Role of Surface Guided Radiation Therapy: Rationale and Clinical Implications

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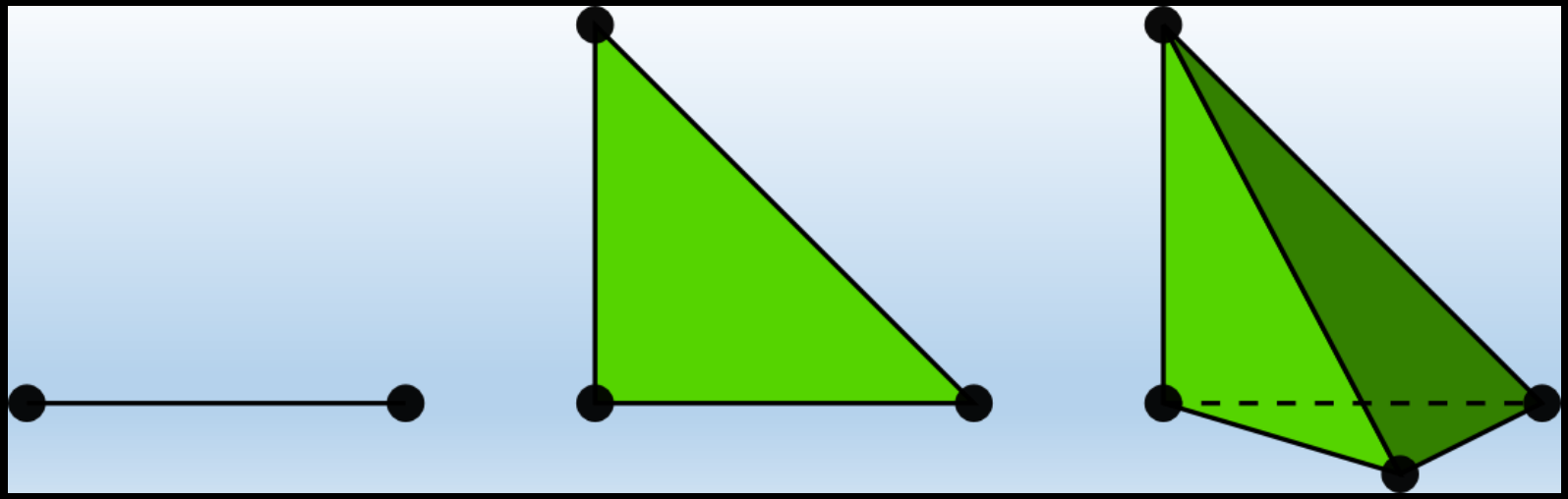
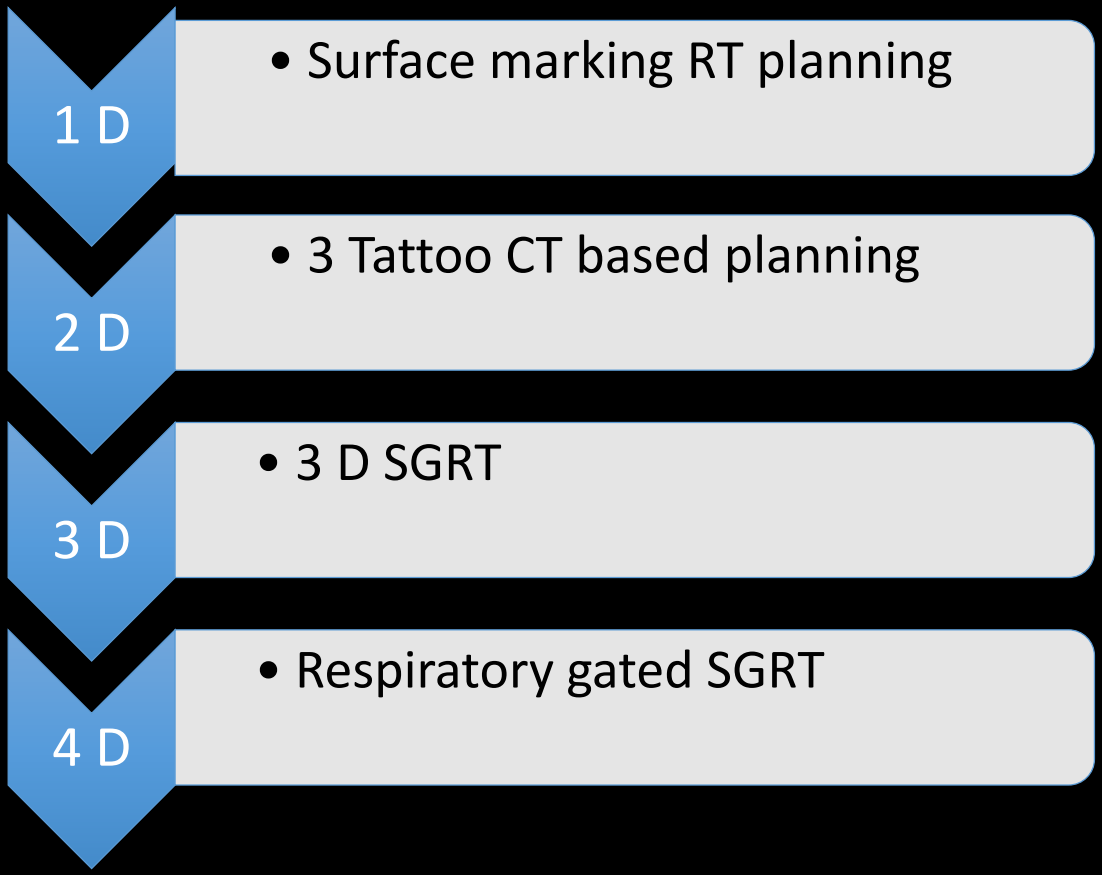
Sri HN Reliance Foundation, Mumbai


TREATMENT ROOM
उपचार
TATA MEMORIAL CENTRE
ROLL NO.
106




1 D
• Surface marking RT planning
2 D
• 3 Tattoo CT based planning
3 D
• 3 D SGRT
4 D
• Respiratory gated SGRT

The black holes are spinning!!

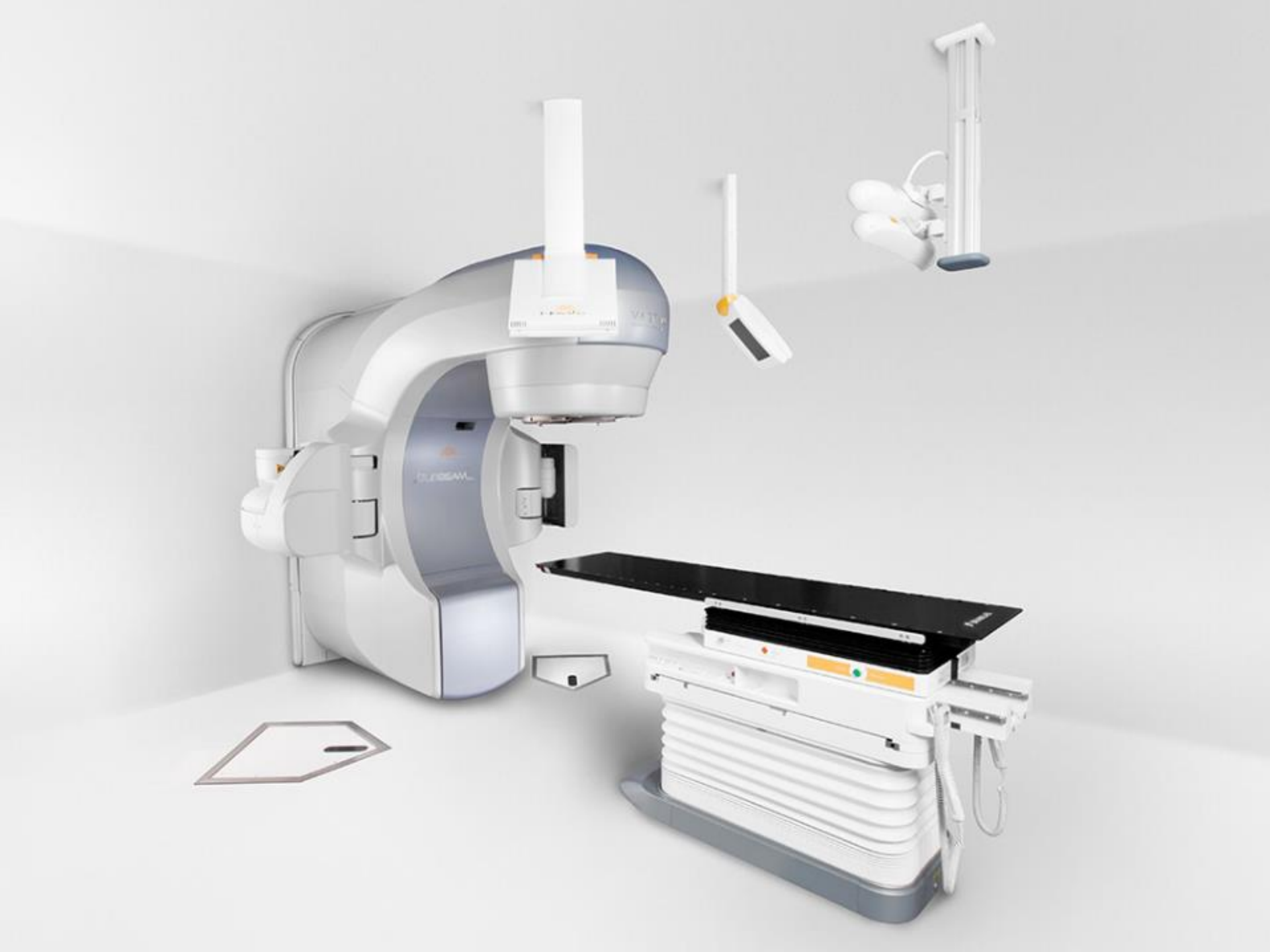
- Patient position and posture
- Target size or shape, location
- OAR size, shape, location
- Physiological variability, breathing, bladder and bowel filling
- Interpersonal set up inaccuracy

