Intensity Modulated Radiation Therapy in Breast Cancer

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IMRT in Breast Cancer

Introduction

Problems with Conventional RT

- Scope and Steps of IMRT in ca breast
- Advantages of IMRT in ca breast

Conclusions

Off course thank u slide !

Adjuvant RT in Breast Cancer Rationale Following Mastectomy

Meta-analysis of 18 Randomized Trials In high-risk breast ca pts Adjuvant RT improves survival by 8–10% (p=0.004)

Whelan TJ, JCO 2000

Adjuvant RT in Breast Cancer Breast Conserving Surgery

In high-risk patients, rate of local relapse reduced from 35% to 10%. *NSABP-06 Study, Fisher B, NEJM 1995*

In early stage patients, rate of local relapse reduced from 24% to 8.5% in BCS

Liljegren G, JCO 1999

Conventional RT in Breast Cancer Components

- Tumour Volume
 - Whole Breast or Chestwall
 - Supraclavicular fossa (if >4 axillary LN+)
 - Axilla (if PNE+ or incomplete dissection)
 - IMC (not routinely)
- RT Fields
 - Whole Breast or Chestwall Tangential Pair
 - Supraclavicular fossa + Axilla Anterior Field + Post Boost
- Dose
 - Whole Breast or Chestwall 45-50 Gy + Boost 10-15 Gy
 - Supraclavicular fossa + Axilla 45-50 Gy

IMRT in Ca Breast ...*Rationale*

 Adjuvant RT in breast cancer improves local control following mastectomy and BCS

Breast RT in Early stage Breast Cancer is increasing as most pts are opting BCS

 Conventional RT carries significant acute and chronic toxicities

 IMRT has some advantages over conventional RT in Breast Cancer.

Conventional Adjuvant RT in Breast Ca



Acute Effects

Radiation dermatitis
Radiation esophagitis
Radiation pneumonitis

Adjuvant RT in Breast Cancer Late Effect – Ischemic Heart Disease

Lt Ant Descending Coronary artery lies in or very near to target volume

 Irradiation of LADCA leads to endothelial damage & subsequent enhanced atherosclerosis

 Ortho-voltage radiation, large fraction sizes has lead to significant cardiac toxicity in the past

Adjuvant RT in Breast Cancer Late Effect – Ischaemic Heart Disease

Conventional RT following mastectomy has been associated with an increased risk of late cardiac death, 10–15 yrs following treatment

Fatal MI in left-sided breast ca was increased by 17% compared with right sided

SEER Database, Paszat LF, JCO 1998

Adjuvant RT in Breast Cancer Late Effect – Ischaemic Heart Disease

With modern technique also a small portion of myocardium recieves 50-95% of the total dose

 Myocardial perfusion scintigraphy study has shown hypoperfusion of irradiated myocardium (with modern techniques)

Gyenes G, IJROBP 1996

Adjuvant RT in Breast Cancer Late Effect – Lymphoedema

Either surgery or RT alone is associated with only a low incidence of arm edema

Combination of axillary RT with axillary dissection increases the risk of arm edema from 2–10% to 13–18%

Meek AG , Cancer 1998

Adjuvant RT in Breast Cancer Late Effect – Brachial Plexopathy

Rare but serious complication in past as a result of match line overdosing to breast tangential fields

Johansson S , IJROBP 2001

Can be avoided by

- incorporation of a gap between beams
- half beam blocking
- couch tilt and
- isocentric techniques

Adjuvant RT in Breast Cancer Late Effect – Poor Cosmesis

Significant factors that affect cosmesis

- Large Breast size
- inferior tumor location
- large excision volume
- presence of post-operative complications
- Dose in-homogeneity within the breast
- use of a tumor bed boost.

EORTC study, Vreiling C, Radioth Oncol 2000

Adjuvant RT in Breast Cancer Late Effect – Poor Cosmesis

Cosmesis is affected by

 Fibrosis of breast tissue
 Skin changes

Scope of IMRT in Whole Breast RT

- Reducing dose inhomogeneity across the treatment volume
- Increasing Conformity of the dose
- Internal mammary node irradiation
- Simultaneous Integrated Boost to tumor cavity
- Possibly reduce morbidity

What is IMRT ?



Intensity Modulated Radio Therapy

Conformal Radiation Therapy with <u>Non-uniform intensity distributions</u> generated via <u>Inverse planning</u> by a computer optimization process.

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"Intensity of Radiation is modulated"

3D-Conformal Radiation Therapy



3D-CRT

- Radiation intensity is uniform within each beam
- Modulation conferred only by wedges.

How does I M R T works



Each field is subdivided into numerous "beamlets"

whose intensities are individually modulated

to achieve a <u>nonuniform</u> <u>dose contribution</u> from each field.

How to modulate RT fields?



