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# THE INTENSITY MODULATED RADIOTHERAPY OF BREAST CANCER – A COMPARISON OF fIMRT AND iIMRT TECHNIQUES

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**Summary**

The intensity modulated radiotherapy (IMRT) of breast cancer is a newer irradiation technique used at the University Hospital for Tumors (University Hospital Center Sestre Milosrdnice, Zagreb, Croatia).Two IMRT radiotherapy techniques was used to treat patient with breast cancer. Forward intensity modulated radiotherapy (fIMRT) is a planning technique in which dose distribution, accomplished by main beams, is improved by additional conformed beams. Inverse intensity modulated radiotherapy (iIMRT) is a planning technique in which the terms of irradiation are set to the computer, and planning system is making the optimal intense modulated plan. We showed that it was possible to compare fIMRT and iIMRT results. Because of the treatment plan simplicity, shorter irradiation time and better dose control, fIMRT remains a method of choice at the University Hospital for Tumors.

KEY WORDS: *IMRT, breast cancer*

**INTENZITENO MODULIRANA RADIOTERAPIJA RAKA DOJKE – USPOREDBA fIMRT I iMRT TEHNIKA**

**Sažetak**

Intenzitetno modulirana radioterapija (IMRT) karcinoma dojke novija je tehnika zračenja koja se koristi u Klinici za tumore (Klinički bolnički centar Sestre milosrdnice, Zagreb, Hrvatska). U liječenju bolesnica s karcinomom dojke uspoređene su dvije tehnike: *Forward intensity modulated radiotherapy* (fIMRT) u kojoj se raspodjela doze postiže glavnim snopovima, a poboljšava dodatnim konformalno formiranim snopovima, te *Inverse intensity modulated radiotherapy* (iIMRT) u kojoj se željeni uvjeti radioterapije unose u kompjuter, a kompjuterski sustav planiranja stvara optimalni radioterapijski plan, koristeći veliki broj manjih snopova (segmenata). Pokazali smo da su rezultati primjene ovih tehnika usporedivi. Zbog jednostavnosti izrade plana, kraćeg vremena radioterapije i bolje kontrole doze, fIMRT ostaje metod aizbora u Klinici za tumore.

KLJUČNE RIJEČI: *IMRT, karcinom dojke*

## INTRODUCTION

Radiotherapy of breast cancer is still a clinical challenge. In order to avoid possible acute and chronic side effects, chosen radiotherapy technique has to ensure homogenicirradiation dose distribution in volume of interest, together with maximal protection of organs of risk (1-3). Radiotherapy of breast cancer can be performed by several different techniques and the main goal in clinical practice, except criteria mentioned above, is to be simple, applicable in most clinical centers, and finally feasible in a relatively short period of time (4-12). Intensity modulated radiotherapy (IMRT) of breast cancer is a relatively new method, and one therapy mode of IMRT technique is used at the University Hospital for Tumors, (University Hospital Center SestreMilosrdnice) (13-19).

The aim of the study was to compare the two different IMRT radiotherapy techniques currently most frequently used to treat patients with breast cancer.

## MATERIAL AND METHODS

Clinical target volume (CTV) and patient's organs of risk (OAR) – lung and heart, were marked on CT slices, during the planning of adjuvant radiotherapy in patient after the breast conservative surgery. Planning Target Volume (PTV) is defined as a volume around CTV with a margin of 1 cm (2,3).CMS XIO 4.3.1.radiotherapy planning system and Siemens Oncormultileaf (Optifocus 82) linear accelerator were used (Figures 1 and 2).

Two methods of IMRT have been used to make two different radiotherapy plans: Forward intensity modulated radiotherapy (fIMRT) and Inverse intensity modulated radiotherapy (iIMRT) (13).