Oncologists, not wardens!

- Plaster molds
- Rigid body frames
- Cradles
- Positioning boards
- Head fixation frames
- Thermoplastic head and shoulder masks
- Vacuum bags

- Skin mark with tegaderm.
  - Removed during treatment
  - Washed out during bath
  - Re-planning
  - Skin reactions
- Thermoplastic mask
  - Ill fit
  - Become loose
  - Tattoos to position the mask
  - Inaccurate for pelvis and breast RT


ATTENTION
THIS AREA IS
UNDER
SURVEILLANCE
ACTIVITY
REPORTED

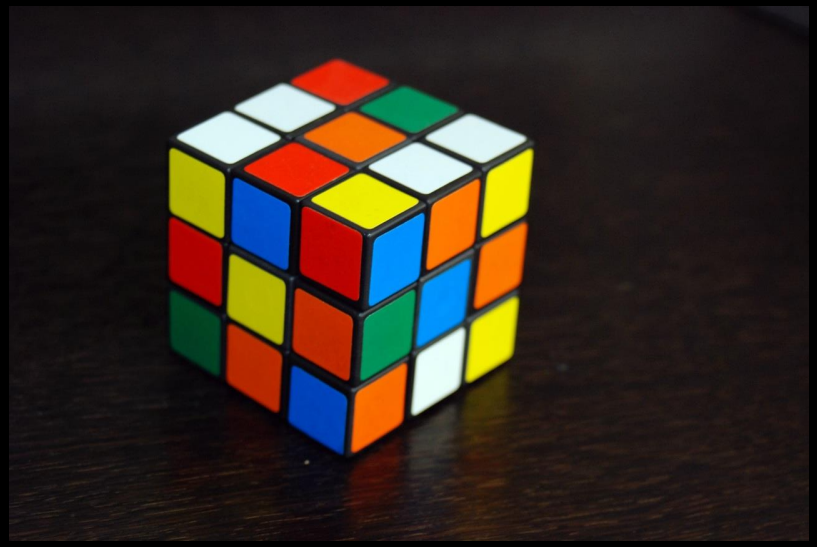


Surface Guided Radiotherapy

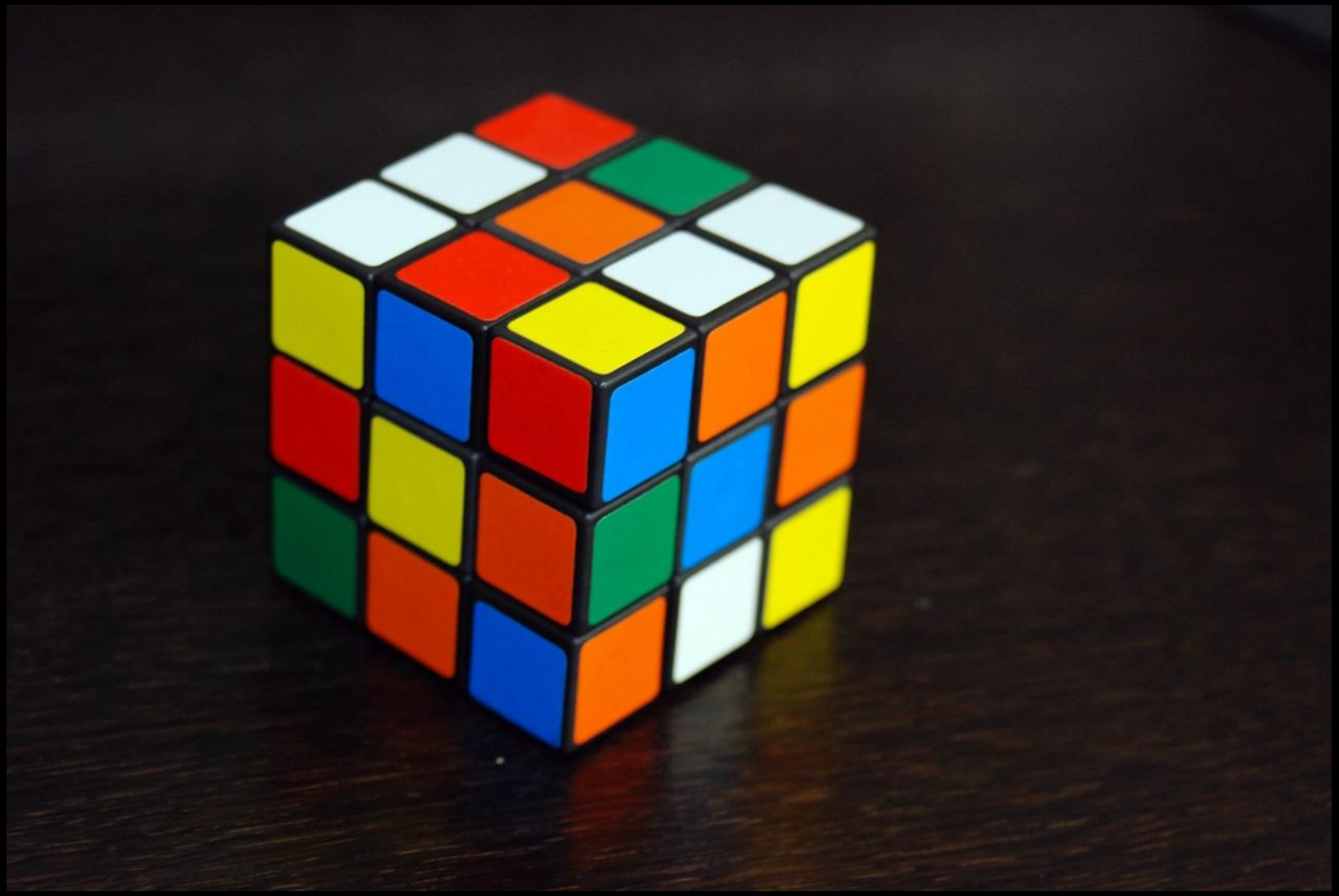
Variety of radiation therapy techniques that employ **optical surface imaging** to reduce localization uncertainty during treatment delivery, which can in turn lead to **reduced target margins and dose to normal tissues.**

- Marker-based

- 3 D Surface-based

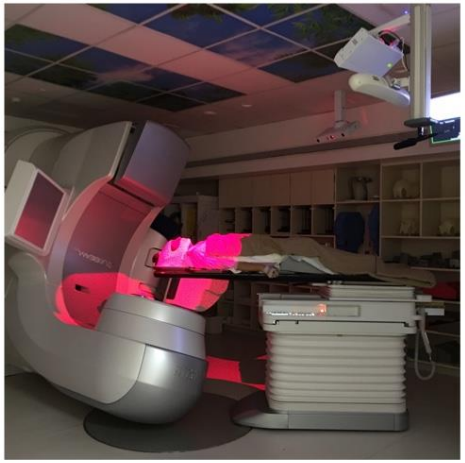


RPM




VARIAN
TrueBeam


VARIAN



- Set up – Tattoos
- Intrafraction motion
- Patient monitoring – CCTV

SGRT

- Eliminating human set up errors
- Always watching
- No need to continuously watch