Beamlet modulation is accomplished by

- <u>actively moving multiple leaves</u> during radiation
- achieving the <u>desired dose distribution throughout</u>

How does I M R T work



- 10 x 10 cm port is divided into 1 cm² beamlets
- There are now 10⁺² beams in the port
- Each can have an intensity weight of 0 – 100%
- Then we have 10^{+200} possibilities
- If we use 5 ports we have 10⁺¹⁰⁰⁰ possibilities

Inverse Planning



- We need to optimize Beam location, energy, modality
- High speed computer tests all the possibilities of a human decision for a best possible solution
- The mathematical process of defining a solution is known as "Inverse planning"

Computer Optimization



Inverse Planning:

The user specifies the goals, the computer then adjusts the beam parameters to achieve the desired outcome.

Forward Planning:

The beam geometry i.e beam angle, shape, modifier, weights etc. is first defined, followed by calculation of the 3D dose distribution.

IMRT

Primary advantage of this technology

- Treating target volumes adjacent to critical or sensitive normal tissues
- Delivery of therapeutic radiation doses to target
- Minimizing normal tissue toxicity.

IMRT Delivery techniques...

I M R T delivery techniques



1. Slit MLC:

- Narrow rectangular slit MLC
- Rotates in an arc around the patient
- Treats a target vol with multiple thin slices.



- 2. Tomotherapy:
- Actively modulated narrow slit beams as the gantry and MLC rotate and also pt moves through gantry ring on a couch.

I M R T delivery techniques Standard MLC :



Beams can be delivered via multiple fixed gantry positions with a standard MLC

- 3. 'Step and shoot'
 - Delivers Sequential subfields with
 - Individualized intensity distributions from each gantry position
 - Radiation beam off between subfields.

4. Dynamic mode

• MLCs move while radiation beam is on

IMRT delivery techniques



- Intensity modulated Arc therapy (IMAT) combining rotational arcs with dynamic multileaf collimation.
- Fully dynamic systems MLC, gantry, and treatment couch all move independently at some point during beam delivery



IMRT / IGRT

Tomotherapy



Steps of IMRT in Whole Breast RT Immobilization



Breast Board (Inclined or Flat)

Position arms above head

Confirm patient position (Straight) on fluoroscopy



Steps of IMRT in Breast Initial Simulation





Place radio-opaque wire around breast to define clinical borders

Thermoplastic mask

Marks made anterior and each side on chest

Steps of IMRT in Whole Breast RT Planning CT Scan



Superiorly from the chin to inferiorly 5 cm below breast

Acquire 5 mm cuts

Steps of IMRT in Whole Breast RT Target Volume Definition



Define Lumpectomy Cavity

Steps of IMRT in Whole Breast RT Target Volume Definition

Inter-physician variation in PTV delineation after BCS is high

No clear definition in the literature about a clinically acceptable variability in breast delineation using CT image Steps of IMRT in Whole Breast RT Target Volume Definition – PTV William Beaumont definition in NSABP B-39 trial



PTV is defined as

- the tissue within the conventional tangential fields
- excluding lung, heart and liver
- minus a 5 mm margin from the beam edges and skin surface

Steps of IMRT in Whole Breast RT Target Volume Definition



 The superior, inferior, and medial-lateral borders of PTV are according to the conventional tangent beams.
Steps of IMRT in Whole Breast RT Organs at Risk (OAR) Definition



Skin surface

Lungs

Heart

All myocardium from apex to the infundibulum of the right ventricle, the right atrium, and auricle

Steps of IMRT in Whole Breast RT Treatment Planning – 1st Step Conventional



- Two tangential beams are chosen with appropriate angle to align the radio-opaque markers
- Posterior border of the lateral and medial fields are coplanar, so as to prevent extra dose to the lung due to the divergence of the beams.

Steps of IMRT in Whole Breast RT Treatment Planning – 1st Step Conventional



Beam depth, gantry angle, and collimator angle are adjusted at the computer work station as need to avoid unnecessary normal tissue irradiation (e.g., heart, lung, contra lateral breast) and to ensure full coverage of the breast and lumpectomy cavity with a "sufficient" margin.

Steps of IMRT in Whole Breast RT Treatment Planning – 1st Step Conventional



Field size and isocenter are adjusted

- to cover PTV in the all directions with 0.5 cm margin
- to allow at least 2 cm flash beyond the skin surface anteriorly
- 1.5 cm 2 cm depth into lung

Steps of IMRT in Whole Breast RT Organs at Risk (OAR) Definition



Contour the tangential beam edge to create a "Dummy ROI"

Steps of IMRT in Whole Breast RT Regions of Interest are defined

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Steps of IMRT in Whole Breast RT Treatment Planning Methods

- Inverse Planning
- Forawrd planning
- BEV Contouring
- Plane Compensation
- Minimization of Dose Variation; Equalization of Maximum Dose



The beam parameters for the intensity modulated tangential fields were the same as those used for the conventional field plan.

