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Radiation Damage Comparison between Intensity Modulated Radiotherapy (IMRT) and Field-in-field (FIF) Technique In Breast Cancer Treatments

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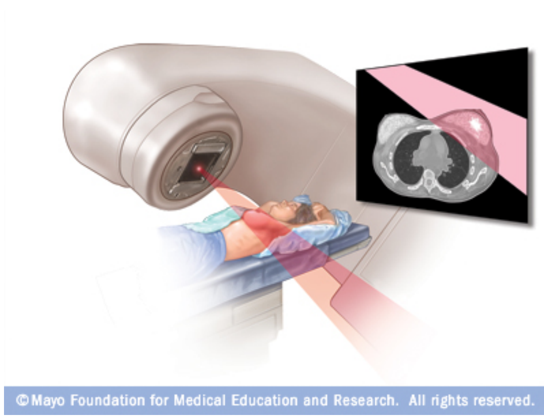
Introduction

- Radiotherapy in Breast Cancer Treatments
  i. Whole breast radiotherapy (external beam): photon for whole breast, electron or photon for boost volume

  ii. Partial breast radiotherapy (brachytherapy): interstitial or intracavity (APBI: Mammosite®, SAVI™)

  iii. Chestwall



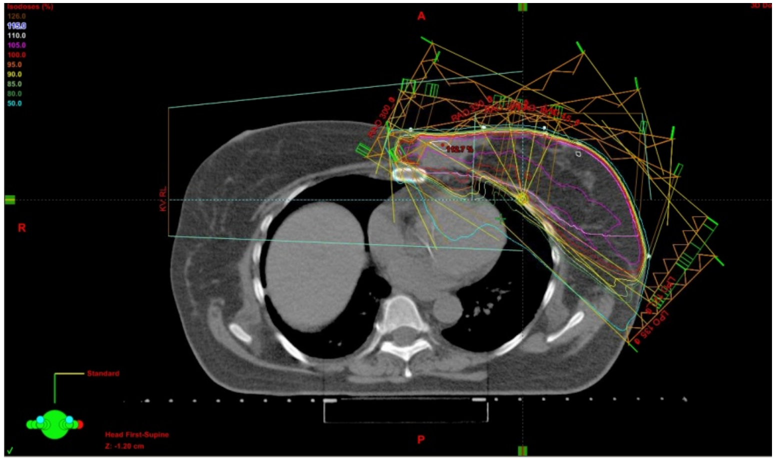
IMRT vs. Field-in-Field

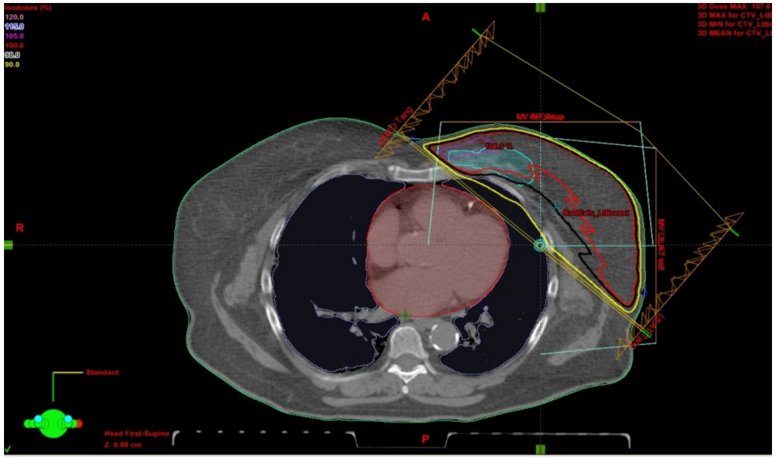
- Intensity Modulated Radiotherapy (IMRT)

1. IMRT is widely promoted as a treatment that minimizes the radiation to surrounding critical structures because of its customizing features (inverse planning).
2. IMRT utilizes numerous small radiation beams or beamlets with different weight to deliver non-uniform dose fluence to target volume

- Field-in-field Radiotherapy

1. Field-in-field normally includes at least four tangential external beams of radiation, two primary fields in opposite direction are delivered to cover the whole breast.
2. Two or more boost fields inside each primary field are given to generate more uniform dose to the tumor.