  CCTV

Clinical indications of SGRT

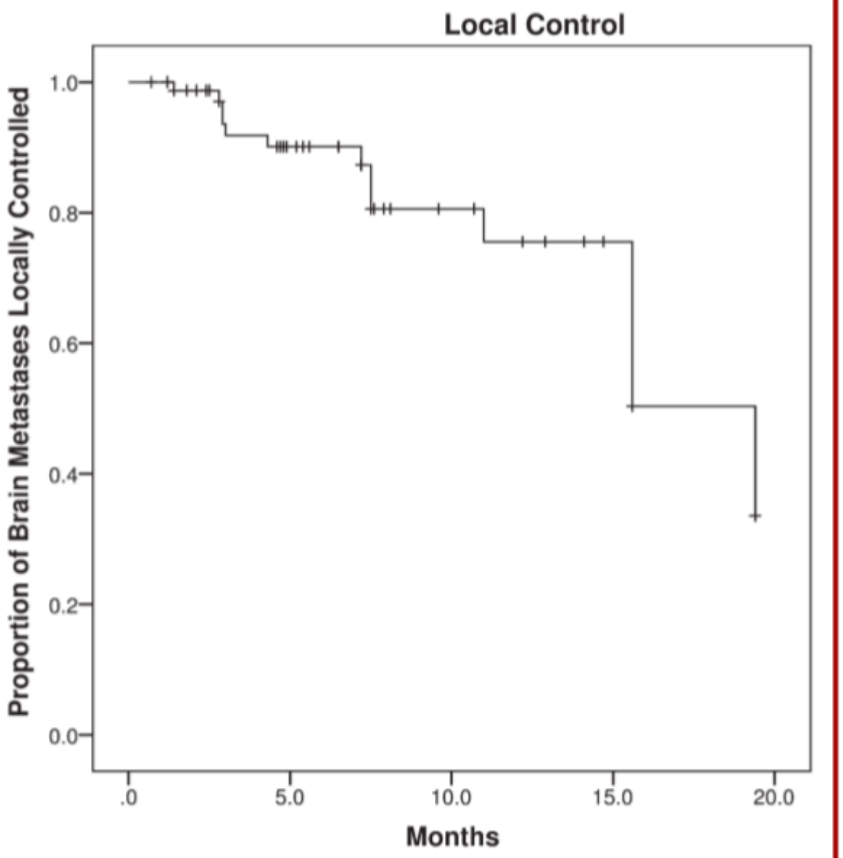


FIGURE 2. *Local control of 88 intracranial metastases in 35 patients treated with real-time, surface imaging-guided, frameless radiosurgery. The 12-month actuarial local control was 76%.*

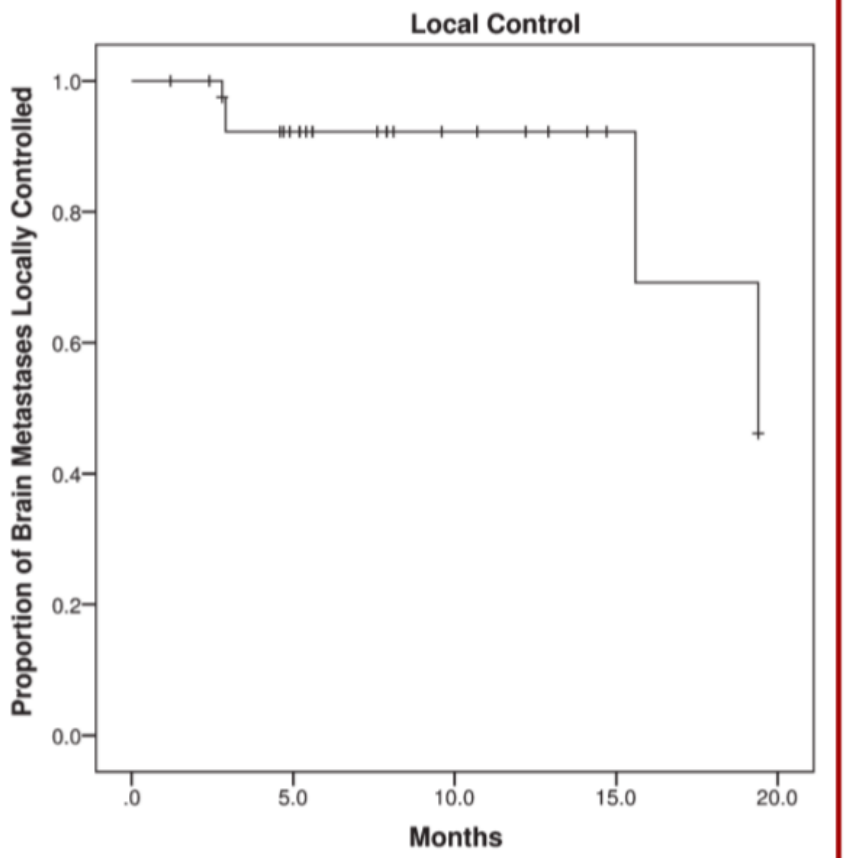
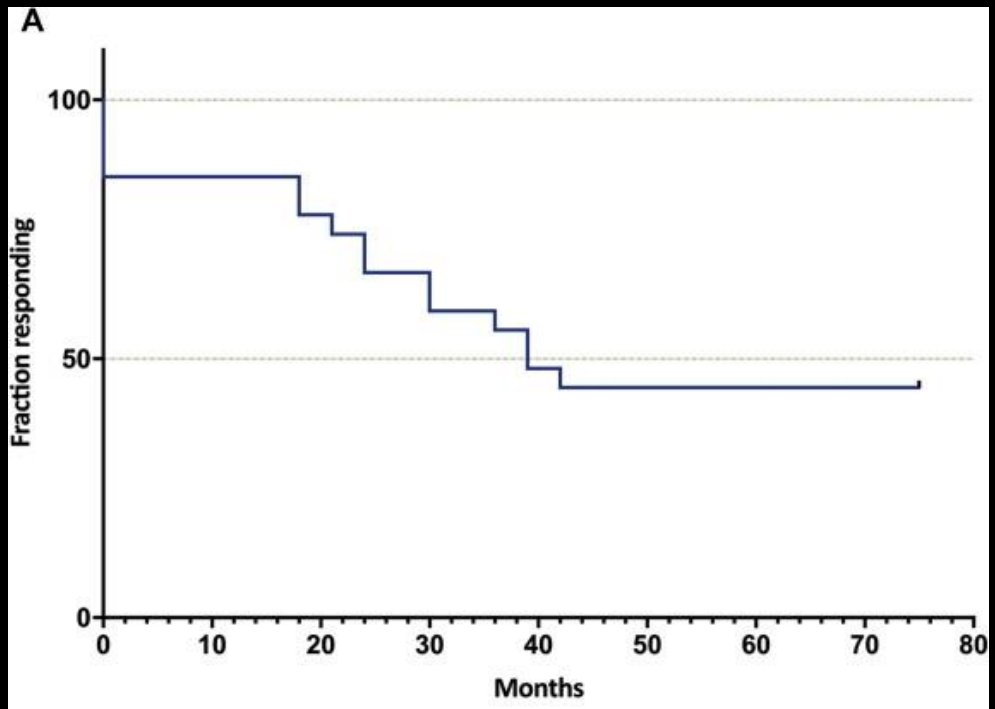
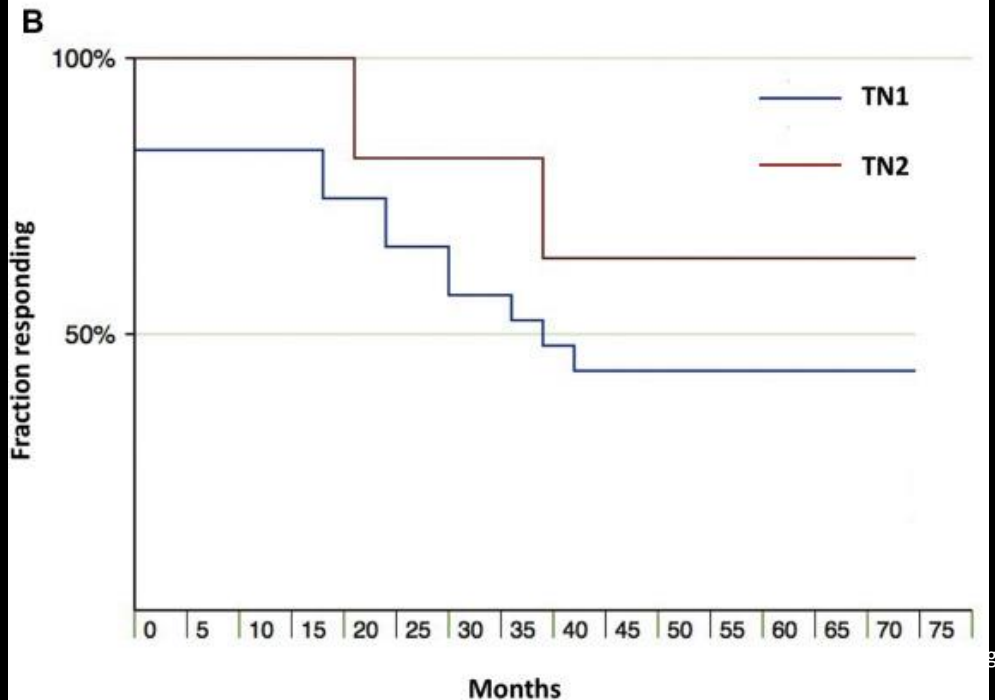


