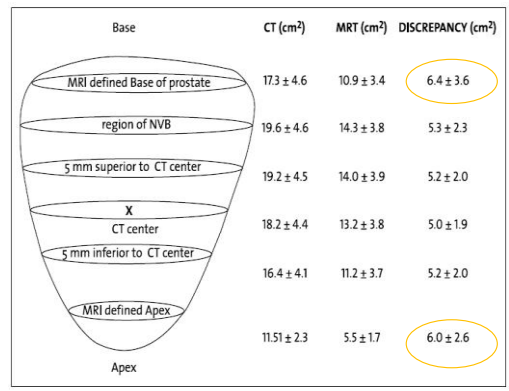


IRCCS CROB

IMAGING IN SBRT PROSTATE

Imaging for TVD in SBRT Prostate

CT scans overestimate prostate volume by 35% vs MRI



	CT (cm^2)	MRT (cm^2)	DISCREPANCY (cm^2)
MRI defined Base of prostate	17.3 ± 4.6	10.9 ± 3.4	6.4 ± 3.6
region of NVB	19.6 ± 4.6	14.3 ± 3.8	5.3 ± 2.3
5 mm superior to CT center	19.2 ± 4.5	14.0 ± 3.9	5.2 ± 2.0
CT center	18.2 ± 4.4	13.2 ± 3.8	5.0 ± 1.9
5 mm inferior to CT center	16.4 ± 4.1	11.2 ± 3.7	5.2 ± 2.0
MRI defined Apex	11.51 ± 2.3	5.5 ± 1.7	6.0 ± 2.6

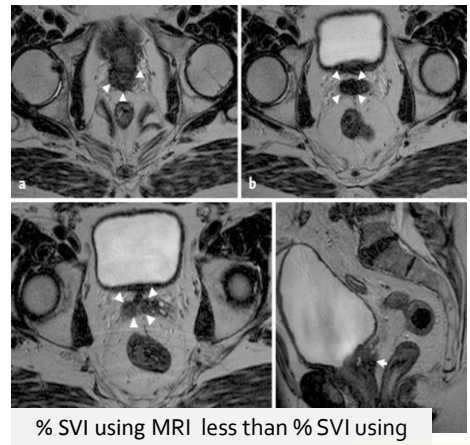
Hentschel et al. Strahlenther Onkol 2011

IRCCS CROB

Imaging for TVD in SBRT Prostate

SVI identified by MRI

entschel et al. Strahlenther Onkol 2011

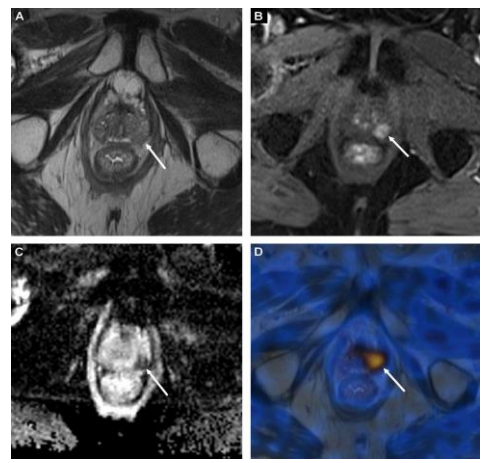


% SVI using MRI less than % SVI using Roach–Diaz

SVI =
PSA value + (Gleason score – 6) × 10

IRCCS CROB

Imaging for TVD in SBRT Prostate



IRCCS CROB

SBRT FOR PROSTATE the "current passion"

Volume 89 • Number 1 • 2014

Oncology Scan—Rising Stars, Fading Stars, and Shooting Stars: New Trends in Prostate Cancer Management

By Danny Y. Song, MD, *Associate Editor*

In this edition of Oncology Scan, Associate Editor Danny Song reviews 3 very provocative papers affecting the management of prostate cancer at different points along its evolution. The first report, by Thompson et al (1), looks at finasteride, the "fading star" of prostate cancer prevention; the second report investigates hypofractionation, the "current passion" of radiation oncologists for treatment of localized disease; and the third paper looks at radium-223 (^{223}Ra), the "rising star" in skeletal metastatic disease. These practice-defining papers are testament to the numerous, high-quality, clinical research initiatives currently underway in this disease.

