Pre-Operative Linac Based Breast Radiosurgery

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Preoperative partial breast radiosurgery (SBRT)

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CLINICAL INVESTIGATION — Breast Cancer

PREOPERATIVE SINGLE FRACTION PARTIAL BREAST RADIOTHERAPY FOR EARLY-STAGE BREAST CANCER

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- Postop APBI: subcutaneous fibrosis and/or poor cosmetic outcome due to large breast irradiated volume with high dose (Jagsi et al – RedJ 2010 , Hepel et al – RedJ 2010)
- Preop target volume is much smaller than postop target volume PBI
- Preop V100=3.8% vs postop V100=18%
- Preop V50= 13.5% vs postop V50= 53%

Disclosure

- No conflict of interest

Preoperative partial breast radiosurgery (SBRT)

- **Edibility criteria:** Age>= 55yr with cT1N0, noninvasive, tumor <= 2cm, biopsy
- **Phase I: Dose escalation study (32 patients. Started in 2007)**
  - **8 patients at 15Gy, 8 patients at 18Gy, and 16 patients at 21Gy**
  - **To determine the maximum tolerated dose of single-dose partial breast irradiation based on toxicity**
- **Phase II: Evaluation of single-fraction treatment (100 patients. Finished in 2022)**
  - **21Gy → modified to SIB 15Gy to PTV_CTV and 21Gy to PTV_GTV**
  - **To determine rate of good/excellent cosmesis**
- **Single fraction**

Horton et al – RedJ2015

Learning objectives

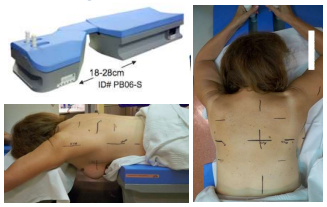
(1) To review current practice of breast SBRT and APBI.

(2) To learn treatment planning and delivery techniques for breast SBRT and APBI using Linac, GammaPod and Proton.

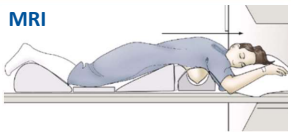
(3) To improve efficiency, accuracy and safety though experience.

Immobilization and CT/MRI simulation

Planning CT

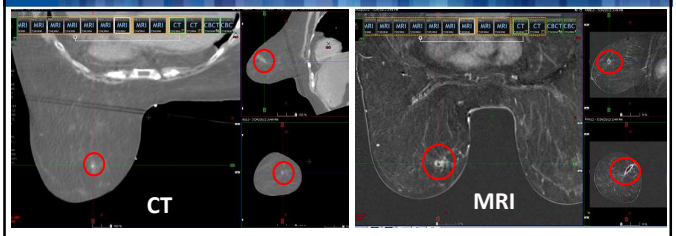


MRI



- **breast surface coil**
- **T1-weighted/T2-weighted/inversion-recovery/diffusion weighted (DWI), and dynamic contrast enhanced (DCE)**

CT and MRI



Challenge! Different immobilization devices make the breast shape different

Solution! All patients have a biopsy marker (clip) at the tumor location.

Image registration: Align CT clip to MR clip, and confirm with soft tissue pattern.

Dose constraints – updated phase II

- Prescription: SIB. Single fraction. 15Gy to PTV_CTVeval and 21Gy to PTV_GTVeval
- **Target coverage**
  - CTV: V100% (100% of 15Gy) >= 95%
  - PTV_CTVeval: V95% (95% of 15Gy) >= 90%
  - PTV_GTVeval: V95% (95% of 21Gy) >= 95%
- **OAR constraints**
  - Ipsilateral breast: V50% <= 30%
  - Contralateral breast: Dmax <= 2.1 Gy
  - Lungs: Dmean <= 3.6 Gy
  - Heart: Dmean <= 1.5 Gy
  - Chest wall: D20cc <= 16.3 Gy
  - Skin dose: Dmax <= 21Gy, D1cc <=14Gy, D10cc <= 9Gy

Structures

- Biopsy clip
- GTV (CT and MR combined)
- CTV= GTV + 1.5cm; exclude **5mm from skin surface;**
- Skin (3mm layer);
- chestwall; Lt/Rt breast; Rt/Lt lung; heart;

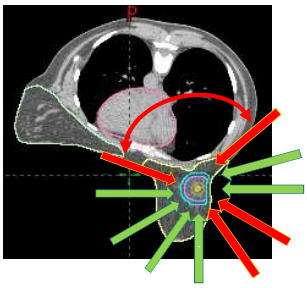
Phase I and Phase II

- PTV= CTV+0.5cm; PTV_Eval to exclude **chestwall and 5 mm from skin surface**

Modified Phase II SIB

- PTV_GTV=GTV+0.5cm; PTV_GTVeval to exclude **chestwall and 5mm from skin surface**
- PTV_CTV= CTV+0.5cm; PTV_CTVeval to exclude **chestwall and 5mm from skin surface**