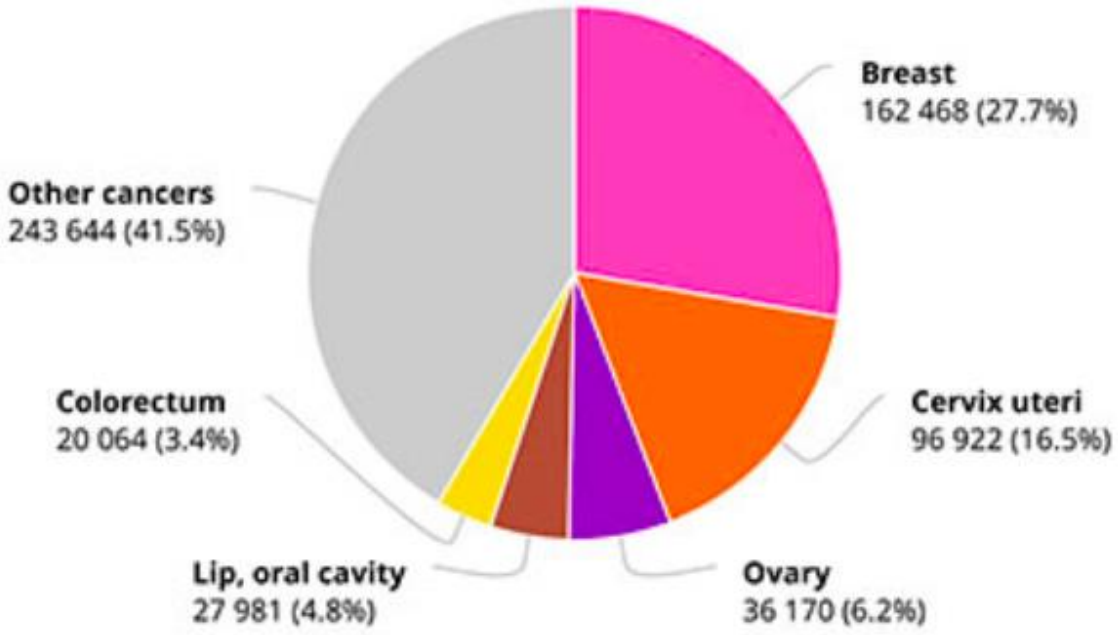
FIGURE 3. *Local control of 55 intracranial metastases in 22 patients treated with a single fraction of real-time, surface imaging-guided, frameless radiosurgery with no prior treatment and subsequent magnetic resonance imaging follow-up. The 12-month actuarial local control was 92%.*

Pan et al, Neurosurgery 71:844–852, 2012

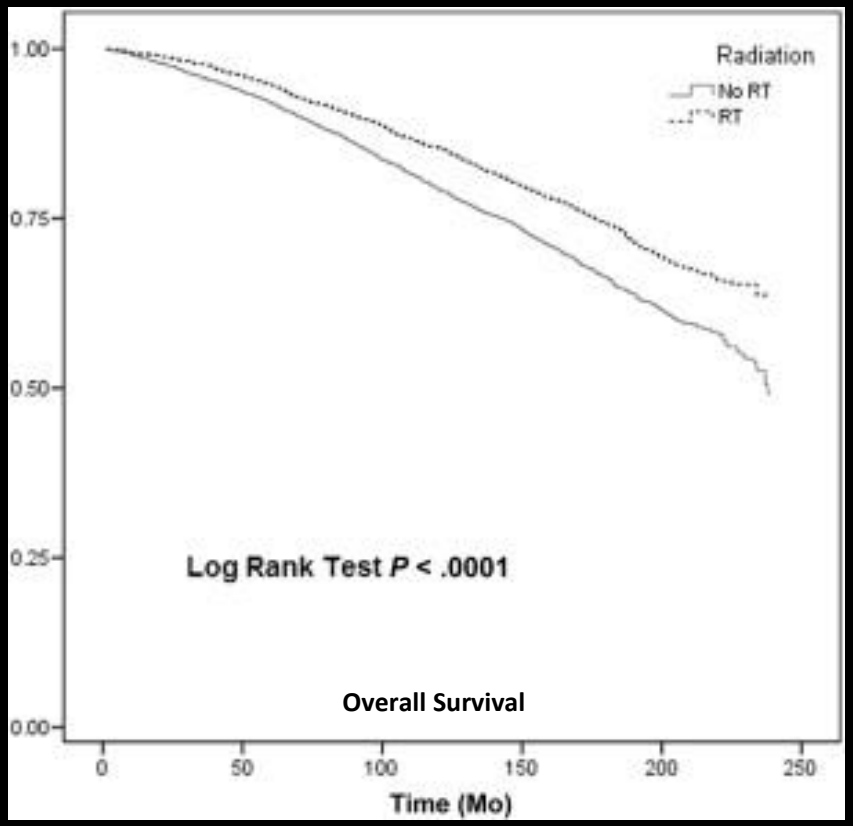

A
100
50
0
Fraction responding
0
10
20
30
40
50
60
70
80
Months


B
100%
50%
Fraction responding
TN1
TN2
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Months

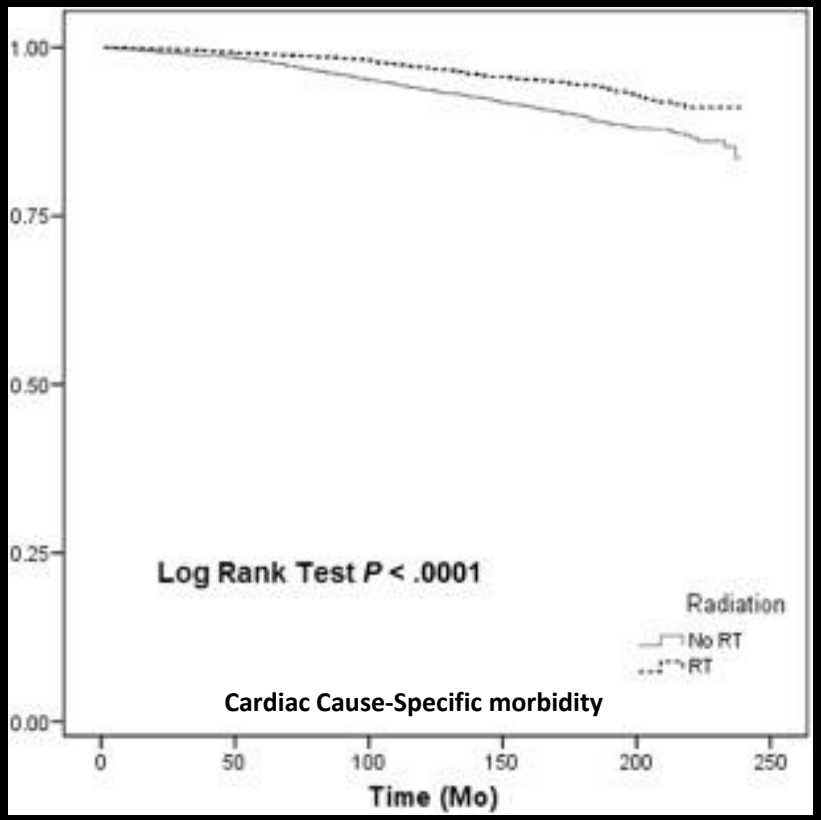
Number of new cases in 2018, females, all ages