Fractionation schemes in SBRT Prostate

G.d.L. SBRT

	TOTAL DOSE	DOSE Fx	N. Fx	OTT (Days)
EHF	33.5-50Gy	6.7-10Gy	4-5	4-29 days
MFH	51-72Gy	2.63-3.64Gy	14-30	19-45 days

EHF= Extreme Hypofractionation (<5 fx)
MHF= Moderate Hypofractionation (<35 fx)

Clinical outcome in SBRT Prostate

G.d.L. SBRT

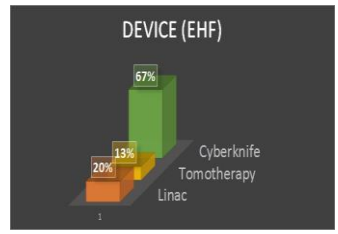
		EHF	MHF
4.8 y -bRFS	Low	86-100%	50-100%
	Intermediate	86-100%	56-100%
	High	78-100%	31-99%
Tox GU≥G2	Acute	1-45%	0-47%
	Late	1-20%	0-45%
Tox GI≥G2	Acute	0-21%	4-38%
	Late	0-28%	0-33%

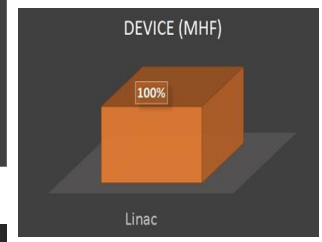
IRCCS CROB

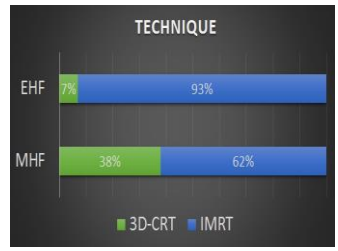
Correlation of outcome with technical aspect such as imaging, immobilization, margins…

?

Device and technique in SBRT Prostate

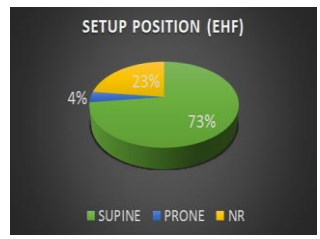




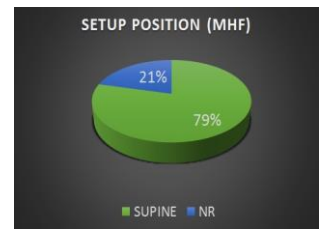


G.d.L. SBRT

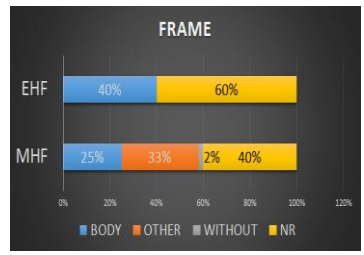
Set-up and frames in SBRT Prostate



G.d.L. SBRT



Set-up and frames in SBRT Prostate



G.d.L. SBRT

Rate of bRFS higher if frames were used

10 Clemente et al. International Journal of Radiation Oncology • Biology • Physics

Table 5 Biochemical relapse-free survival (bRFS) from studies at a median follow-up of 4.8 years

	Low risk			Intermediate risk			High risk		
Parameter	Mean (%)	Median (%)	SD (%)	Mean (%)	Median (%)	SD (%)	Mean (%)	Median (%)	SD (%)
FRAME Y	92.8	94.5	6.5	88.2	86	8.3	83.3	81.8	11.6
FRAME N	69.6	69.6	27.5	—	—	—	—	—	—

10 Clemente et al. International Journal of Radiation Oncology • Biology • Physics

Table 5 Biochemical relapse-free survival (bRFS) from studies at a median follow-up of 4.8 years