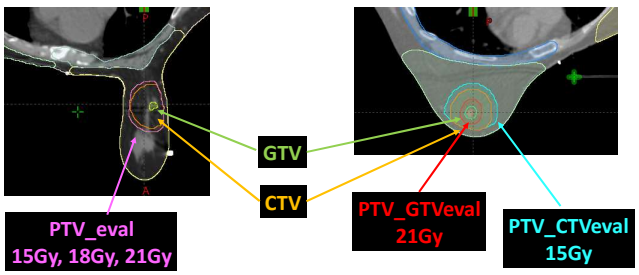
Planning – Limited beam angles



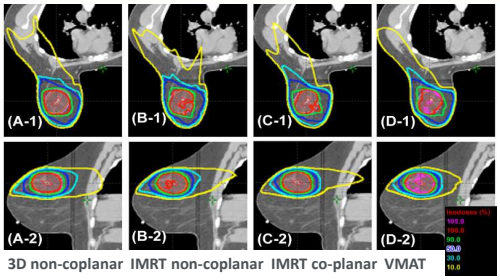
- **4 to 7 beams for IMRT**
- **Limited beam angles to**
  - **avoid posterior beams**
  - **avoid contralateral breast**
  - **minimize heart exposure**

Structures

Phase I and Phase II targets | **Updated Phase II targets**



Planning comparison



Yoo et al – JACMP 2015

Planning comparison

TABLE 2. Mean dosimetric parameters ± standard deviation from 3D CRT, $IMRT_{NC}$, $IMRT_{CO}$, and VMAT.

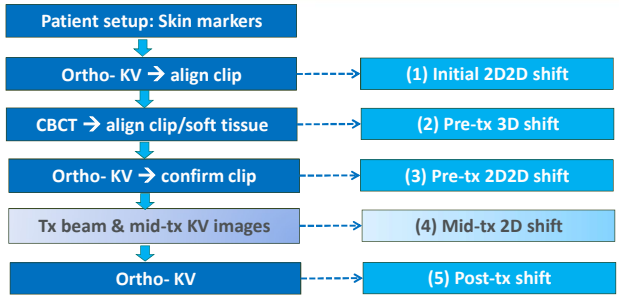
		3D CRT	$IMRT_{NC}$	$IMRT_{CO}$	VMAT
CTV	$V_{95\%}$	99.8±0.4	99.5±0.6*	99.5±0.6*	99.5 ± 0.6*
	HI	1.05±0.02	1.07±0.04*	1.07±0.03*	1.11±0.04*†‡
	CI	1.56±0.27	1.42±0.32	1.44±0.30	1.60±0.32
PTV	$V_{95\%}$	98.5±1.4	96.3±2.0*	96.5±1.5*	96.4±1.8*
	HI	1.05±0.02	1.08 ±0.05*	1.07±0.04*	1.12±0.02*†‡
	CI	1.04±0.17	0.95±0.20	0.96±0.21	1.07±0.22*†‡
Skin	$D_{10\ cm^3}$ (%)	45.9±7.1	41.9±5. 9*	43.8±6.5	46.3±7.42†‡
	$D_{1\ cm^3}$ (%)	72.9±9.6	59.2±10.3*	61.1±11.9*	64.2±11.7*†
	D_{max} (%)	86.5±6.7	73.7±11.5*	74.3±12.1*	76.3±12.5*
ILB	$V_{20\%}$ (%)	28.5±8.5	27.0±7.8*	26.4±8.3*	23.5±7.5*†‡
	$V_{50\%}$ (%)	15.3±5.3	14.3±3.9	14.8±5.5	14.1±5.6*†
	$V_{100\%}$ (%)	4.3±1.6	3.8±1.3*	3.9±1.4	4.4±1.9*‡
	$D_{1\%}$ (%)	103.7±1.8	103.9±2.5*	104.0±2.3*	105.6±2.8*
Heart	D_{10cm^3}(%)	2.5±1.7	1.8±1.6*	1.6±1.4*	1.3±1.1*†‡
CB	D_{10cm^3}(%)	1.0±0.5	0.7±0.3*	0.8±0.3*†	0.6±0.2*‡
ILL	D_{10cm^3}(%)	11.4±8.3	13.2±10.8	11.8±9.8	9.6±9.9*‡
Ribs	D_{max} (%)	33.6±33.0	34.3±36.6	33.7±35.8	30.4±36.6*‡
Dose fall off	$V_{50\%}/V_{100\%}$ of ILB	3.7±0.8	3.9±0.8	4.0±1.1	3.3±0.8*†‡
Delivery time (min)		11.0±1.5	9.7±1.0*	8.3±1.1*†	7.0±1.0*†‡