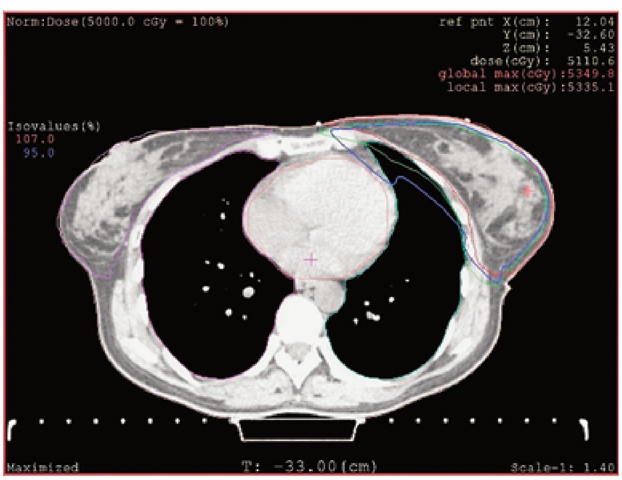



*Figure 1. CT sagittal slice from XiO Treatment Planning System*

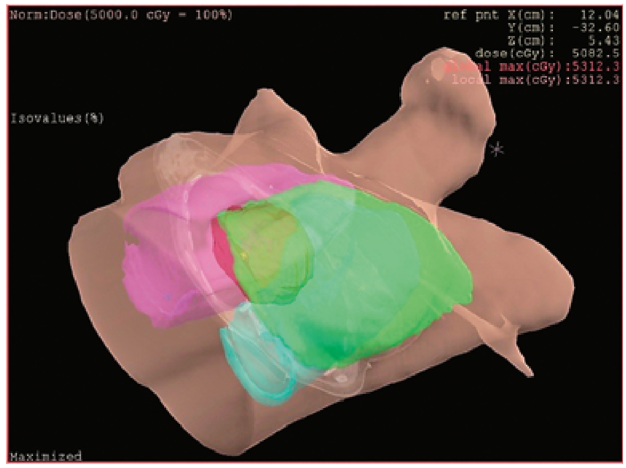



*Figure 2. PTV and OAR reconstruction from XiO Treatment Planning System*

**Forward intensity modulated radiotherapy (fIMRT)** is a method where two basic tangential beams are used with the addition of smaller, manually conformed beams, They are used for homogenization of the dose distribution and fulfilling the given condition terms (Figure 3). Basic conformal beams are divided into two parts (R1, R2 90%, R1a, R2 10%). After primary calculations, by moving leafs R1a and R2, hot spots can be removed. By changing beams R1 and R2 the doses on PTV and on OAR can be regulated.