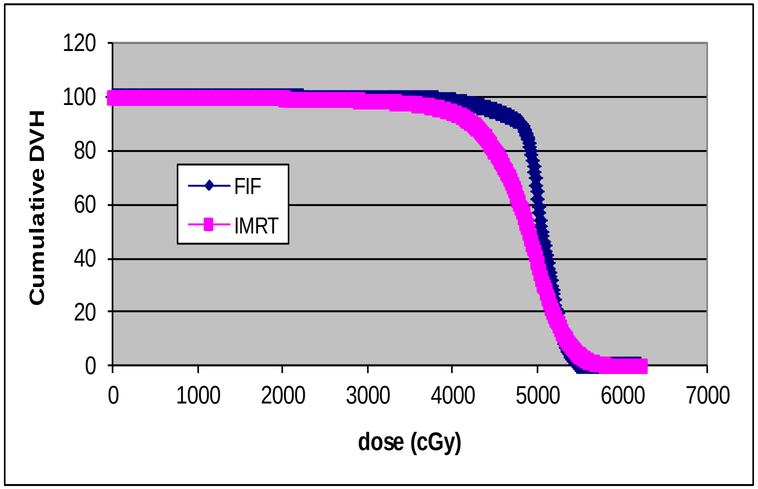


Equivalent Uniform Dose

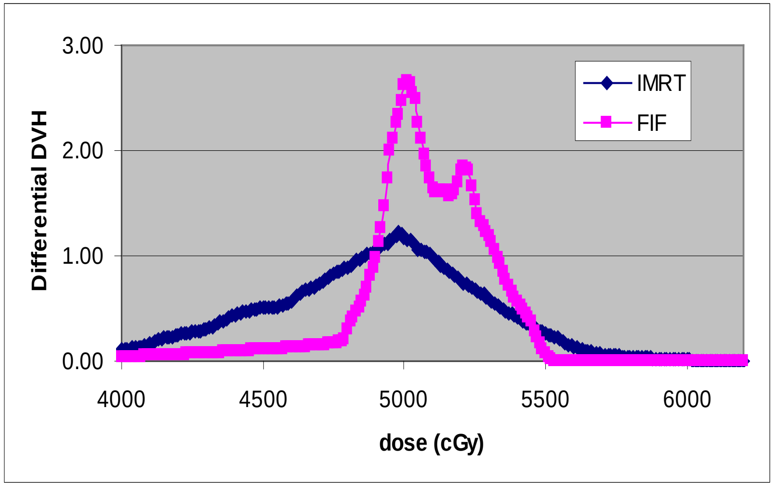
- Traditionally, radiation damage was evaluated by setting a calculation point inside organs at risk (OARs).
- Dose of calculation point can't give comprehensive evaluation of damage to the whole structure.
- EUD is defined as the absorbed dose that, when homogeneously given to a tumor, yields the same mean surviving clonogen numbers as the given non-homogeneous irradiation.
- EUD is a concept based on the cell survival calculation of the whole structure, to evaluate damage from radiotherapies.
- Study Objective: to compare normal tissue complications between IMRT and Field-in-field techniques in whole breast radiotherapy. Average suvivial fraction (SF) and EUD for normal tissue cells were calculated and evaluated.

Material and Methods

- Patients: 16 patients treated with IMRT plan and 20 patients treated with Field-in-field plan
- Tumor volumes along with OARs were contoured by radiation oncologist, treatment plans were generated using Eclipse treatment planning system by dosimetrist following clinical radiotherapy treatment guidelines.
- Eclipse calculated the dosage delivery of tumor volume and OARs. Dose spectrum of different structures can be exported from Dose Volume Histogram (DVH).