	Low risk			Intermediate risk			High risk		
Parameter	Mean (%)	Median (%)	SD (%)	Mean (%)	Median (%)	SD (%)	Mean (%)	Median (%)	SD (%)
FRAME Y	92.8	94.5	6.5	88.2	86	8.3	83.3	81.8	11.6
FRAME N	69.6	69.6	27.5	—	—	—	—	—	—
Rectum PREP Y	93.0	93.5	6.4	90.7	91	8.1	80.3	77.6	10.3
Rectum PREP N	—	—	—	79.0*	—	—	—	—	—
Bladder PREP Y	89.7	93.5	14.0	87.8	88.0	9.5	81.2	77.5	12.4
Bladder PREP N	94.4	94.0	5.3	93.9	94.8	7.2	90.4	92.0	10.5
MRI Y	94.2	96.4	7.2	93.6	95.0	8.5	88.7	89.0	10.5
MRI N	86.8	91.5	15.2	84.0	85.0	13.1	71.7	72.0	—
Only P Y	95.4	97.9	4.8	99.3	100.0	1.2	100*	—	—
Only P N	86.1	91.3	16.0	83.7	84.0	12.7	75.6	77.5	—
MARG ≥5 mm Y	85.7	91.2	15.1	83.5	84.0	12.4	71.7	74.8	—
MARG ≥5 mm N	95.9	97.9	—	—	—	—	—	—	—
MARKERS Y	95.1	95.0	—	—	—	—	—	—	—
MARKERS N	87.0*	—	—	—	—	—	—	—	—
IMG3D Y	81.7	95.0	—	—	—	—	—	—	—
IMG3D N	93.4	94.0	—	—	—	—	—	—	—
IMGDAY Y	94.1	95.0	—	—	—	—	—	—	—
IMGDAY N	75.6	87.6	—	—	—	—	—	—	—
TRACK Y	95.8	97.7	—	—	—	—	—	—	—
TRACK N	87.9	91.7	—	—	—	—	—	—	—

Great care has to be taken to compensate for prostate swelling if segmentation was performed with MRI-only

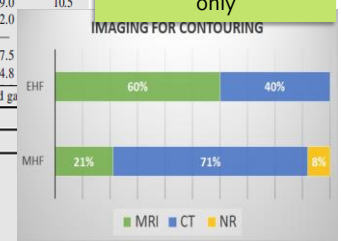


Table 6 Acute and late grade ≥2 (≥G2) genitourinary (GU) and ga

	≥G2 GU toxicity	
Parameter	Mean (%)	Median (%)
Acute FRAME Y	21.4	19.0
Acute FRAME N	4.3*	—
Late FRAME Y	15.0	11.5
Late FRAME N	2.5	2.5
Acute PREP Y	19.7	13.9
Acute PREP N	18.9	16.3
Late PREP Y	13.9	7.0
Late PREP N	9.7	8.5
Acute MRI Y	21.4	22.0
Acute MRI N	19.8	13.8
Late MRI Y	15.9	11.5
Late MRI N	10.3	5.2

							14.7	36.0*	—
							14.7	11.9	5.0
							6.6	2.5*	—
							13.4	10.3	10.4
							16.2	13.0	9.0
							13.2	8.1	5.0
							11.1	10.1	4.3

G.d.L. SBRT

G.d.L. SBRT

Table 5 Biochemical relapse-free survival (bRFS) from studies at a median follow-up of 4.8 years

Parameter	Low risk			Intermediate risk			High risk		
	Mean (%)	Median (%)	SD (%)	Mean (%)	Median (%)	SD (%)	Mean (%)	Median (%)	SD (%)
FRAME Y	92.8	94.5	6.5	88.2	86	8.3	83.3	81.8	11.6
FRAME N	69.6	69.6	27.5	—	—	—	—		
Rectum PREP Y	93.0	93.5	6.4	90.7	91	8.1	80.3		
Rectum PREP N	—	—	—	79.0*	—	—	—		
Bladder PREP Y	89.7	93.5	14.0	87.8	88.0	9.5	81.2		
Bladder PREP N	94.4	94.0	5.3	93.9	94.8	7.2	90.4		
MRI Y	94.2	96.4	7.2	93.6	95.0	8.5	88.7		
MRI N	86.8	91.5	15.2	84.0	85.0	13.1	71.7		
Only P Y	95.4	97.9	4.8	99.3	100.0	1.2	100*		
Only P N	86.1	91.3	16.0	83.7	84.0	12.7	75.6		
MARG ≥5 mm Y	85.7	91.2	15.1	83.5	84.0	12.4	71.7		
MARG ≥5 mm N	95.9	97.9	4.9	95.9	100.0	6.4	92.1		
MARKERS Y	95.1								
MARKERS N	87.0*								
IMG3D Y	81.7								
IMG3D N	93.4								
IMGDAY Y	94.1								
IMGDAY N	75.6								
TRACK Y	95.8								
TRACK N	87.9								

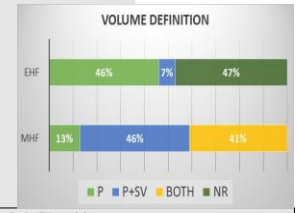
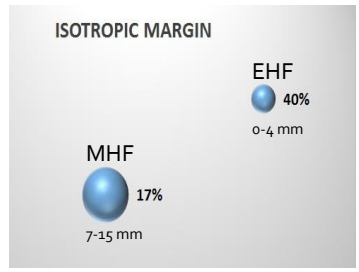