Total: 587 249



Overall Survival



Cardiac Cause-Specific morbidity

Jason C et al, Clinical Breast Cancer, 2015-02-01, Volume 15, Issue 1, Pages 54-59

Table 3 Modeled risk estimates for ischemic heart disease 5 years at baseline and following radiation therapy while FB or with deep inspiration breath hold (DIBH)

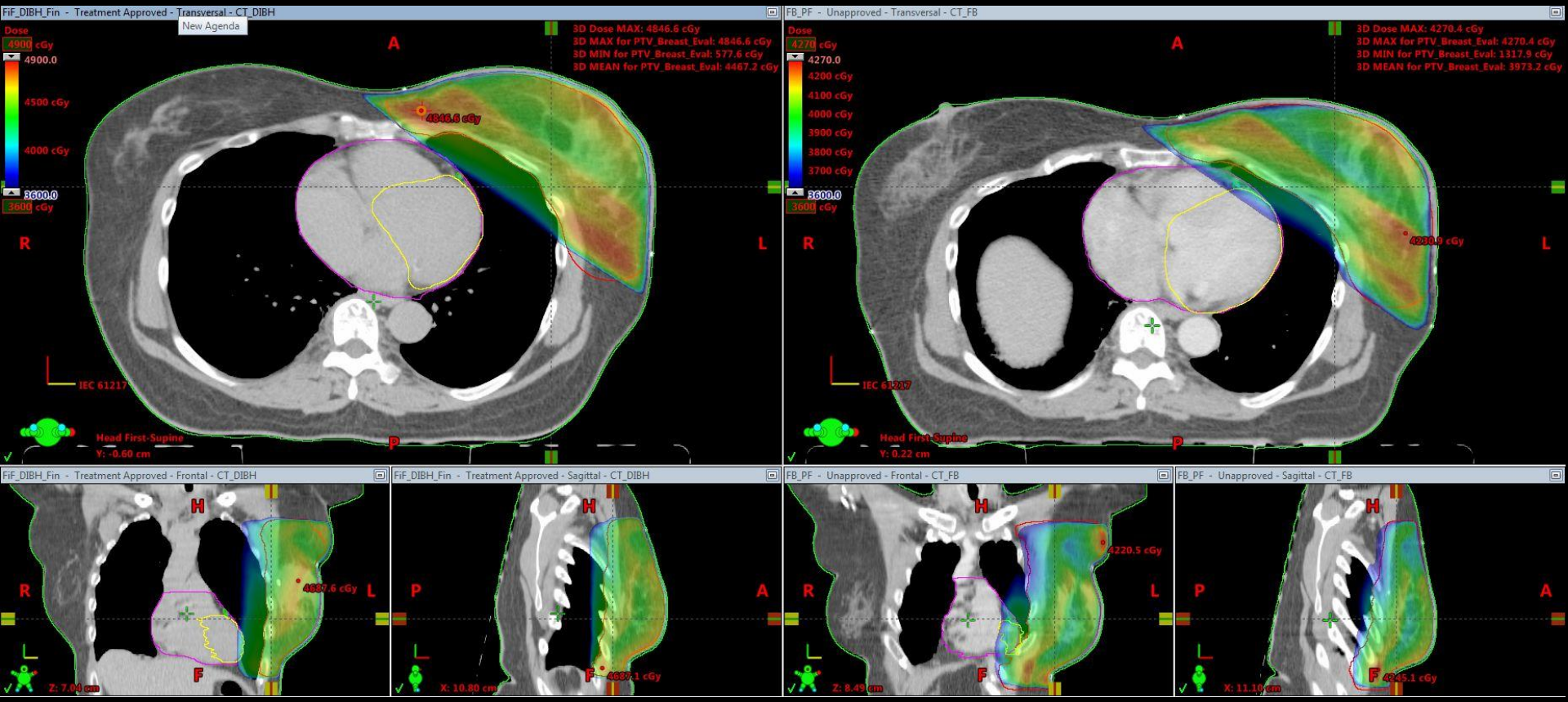
	MHD_{EQD2} (Gy) Median (range)	All risks (n =61) Median (IQR)	Optimal risk (n =23) Median (IQR)	At risk (n =29) Median (IQR)	High risk (n =9) Median (IQR)
Baseline risk[14,15]	0 (ref)	0.64% (0.38-1.70)	0.42% (0.29-0.78)	0.64% (0.50-1.32)	2.17% (1.83-3.97)
DIBH	0.52 (0.05-2.42)	0.70% (0.40-1.82)	0.51% (0.29-0.83)	0.70% (0.53-1.44)	2.41% (1.88-4.26)
FB	1.42 (0.55-4.47)	0.79% (0.44-2.11)	0.58% (0.35-1.00)	0.79% (0.58-1.63)	2.67% (2.25-4.55)
P	<.001	<.001	<.001	<.001	<.05

FB, free breathing; IQR, interquartile range; MHD_{EQD2}, mean heart dose equivalent dose in 2-Gy fractions; ref, reference.

Table 4 Modeled risk estimates for ischemic heart disease 10 years following radiation therapy while FB or with deep inspiration breath hold (DIBH)

	MHD_{EQD2} (Gy) Median (range)	All risks (n =104) Median (IQR)	Optimal risk (n =43) Median (IQR)	At risk (n =48) Median (IQR)	High risk (n =13) Median (IQR)
Baseline risk[13,16]	0 (ref)	3.00% (1.10-3.30)	1.10% (1.10-1.95)	3.10% (2.80-3.10)	12.50% (12.00-12.50)
DIBH	0.52 (0.05-2.42)	3.25% (1.20-3.44)	1.19% (1.17-2.19)	3.35% (3.26-3.44)	13.56 (13.49-13.62)
FB	1.42 (0.55-4.47)	3.64% (1.43-3.81)	1.34% (1.29-2.55)	3.78% (3.61-3.80)	15.24% (15.22-15.30)
P	<.0001	<.0001	<.0001	<.0001	.0015

FB, free breathing; IQR, interquartile range; MHD_{EQD2}, mean heart dose equivalent dose in 2-Gy fractions; ref, reference.


FiF_DIBH_Fin - Treatment Approved - Transversal - CT_DIBH
New Agenda
Dose
4900 cGy
4900.0
4500 cGy
4000 cGy
3600.0
3600 cGy
3D Dose MAX: 4846.6 cGy
3D MAX for PTV_Breast_Eval: 4846.6 cGy
3D MIN for PTV_Breast_Eval: 577.6 cGy
3D MEAN for PTV_Breast_Eval: 4467.2 cGy
4846.6 cGy
A
R
L
P
IEC 61217
Head First-Supine
Y: -0.60 cm
FB_PF - Unapproved - Transversal - CT_FB
Dose
4270 cGy
4270.0
4200 cGy
4100 cGy
4000 cGy
3900 cGy
3800 cGy
3700 cGy
3600.0
3600 cGy
3D Dose MAX: 4270.4 cGy
3D MAX for PTV_Breast_Eval: 4270.4 cGy
3D MIN for PTV_Breast_Eval: 1317.9 cGy
3D MEAN for PTV_Breast_Eval: 3973.2 cGy
4270.4 cGy
A
R
L
P
IEC 61217
Head First-Supine
Y: 0.22 cm
FiF_DIBH_Fin - Treatment Approved - Frontal - CT_DIBH
H
F
R
L
4887.6 cGy
Z: 7.04 cm
FiF_DIBH_Fin - Treatment Approved - Sagittal - CT_DIBH
H
F
P
A
4887.1 cGy
X: 10.80 cm
FB_PF - Unapproved - Frontal - CT_FB
H
F
R
L
4220.5 cGy
Z: 8.49 cm
FB_PF - Unapproved - Sagittal - CT_FB
H
F
P
A
X: 11.10 cm