Cumulative DVH



Differential DVH

EUD Calculation

- Using linear quadratic model, SF of normal tissue cells after N fractions of treatments can be calculated by:

$$SF = e^{-\alpha \cdot D - \beta \cdot D^2 / N}$$

- α and β are radiobiological parameters that represent the radiobiological response of concerned cells to radiation. Three different normal tissue represents 30%, 50% and 70% SF for a 200 cGy open field were used.

Tissue Type	Alpha Value	Beta Value
Radiosensitive Normal Tissue (30% SF)	0.366	0.118
Moderately radiosensitive Normal Tissue (50% SF)	0.211	0.068
Radio-resistant Normal Tissue (70% SF)	0.108	0.035

- Average SF thoughout the whole OAR

$$\overline{SF} = \frac{\sum f_i \cdot SF_i}{\sum f_i}$$

- EUDs for three types of normal tissue of each OAR were calculated from average SF

$$\overline{SF} = e^{-\alpha \cdot EUD - \beta \cdot EUD^2 / N}$$

Plan Quality

- Play quality were compared by calculating the conformity (CI) and homogeneity index (HI).

- Conformity Index:

$$CI = \frac{{PTV_{PIV}}^2}{PTV \times PIV}$$

- PTV_{PIV} is the PTV encompassed within the PIV, which is the volume covered by the prescription isodose surface.

- Homogeneity Index:

$$HI = \frac{D_5}{D_{95}}$$

- D_5 and D_{95} are the minimum doses received by 5% and 95% of the PTV, HI is a indication of dose uniformity within the PTV.

Results

- Prescription Dose:
  IMRT: 34.2 Gy-59.92 Gy (Avg. 49.4 Gy); Field in Field: 34.58 Gy-50.4 Gy (Avg. 45.2Gy)

Lung (treated side)	**IMRT**		**FinF**	
	Abs Dose	**Relative Dose**	Abs Dose	**Relative Dose**
EUD1(sensitive)	7.53Gy	**15.6%**	2.75Gy	**6.0%**
EUD2(moderate)	8.89Gy	**18.4%**	3.48Gy	**7.5%**
EUD3(resistant)	10.55Gy	**21.8%**	4.76Gy	**10.3%**

Lung (Contralateral)	**IMRT**		**FinF**	
	Abs Dose	**Relative Dose**	Abs Dose	**Relative Dose**
EUD1(sensitive)	2.17Gy	**4.4%**	0.51Gy	**1.0%**
EUD2(moderate)	2.33Gy	**4.7%**	0.59Gy	**1.2%**
EUD3(resistant)	2.45Gy	**5.0%**	0.70Gy	**1.4%**

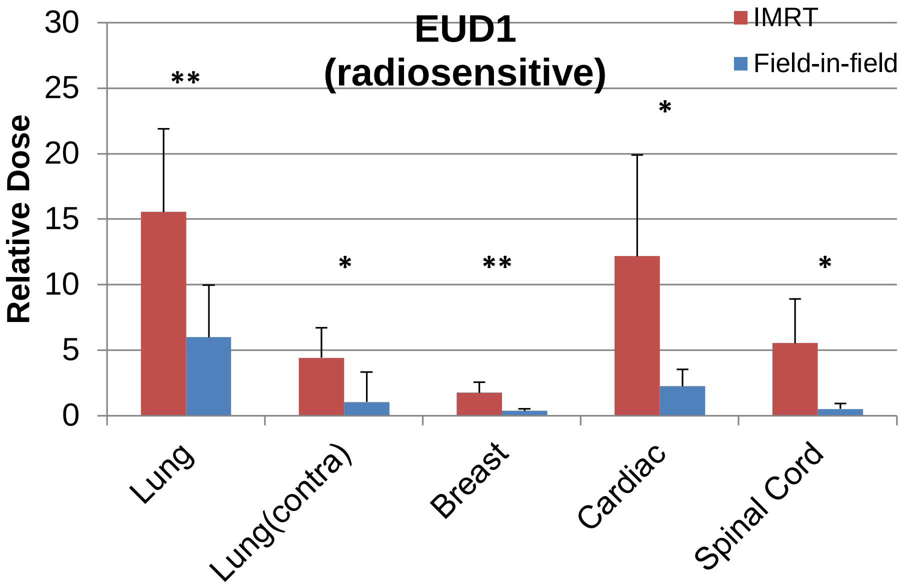
Breast (contralateral)	**IMRT**		**FinF**	
	Abs Dose	**Relative Dose**	Abs Dose	**Relative Dose**
EUD1(sensitive)	0.85Gy	**1.7%**	0.17Gy	**0.4%**
EUD2(moderate)	0.94Gy	**1.9%**	0.18Gy	**0.4%**
EUD3(resistant)	1.03Gy	**2.1%**	0.18Gy	**0.4%**