Table 6 Acute and late grade ≥2 (≥G2) genitourinary (GU) and gastrointestinal (GI) toxicity

Parameter	≥G2 GU toxicity			≥G2 GI toxicity		
	Mean (%)	Median (%)	SD (%)	Mean (%)	Median (%)	SD (%)
Acute only P Y	15.8	13.0	13.8	7.6	6.0	6.0
Acute only P N	24.7	25.5	15.7	17.6	12.3	11.5
Late only P Y	12.1	11.0	11.7	10.2	6.0	11.0
Late only P N	14.3	12.0	13.4	10.2	5.0	10.6
Acute MARG ≥5 mm Y	22.3	22.0	16.5	15.7	12.2	12.2
Acute MARG ≥5 mm N	17.9	13.6	13.1	7.7	7.0	5.7
Late MARG ≥5 mm Y	13.6	9.5	13.3	11.2	5.0	10.8
Late MARG ≥5 mm N	11.1	9.0	9.3	6.4	2.3	8.5

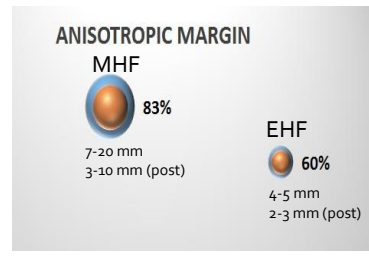
IRCCS CROB

Margins in SBRT Prostate



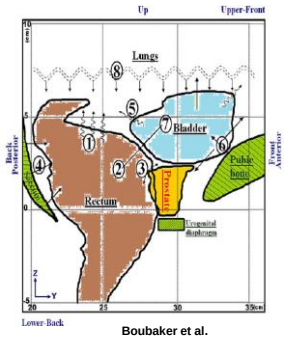
G.d.L. SBRT

Rate of Tox lower and bRFS higher if margins<5mm



IRCCS CROB

Organ motion: preparation in SBRT Prostate



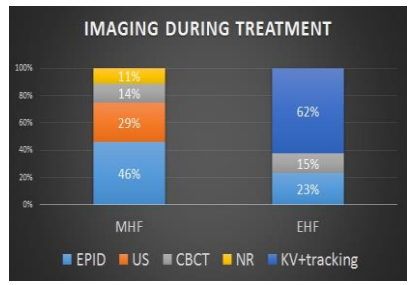
Boubaker et al. JBIOMECH 2009

G.d.L. SBRT

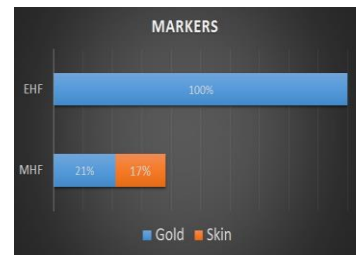
Rate of late ≥G2 GU Tox lower if preparation

IRCCS CROB

Imaging during treatment in SBRT Prostate



G.d.L. SBRT



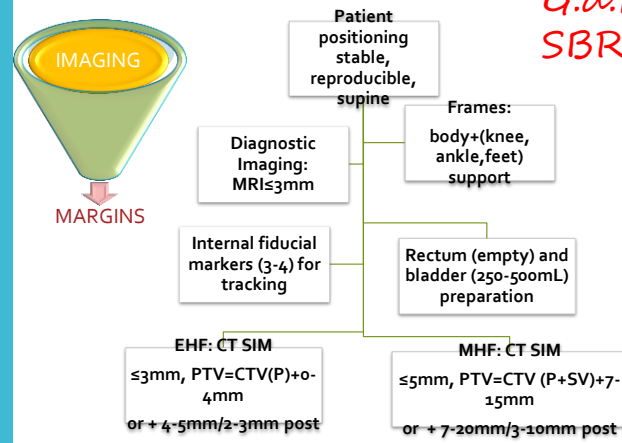
Daily imaging and tracking have a good impact on Tox and bRFS

IRCCS CROB

Imaging protocol for TVD in SBRT Prostate

PROSTATE

G.d.L. SBRT



G.d.L. SBRT

Ringraziamenti al Gruppo di Lavoro SBRT
"Imaging for target Volume Determination"

Valeria Landoni, IFO, Roma
Roberata Nigro, ASL Rieti
Caterina Oliviero, IRCCS CROB, Rionero in Vulture, PZ
Chiara Marchioni, ASL Rieti

IRCCS CROB