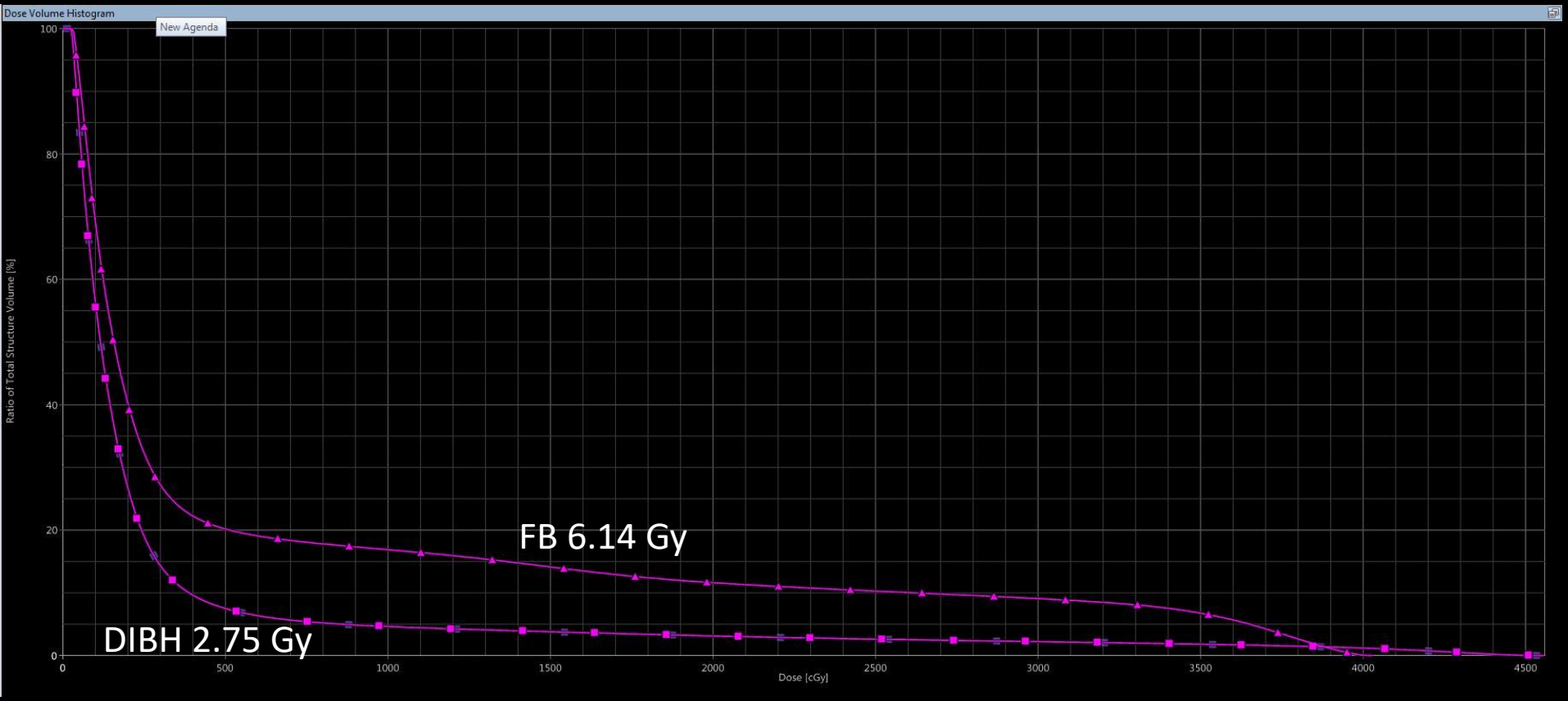

Dose Volume Histogram
New Agenda
Ratio of Total Structure Volume [%]
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Dose [cGy]
FB 6.14 Gy
DIBH 2.75 Gy

Table 2 Residual setup error

Technique	Anterior/ Posterior (mm)	Superior/ Inferior (mm)	Right/Left Lateral (mm)	Vector Spatial Deviation (mm)
Video surface mapping	1.9 ± 2.2	1.8 ± 1.9	1.8 ± 2.1	4.0 ± 2.3
Orthogonal imaging	3.2 ± 2.9	4.2 ± 3.5	4.7 ± 5.3	8.3 ± 3.8
Laser	3.9 ± 3.7	4.6 ± 3.9	4.3 ± 4.5	8.8 ± 4.2

A.J. Chang et al Practical Radiation Oncology: Month 2011

DIBH Parameter

	Breast	Chest wall
Average Breath hold amplitude (cm)	1.99	1.76
Lower threshold for BH (cm)	1.65	1.44
Upper threshold for BH (cm)	2.26	2.15
Average Breath hold duration (Sec)	20.78	20.83

	FB	DIBH	P
Volume of left lung (cc)	957.56	1596.33	<0.001
Maximal heart distance (cm)	1.61	0.55	<0.001
Heart to Chest wall contact ((cm)	4.8	3.3	0.01
left ventricle to Chest wall contact (cm)	2.7	1.8	0.02
Volume of heart (cc)	534.56	476.56	0.01
Haller index	2.45	2.16	<0.001

Breast Conservation Patients

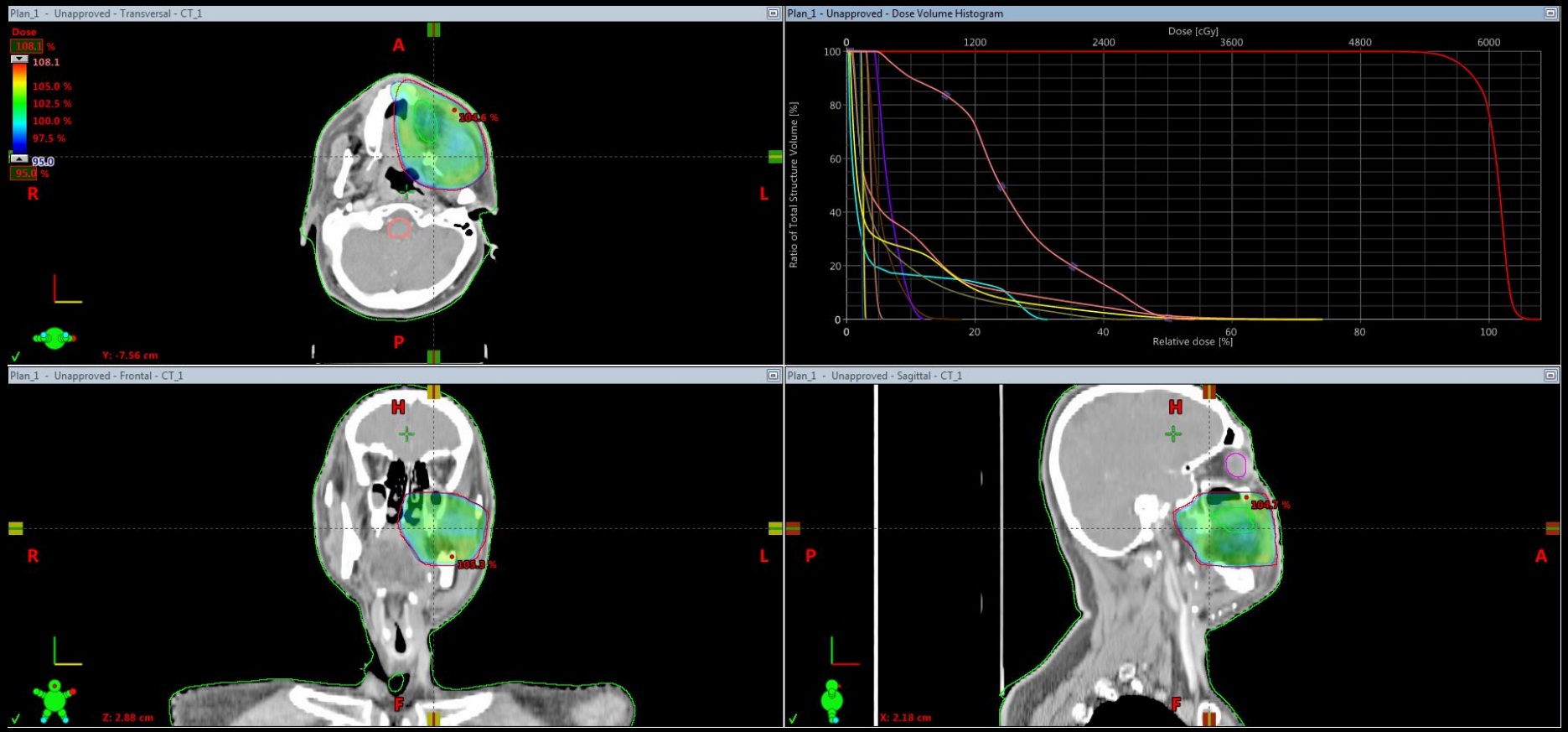
	FB	DIBH	p
Volume of irradiated heart (cc)	41.41	6.31	0.01
Mean Heart dose	5.22	1.95	<0.001
V5 (%)	14.93	4.75	<0.001
V10 (%)	10.88	2.29	<0.001
V15 (%)	9.50	1.78	0.01
V20 (%)	8.39	1.45	0.01
V25 (%)	7.50	1.22	0.01
V30 (%)	6.76	1.03	0.01
Lung			
V5 (%)	31.03	32.25	0.59
V10 (%)	23.08	21.65	0.37
V15 (%)	20.57	18.22	0.12
V20 (%)	18.84	16.31	0.07
Mean Lung dose	9.47	8.92	0.36
LAD Mean	19.82	9.41	0.01
LAD Maximum	37.11	26.16	0.07
V25 (%)	40.20	14.39	0.01
Contralateral Breast Maximum (Gy)	3.42	4.17	0.34