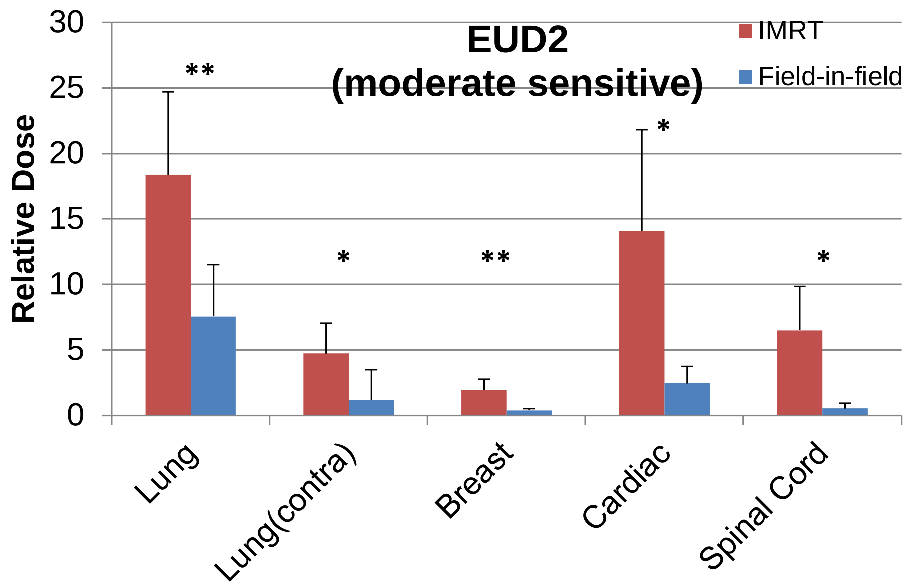
Cardiac	**IMRT**		**FinF**	
	Abs Dose	**Relative Dose**	Abs Dose	**Relative Dose**
EUD1(sensitive)	5.74Gy	**12.2%**	1.00Gy	**2.2%**
EUD2(moderate)	6.63Gy	**14.1%**	1.09Gy	**2.4%**
EUD3(resistant)	7.66Gy	**16.2%**	1.19Gy	**2.7%**