Dose distribution is calculated for equally weighted, open tangential fields (i.e., no blocks, no wedges)



Use the beam's eye view of the projected isodoses for the tangential fields to create multiple static fields to shield the area of higher dose (hot spot)



- The MLCs are moved manually to cover the hot spots
- The MLC field is used to deliver approximately 6-10% of the total dose

 Beam weighting is adjusted until the most homogenous dose distribution is achieved





Forward IMRT planning



b) Medial IMRT Segments



- The gantry angles for the intensity-modulated tangential fields were the same as those used for the conventional technique.
- Beam configuration and dose volume constraint are given to the computer.
- Computer will Optimize the dose distribution
- A separate sequencer (leaf motion calculator) is used to convert the optimal fluencies profiles to suitable sliding windows MLC movement

- The gantry angles for the intensity-modulated tangential fields were the same as those used for the conventional technique.
- Beam configuration and dose volume constraint are given to the computer.
- Computer will Optimize the dose distribution

Steps of IMRT in Whole Breast RT Plan Evaluation - PTV

- Prescription dose 45- 50 Gy in 25-28 fr over 5 weeks.
- Prescribed at the isodose line which encompasses at least 95% of the PTV
- < 5% of PTV should receive > 105% of prescribed dose
- < 1% of PTV should receive < 95% of its prescribed dose</p>
- < 1% or 1 cc of the tissue outside the PTV should receive > 110% of the prescribed dose

Steps of IMRT in Whole Breast RT Plan Evaluation - Critical organs

Heart V30Gy < 3% (Heart volume receiving 30Gy should be <3%)</p>

- Ipsilateral lung V20Gy < 10% (Ipsilateral lung volume receiving 20Gy should be <10%)
- Contralateral lung V20Gy < 5% (Contralateral lung volume receiving 20Gy should be <5%)
- Contralateral breast V2Gy < 50% (Contralateral Breast volume receiving 2Gy should be <50%)

Advantages of IMRT ... Reducing dose inhomogeneity



Conventional RT

Medial and lateral aspects of the breast may be exposed to higher doses of radiation due to lower attenuation of which is always included in the treatment volume

Advantages of IMRTReducing dose inhomogeneity

Wedges



Conventional RT

Superior and inferior part of breast shows 15-20% dose in-homogenity due to continuous change in shape of the breast in multiple planes

IMRT in Whole Breast RT Advantage - Reducing dose inhomogeneity



Fig. 4. Axial images at central axis and at the inframanmary fold for the same patient, comparing standard wedges versus IMRT. The use of IMRT resulted in smaller "hot spots," while maintaining similar coverage of the target volume. Dark blue = 90-94%, light blue = 95-99%, lavender = 100-104%, red = 105-109%, yellow = 110-114%, white = 115-119%



Fig. 4. Examples of sagittal dose distribution for (a) standard wedged plan and (b) IMRT plan. Data are from the in-house program for one patient. Colour scale: dark blue = 90%, mid blue = 95%, light blue = 98%, mid green = 100%, light green = 102%, yellow = 105%, orange = 110%, red = 112%.



Scope of IMRT in Whole Breast RT Advantage - Reducing dose inhomogeneity

300 patients data

Application of IMRT to the tangential field reduces high dose regions in both volume and dose level

 IMRT reduced the volume receiving a dose greater than 105% by a mean of 10.7% (p= <0.001)

Donovan EM, Br J Rad 2002

Scope of IMRT in Whole Breast RT Advantage - Reducing dose inhomogeneity

110 patients

- The use of IMRT technique for breast is an efficient and effective method for achieving uniform dose throughout the breast.
- It is dosimetrically superior to the treatment techniques that employ only wedges.

Kestin LL, IJROBOP 2000

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ELSEVIER	doi:10.1016/j.ijrobp.2007.06.060
PHYSICS CONTRIBUTIO	Ν
IS MULTIB P	EAM IMRT BETTER THAN STANDARD TREATMENT FOR ATIENTS WITH LEFT-SIDED BREAST CANCER?
WAYNE A. BECKHA	am, Ph.D.,* [†] Carmen C. Popescu, M.S.,* Veronica V. Patenaude, B.Sc.,* Elaine S. Wai, M.D.,* [‡] and Ivo A. Olivotto, M.D. ^{*‡}
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Conclusions: IMRT signi the CTV. Heart and lung	ificantly improved conformity and homogeneity for plans when the breast + IMNs were in t volume receiving high doses were decreased, but more healthy tissue received low doses.
A simple algorithm base	d on amount of heart included in the standard plan showed limited ability to predict the
benefit from IMRT.	2007 Elsevier Inc.