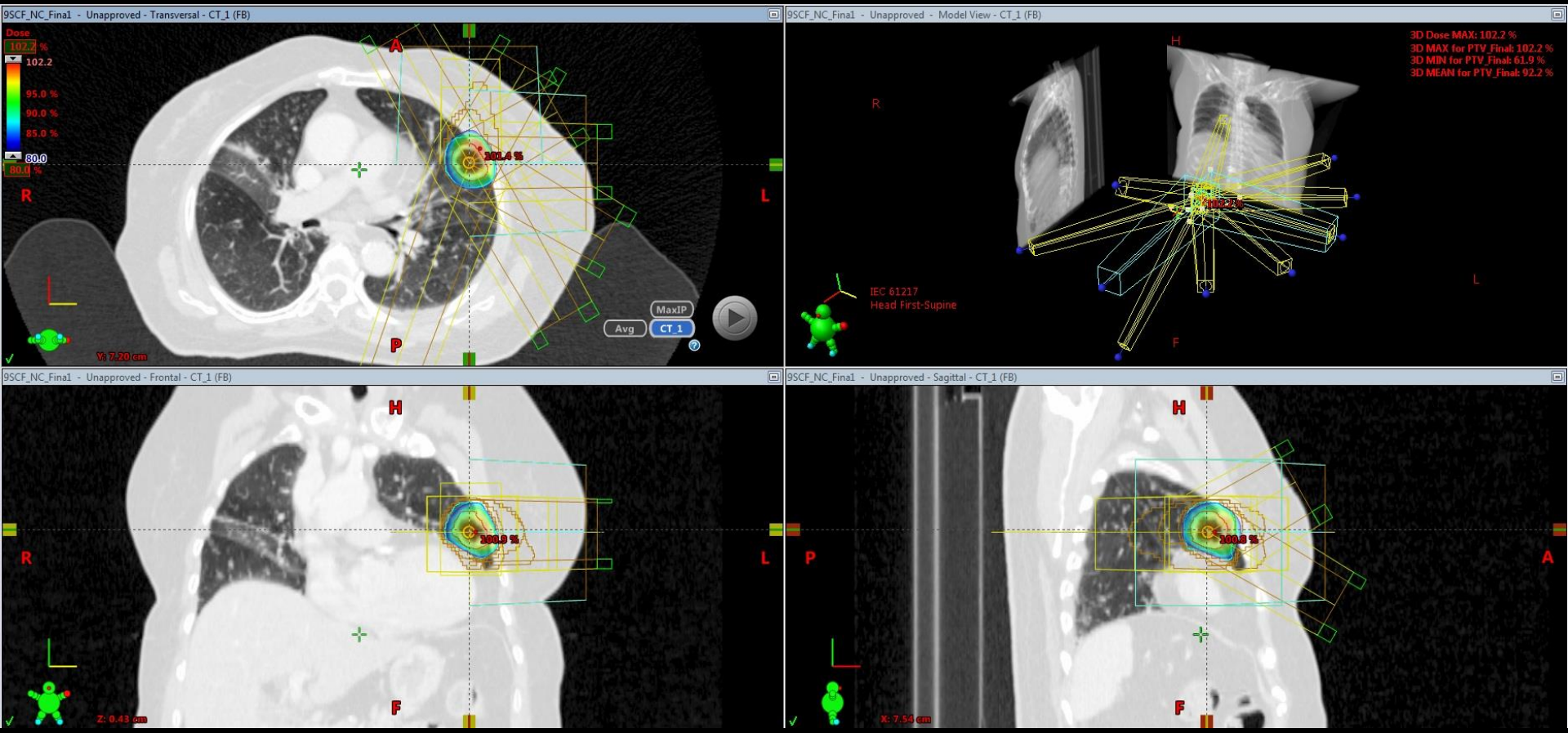
Chest wall + Regional LNs

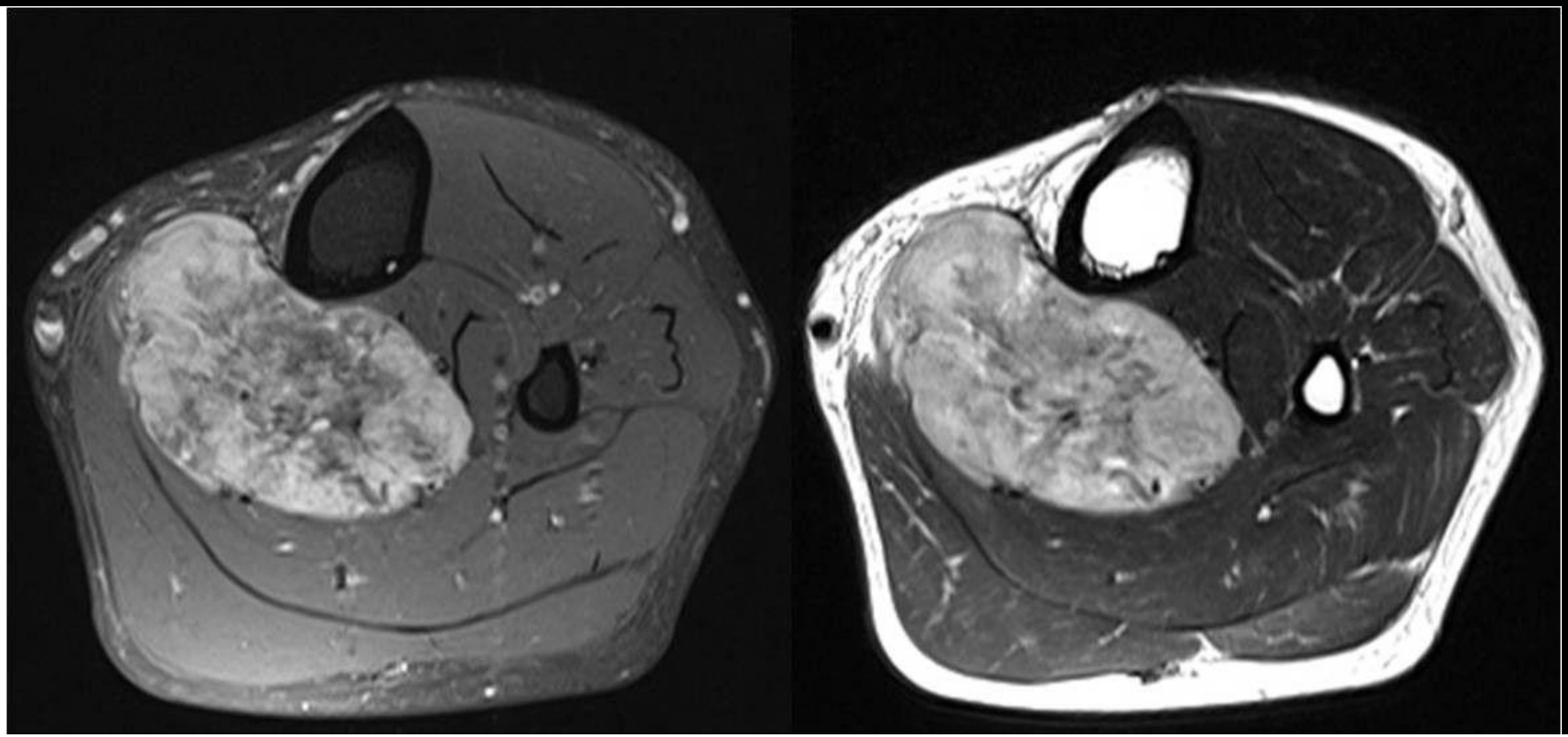
	FB	DIBH	P
Volume of irradiated heart (cc)	30.07	8.52	**0.01**
V5 (%)	13.53	8.13	0.06
V10 (%)	10.47	4.21	0.01
V15 (%)	9.21	3.30	0.01
V20 (%)	8.17	2.72	0.01
V25 (%)	7.15	2.27	0.01
V30 (%)	6.31	1.87	0.01
Lung			
V5 (%)	29.51	29.92	0.81
V10 (%)	22.24	20.97	0.42
V15 (%)	19.53	19.52	1
V20 (%)	17.77	16.18	0.29
Mean Lung dose	9.30	8.80	0.43
LAD Mean	24.53	16.29	0.20
LAD Maximum	46.62	41.71	0.43
V25 (%)	49.08	20.85	0.08
Contralateral Breast Maximum (Gy)	3.08	2.46	0.2