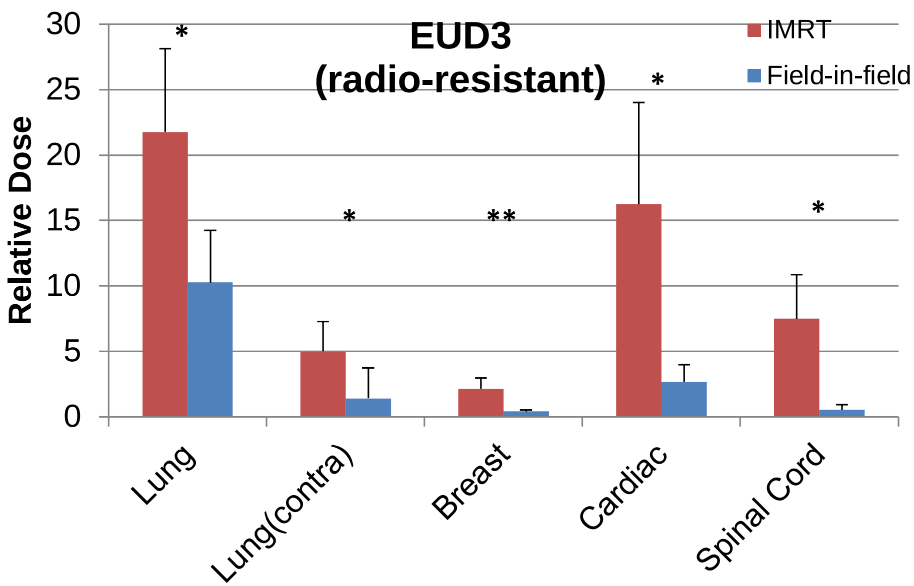
Spinal Cord	**IMRT**		**FinF**	
	Abs Dose	**Relative Dose**	Abs Dose	**Relative Dose**
EUD1(sensitive)	2.80Gy	**5.5%**	0.24Gy	**0.5%**
EUD2(moderate)	3.29Gy	**6.5%**	0.25Gy	**0.5%**
EUD3(resistant)	3.79Gy	**7.5%**	0.25Gy	**0.5%**

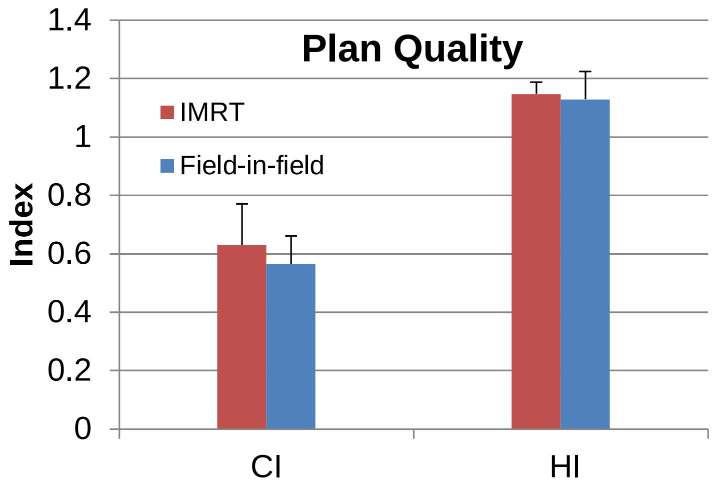
Plan Quality	**Mean ± STD**		**P-value**
	IMRT	**FinF**	
Conformity Index (CI)	**0.630 ± 0.141**	**0.565 ± 0.096**	0.167
Homogeneity Index (HI)	**1.147 ± 0.041**	**1.129 ± 0.096**	0.460

Results









** means P-value < 0.0001
* means P-value < 0.01

Summary

- EUDs of the lungs, heart, contralateral breast and spinal cord with both IMRT and FIF plans were calculated.
- The patients treated with IMRT plans were delivered higher normal tissue EUDs than those treated with FIF plans.
- For lung of treated side, IMRT delivered 15.6%, 18.4% and 21.8% of prescription dose to radiosensitive, moderately sensitive and resistant normal tissue, while FIF delivered 6.0%, 7.5% and 10.3% of prescription.
- For cardiac, IMRT vs. FIF: 12.2%, 14.1% and 16.2% vs. 2.2%, 2.4% and 2.7% for three kinds of tissue, respectively.
- IMRT plans have better average CI while worse average HI than FIF plans. But no significant differences are found.
- The results indicated that FIF had more effective normal tissue dose reduction while maintain the plan quality in whole breast radiotherapy.
- If the damage to critical organs is concerned, a simpler and more organ avoidant field-in-field technique should be considered.


THANK YOU