Why IMRT Outcomes are Superior? Superior Dosimetry

 Larger V105 volumes correlated with higher rates of Inferior cosmetic outcome and Development of induration within the treated breast

- Two V105 thresholds were predictive of inferior outcome:
 - V105 > 1% of PTV
 - A hot spot (i.e. one area) exceeding 105% of Rx

Donovan et al, Radiother Oncol, 2007

IMRT : Simultaneous Boost Lumpectomy site



Proven Benefits IMRT in Breast RT Decrease in moist desquamation

IMRT significantly decreased the risk of developing moist desquamation during RT (from 48% to 31%; p = 0.002).

Pignol et al, JCO, 2008

Proven Benefits of IMRT in ca breast Preserved Cosmesis

IMRT significantly demonstrates no change in appearance 5 years after RT (from 42% to 60%; p = 0.008).

IMRT significantly decreased the likelihood that the irradiated breast developed palpable induration 5 years after RT (from 61% to 37%; p < 0.001).

Donovan et al, Radiother Oncol, 2007

Does IMRT spare Heart?



Fig. 1. Beam arrangement for four-field IMRT technique.

- With tangent fields IMRT, you cannot spare the heart
- You can't use nontangential fields because of an increase in scattered dose to lung and contralateral Breast

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Multible beam technique...

INVERSE-PLANNED, DYNAMIC, MULTI-BEAM, INTENSITY-MODULATED RADIATION THERAPY (IMRT): A PROMISING TECHNIQUE WHEN TARGET VOLUME IS THE LEFT BREAST AND INTERNAL MAMMARY LYMPH NODES

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Abstract—The purpose of this study was to determine the optimum beam number and orientation for inverseplanned, dynamic intensity-modulated radiation therapy (IMRT) for treatment of left-sided breast cancer and internal mammary nodes (IMNs) to improve target coverage while reducing cardiac and ipsilateral lung irradiation. Computed tomography (CT) data was used from 5 patients with left-sided breast cancer in whom the heart was close to the chest wall. The planning target volume (PTV) was the full breast plus ipsilateral IMNs. Two geometric beam arrangements were investigated, 240° and 190° sector angles, and the number of beams was increased from 7 to 9 to 11. Dose comparison metrics included: PTV homogeneity and conformity indices (HI, CI), heart V30. left lung V20, and mean doses to surrounding structures. To assess clinical application, the IMRT plans with 1 beams equally spaced in a 190° sector angle ere compared to conventional plans. Treatment times were modeled. The 190 IMRT plans improved PTV HI and CI and reduced mean dose to the heart, lungs, contralateral breast, and total healthy tissue (all p < 0.05) compared to a 240° sector angle. The 11-beam plan significantly improved PTV HI and CI, heart V30, left lung V20, and healthy tissue V5 compared to a 7-beam plan (all p < 0.05). The 11-beam plan reduced heart V30 and left lung V20 (p < 0.05) without compromising PTV coverage, compared to a 9-beam plan. Compared to a conventional plan, the IMRT class solution significantly improved PTV HI and CI (both p < 0.01), heart V30 (p = 0.01), and marginally reduced left lung V20 (p = 0.07) but increased contralateral breast and lung mean dose (p < 0.001) and healthy tissue V5 (p < 0.001). An 11-beam 190° sector angle IMRT technique as a class solution is clinically feasible. Crown Copyright © 2006 Published by Elsevier Inc. on behalf of American Association of Medical Dosimetrists.



technique" showing the 11 beams equally spaced in a 190° Fig. 4. A typical isodose distribution for the "Victoria IMRT sector angle around the left breast.

What are the ideal beams for IMRT? Tangentials

Tangential Beams with co-planar deep border are ideal due to less scatters dose to opposite breast

Using multiple (4 or 6) non-coplanar beams increases scatter dose, esp. to the opposite breast and ipsilateral lung.

Landau, Radiother Oncol, 2007

What are the ideal beams for IMRT? Tangentials

Dose homogeneity within the breast was improved with the two- and four-field IMRT techniques.

The four-field tangential arrangement was found to be the best of the IMRT techniques considered here in terms of cardiac avoidance and gave improved sparing
How to spare the heart ? Deep Breath Hold Technique

Patient is treated while holding breath

Inspiration increases the separation between the heart and the left breast/chest wall

Allows tangents to be used (which minimizes scattered dose)

Requires special monitoring

IMRT in Breast Radiation Conclusions

- Whole breast IMRT achieves
 - more uniform dose distribution compared to conventional methods
- Other advantages:
 - IMC RT & Simultaneous boost
 - Less moist desquamation, less fibrosis
 - Better cosmesis
- Tangential Beam arrangement is the standard for Whole Breast IMRT
- Breath holding technique can be employed for tangential beams intending to spare heart

Thank You!

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