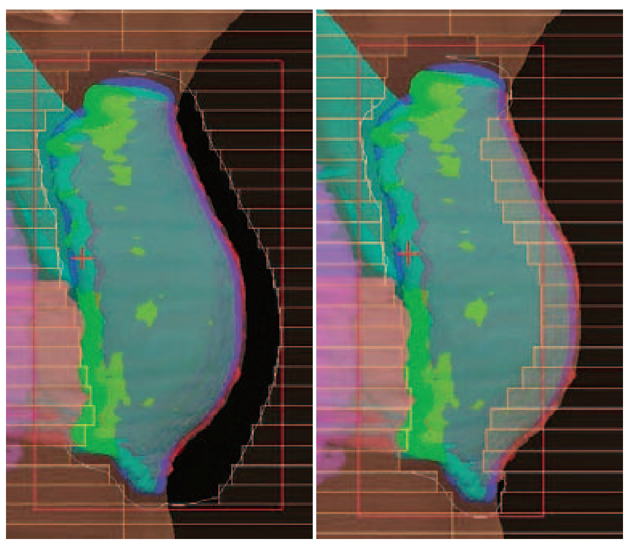
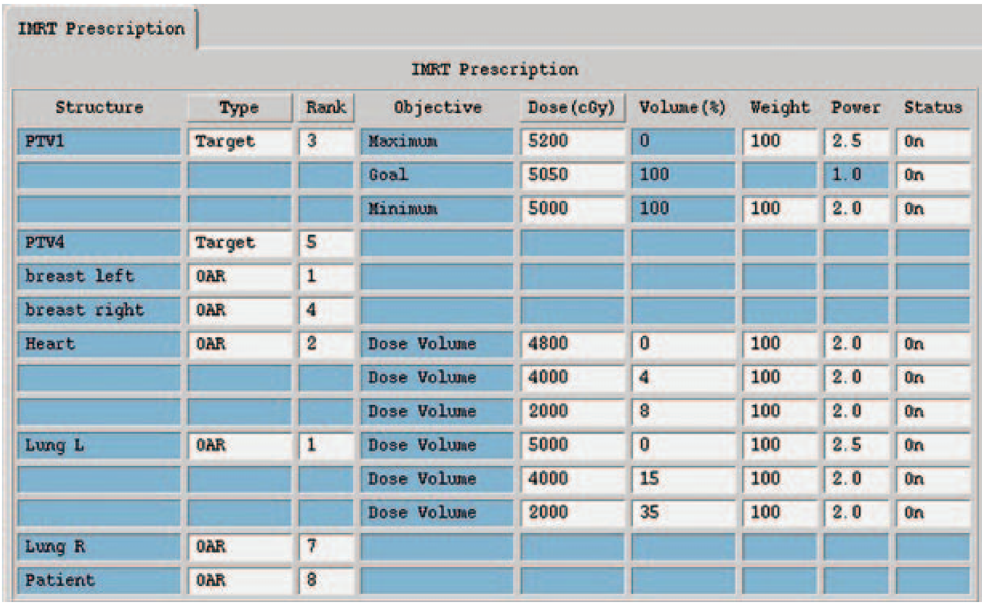


*Figure 3. Basic tangential beam (left) and conformed beam (right)*

**Inverse intensity modulated radiotherapy (iIMRT)** is a method in which the number, direc-



IMRT Prescription

IMRT Prescription

| Structure | Type | Rank | Objective | Dose(cGy) | Volume(%) | Weight | Power | Status |
|---|---|---|---|---|---|---|---|---|
| PTV1 | Target | 3 | Maximum | 5200 | 0 | 100 | 2.5 | On |
| | | | Goal | 5050 | 100 | | 1.0 | On |
| | | | Minimum | 5000 | 100 | 100 | 2.0 | On |
| PTV4 | Target | 5 | | | | | | |
| breast left | OAR | 1 | | | | | | |
| breast right | OAR | 4 | | | | | | |
| Heart | OAR | 2 | Dose Volume | 4800 | 0 | 100 | 2.0 | On |
| | | | Dose Volume | 4000 | 4 | 100 | 2.0 | On |
| | | | Dose Volume | 2000 | 8 | 100 | 2.0 | On |
| Lung L | OAR | 1 | Dose Volume | 5000 | 0 | 100 | 2.5 | On |
| | | | Dose Volume | 4000 | 15 | 100 | 2.0 | On |
| | | | Dose Volume | 2000 | 35 | 100 | 2.0 | On |
| Lung R | OAR | 7 | | | | | | |
| Patient | OAR | 8 | | | | | | |

*Figure 4. Inverse IMRT setup*

tions and terms of irradiation beams (dose homogeneity and dose limitation to OAR) are set into the computer, and planning system is making the optimal intensity modulated plan (Figure 4).

Irradiated volume of patient was divided in elements 0.2 $cm^3$, some of them belong to the target volumes (PTV, breast), organs of risk (OARs), or both. Terms of achievable dose, and overdose in each volume is set in form of table. Conformal beam is divided in elementary beams (beamlets) cross section 1$cm^2$; every beam can have 10 levels of intensity. Seeking of minimum difference that is made ($\mathbf{x}_i$), and prescribed dose ($\mathbf{xi}_z$) in each element of volume, optimum selection of beams is acquired. Function that is minimizing has the ability that in each tissue can give different importance by multiplying**a** (values from 1 to 1000, usually 100) and exponent **n** (2 to 5). Result of optimization process is a beam that consisted of elementary beams of different intensity that can be shown as fluency map. In the next step, there is a calculation of segments which, if irradiated consecutively, are best making fluency map (Figure 5).