DIBH is not an option, it is a must

for left breast radiotherapy


Plan_1 - Unapproved - Transversal - CT_1
Dose
108.1 %
108.1
105.0 %
102.5 %
100.0 %
97.5 %
95.0
95.0 %
A
P
R
L
Y: -7.56 cm
Plan_1 - Unapproved - Dose Volume Histogram
Dose [cGy]
Ratio of Total Structure Volume [%]
Relative dose [%]
Plan_1 - Unapproved - Frontal - CT_1
H
F
R
L
Z: 2.88 cm
Plan_1 - Unapproved - Sagittal - CT_1
H
F
P
A
X: 2.18 cm


9SCF_NC_Fina1 - Unapproved - Transversal - CT_1 (FB)
Dose
102.2 %
102.2
95.0 %
90.0 %
85.0 %
80.0
80.0 %
A
P
R
L
MaxIP
Avg
CT_1
Y: 7.20 cm
9SCF_NC_Fina1 - Unapproved - Model View - CT_1 (FB)
3D Dose MAX: 102.2 %
3D MAX for PTV_Final: 102.2 %
3D MIN for PTV_Final: 61.9 %
3D MEAN for PTV_Final: 92.2 %
H
R
L
F
IEC 61217
Head First-Supine
9SCF_NC_Fina1 - Unapproved - Frontal - CT_1 (FB)
H
R
L
F
Z: 0.43 cm
9SCF_NC_Fina1 - Unapproved - Sagittal - CT_1 (FB)
H
P
A
F
X: 7.54 cm



Average intrafraction difference - OSMS 1 mm vert, 1.1 mm long, 0.5 mm lat, 0.6 degree pitch, 0.26 degree roll and 0.39 degree in rotation.

Thoracic patients	CBCT	OSMS
Vert	5 ± 2 (mm)	4 ± 2 (mm)
Long	3.2 ± 2 (mm)	3.1± 4 (mm)
Lat	4.4 ± 2.8 (mm)	3.4 ± 3 (mm)
pitch	0.9 ±0.8 (degree)	0.8 ± 0.7 (degree)
Roll	0.8 ± 0.7 (degree)	1 ± 0.7 (degree)
Rotation	0.8 ± 0.8 (degree)	1.1 ± 0.8 (degree)
Abdomino-pelvic patients		
Vert	3.1 ±2.5 (mm)	3.5±2.5 (mm)
Long	2.1 ± 1.6 (mm)	3 ± 3.5 (mm)
Lat	3.8 ± 3.2 (mm)	3.7 ± 3 (mm)
pitch	0.6 ±0.68 (degree)	2.2 ± 2 (degree)
Roll	0.6 ± 0.5 (degree)	0.9 ± 0.6 (degree)
Rotation	0.5 ± 0.5 (degree)	1.25 ± 1.43 (degree)

Med Phys. 2012 Apr;39(4):1728-47. doi: 10.1118/1.3681967.

Quality assurance for nonradiographic radiotherapy localization and positioning systems: report of Task Group 147.

Willoughby T[1], Lehmann J, Bencomo JA, Jani SK, Santanam L, Sethi A, Solberg TD, Tome WA, Waldron TJ.

Author information

1 Task Group 147, Department of Radiation Physics, Orlando, FL, USA.

Abstract

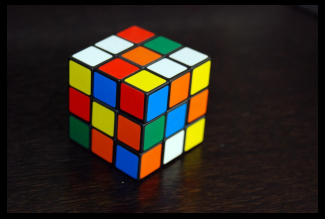
New technologies continue to be developed to improve the practice of radiation therapy. As several of these technologies have been implemented clinically, the Therapy Committee and the Quality Assurance and Outcomes Improvement Subcommittee of the American Association of Physicists in Medicine commissioned Task Group 147 to review the current nonradiographic technologies used for localization and tracking in radiotherapy. The specific charge of this task group was to make recommendations about the use of nonradiographic methods of localization, specifically; radiofrequency, infrared, laser, and video based patient localization and monitoring systems. The charge of this task group was to review the current use of these technologies and to write quality assurance guidelines for the use of these technologies in the clinical setting. Recommendations include testing of equipment for initial installation as well as ongoing quality assurance. As the equipment included in this task group continues to evolve, both in the type and sophistication of technology and in level of integration with treatment devices, some of the details of how one would conduct such testing will also continue to evolve. This task group, therefore, is focused on providing recommendations on the use of this equipment rather than on the equipment itself, and should be adaptable to each user's situation in helping develop a comprehensive quality assurance program.

SGRT: Can’t clean your mess!!

- No replacement for poor quality planning CT scan
- Can’t correct for suboptimal RT plan
- Can’t compensate for poor breath hold or low amplitude

SGRT and set up

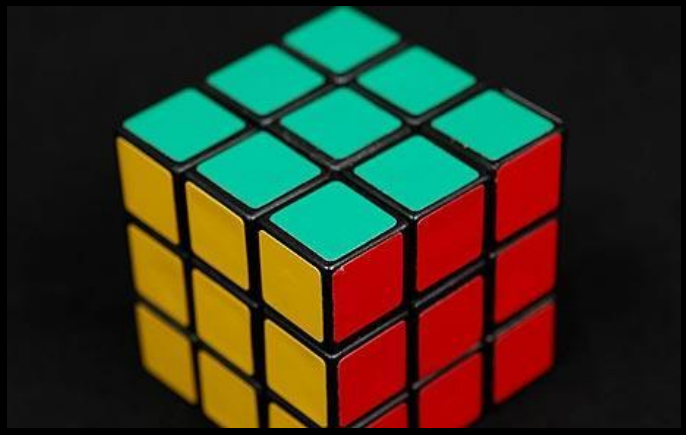
- Improves the set up of patients
- Reduces re-set up and repeat CBCT
- Reduces treatment time
- Reduces radiation exposure
- Reduces discomfort to patient

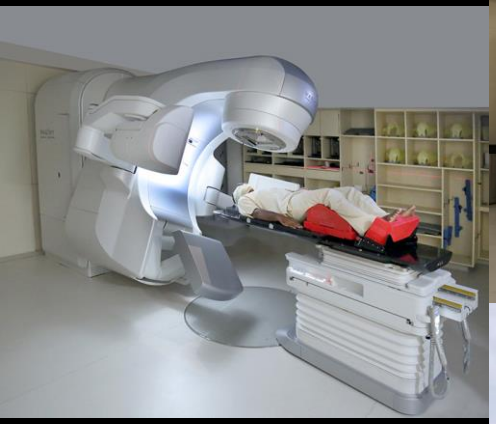


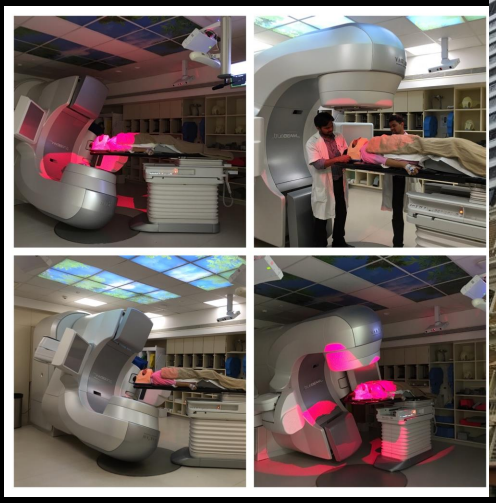
- Set up
- Intra fraction monitoring
- Beam hold
- Gating
- Most clinical site
- Simple QA


BETTER FUTURE

- **NOT** a replacement for IGRT
- set up accuracy and time
- No tattoos
- Intra-fraction motion
- Beam hold
- Gating
- No irradiation
- Reduced re-imaging







Thank you

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