1) VMAT
Good OAR sparing
Poor HI, poor CI

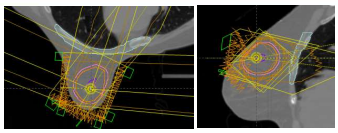
2) IMRT
Good target coverage
Good skin sparing

3) non-coplanar IMRT
Slightly better for skin sparing than coplanar

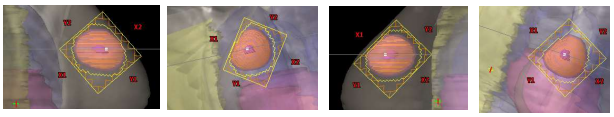
Treatment procedure



Planning – Beam setting based on BEV

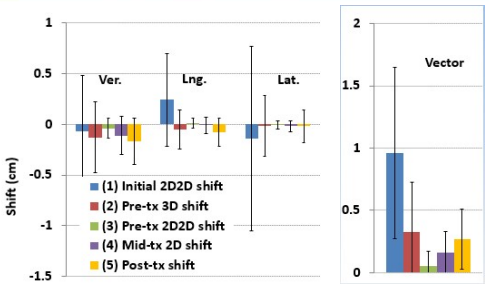


1) Isocenter at GTV.
2) Non-coplanar beams.
(4 to 7 beams, mostly 5 beams)



Challenge! Collision
Challenge! Limited range for couch rotation.

IGRT analysis



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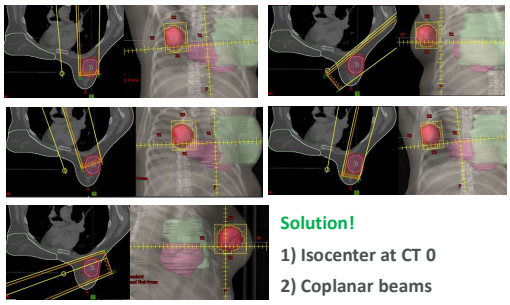
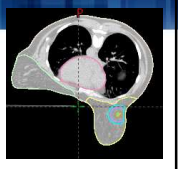
Planning – Beam setting based on BEV



Solution!
1) Isocenter at CT 0
2) Coplanar beams

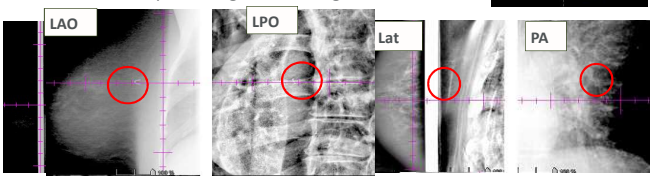
IGRT: Clip display



Orthogonal KV images to align the biopsy clip

Challenge! Clip often not visible due to long path length (30% cases) or board plate (10% cases)

Solution! Oblique orthogonal KV images

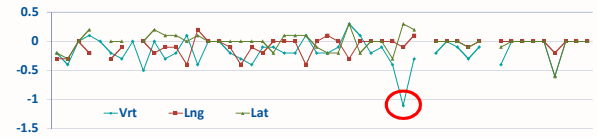


IGRT: Post-tx shift

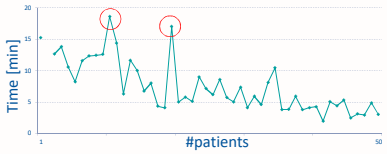
	Ver. (cm)	Lng. (cm)	Lat. (cm)	Vector (cm)
(5) Post-tx shift	-0.17±0.23	-0.08±0.14	-0.02±0.16	0.27±0.24

- To evaluate the patient motion during treatment delivery;
- Mostly in Vertical direction due to roll.

Challenge! 1.1cm shift vertically found for one patient.



Efficiency – (a) Initial 2D2D

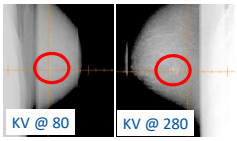


- Average ~ 7 min
- ◯ > 17 min due to collision check and re-positioning
- ~ 5 min save with iso from GTV → CT0 and non-coplanar beams → coplanar beams.
- Improvement over time.

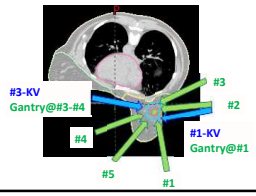
IGRT: Mid-Tx imaging

Solution! Mid-Tx imaging implemented in-between treatment beams

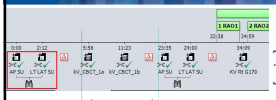
- To verify and correct patient motion during treatment delivery.
- Clip should be clearly visible and identify patient motion in vertical direction.
- Minimize unnecessary gantry rotation for efficient treatment.
- 2 lateral or lateral oblique images are included.

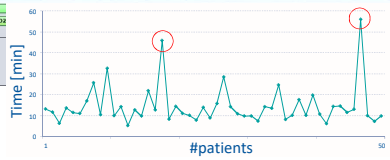


	Field ID	Gantry Rtn [deg]
1	1 RAO	170.0
1-KV	KV Rt G170	80.0
2	2 RPO1	85.0
3	3 RPO2	65.0
3-KV	KV Lt G10	280.0
4	4 LAO1	250.0
5	5 LAO2	225.0



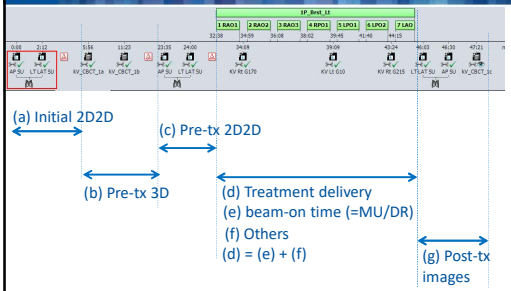
Efficiency – (b) Pre-Tx 3D





- Average ~ 15 min
- CBCT acquisition + alignment + waiting for MD + MD review + re-positioning + re-CBCT + MD final approval
- No improvement over time.

Treatment efficiency (Time) from 50 patients



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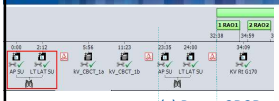
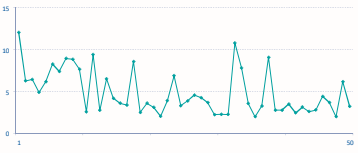
Efficiency – (c) Pre-Tx 2D2D





- Average ~ 5 min
- Imaging time + shift + couch rotation + collision check + timeout
- Improvement with iso from GTV to CT0 and non coplanar beams → coplanar beams ~3 min saving (saving from no couch rotation and no collision check)

Efficiency – (d) Treatment delivery

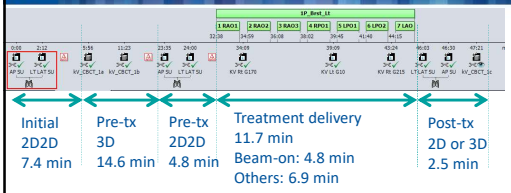
(d) Treatment delivery
(e) beam-on time (=MU/DR)
(f) Others;

- **Average ~ 12 min = beam-on time + beam preparation time**
- **Improved beam-on time: 600 MU/min ~ 8 min vs FFF 1400 MU/min ~ 3 min**
- **Improved beam preparation: non-coplanar plan ~ 10 min vs coplanar plan ~ 4 min**
- **Mid-tx imaging added ~ 2 min**

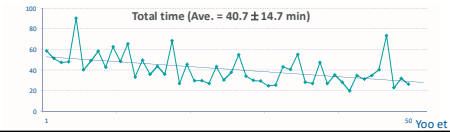
Summary

- Preoperative single fraction partial breast radiosurgery using Linac.
- Why preoperative? → small target volume.
- MRI utilized to identify the tumor.
- Static coplanar IMRT.
- Beams set to avoid contralateral breast and to minimize heart exposure.
- Skin sparing achieved through optimization.
- Biopsy clip is used to localize the target during IGRT.
- Improvements made through experience for efficiency, accuracy and safety.

Efficiency – Summary



Initial 2D2D 7.4 min | Pre-tx 3D 14.6 min | Pre-tx 2D2D 4.8 min | Treatment delivery 11.7 min, Beam-on: 4.8 min, Others: 6.9 min | Post-tx 2D or 3D 2.5 min



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Treatment process

Improvements made through experience!

1) Efficiency improved.
   - Total treatment time reduced **~ 18 min.**
   - **Isocenter at GTV → CT0**: **~ 4 min** saved.
   - Plans with **non-coplanar → coplanar**
     ~ 3 min saved before treatment delivery
     ~ 6 min saved during treatment delivery.
   - **600MU/min → 1400MU/min with FFF**: **~ 5 min** saved for beam-on time
2) Accuracy and quality improved.
   - Oblique orthogonal kV images: improve **clip visibility**
   - Mid-tx kV imaging: **correct patient motion during treatment**
3) Safety improved.
   - **Collision free** with iso at CT0 and coplanar beams.

Thank you!