The analysis gave 17 segments for R1 and 6 segments for R2, entire number of 470 MU and maximums bigger from allowed ones (55.40 instead of 53.50). This was fixed by manually deleting smaller number of segments and rescaling.

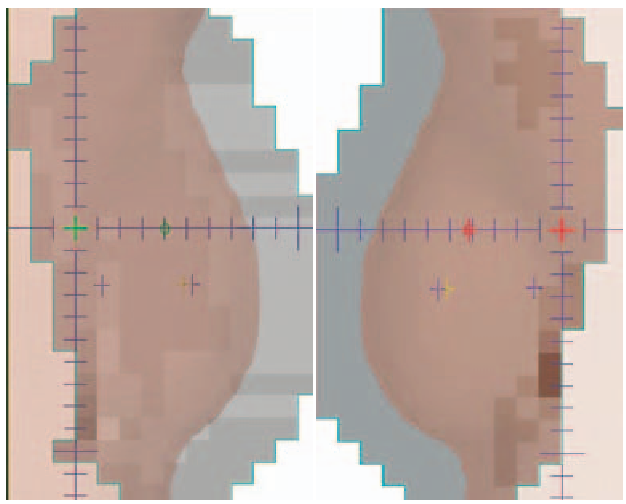


*Figure 5. Breast fluency map*

For remaining segments (R1/11, R2/11) it takes altogether 298MU, and maximal absorbed dose ($\mathbf{D}_{max}$) was in allowed limits. Inverse IMRT required more complex planning and longer time of irradiation.

**Radiotherapy plan evaluation**

**Homogeneity index HI** *(1,2,13)*

Homogeneity index was calculated as ratio of volume of PTV which gets 95%-105% of dose and total volume of PTV:

$$HI(95\%-100\%) = \frac{V_{PTV(95\%-105\%)}}{V_{PTV}}$$

Treatment plan is better when HI is approaching 1.

**Conformity index CI** *(1,2,13)*

This is the ratio of PTV to the treated volume, and indicates how well the PTV is covered by the treatment while minimizing dose to normal tissue.

$$CI = \left(\frac{V_{PTV(95\%)}}{V_{PTV}}\right)\cdot\left(\frac{V_{PTV(95\%)}}{V_{Patient(95\%)}}\right),$$

where $V_{PTV(95\%)}$ is PTV volume which gets more than 95% of dose, $V_{PTV}$ is total volume of PTV and $V_{Patient(95\%)}$ is volume of patient that gets more than 95% of dose.

Plan is better when CI is approaching 1.

**Dose limitations (prescribed by International Commission of Radiation Units, ICRU Reports 50, 62 and 71***) (3,1,2)***:**

Dose to PTV volume should be 50Gy. Maximum dose to PTV should not exceed 107% of prescribed dose. Minimum dose to PTV should not be below 95% of prescribed dose. PTV mean dose should not exceed interval of ±1% of prescribed dose. Total irradiated heart volume should not receive more than 10% of 20Gy dose and 5% of 40Gy dose. Total irradiated lung volume should not exceed 35% of 20Gy dose.

*Table 1.*
*FORWARD IMRT AND INVERSE IMRT PLAN COMPARISON*

| Radiotherapy plans results | | | |
|---|---|---|---|
| | | f IMRT | i IMRT |
| PTV (966 cm³) | $D_{mean}$ | 50.04 Gy | 50.01 Gy |
| | $D_{max}$ | 53.12 Gy | 53.50 Gy |
| Breast (861 cm³) | $D_{mean}$ | 49.01 Gy | 48.50 Gy |
| Lung (1608 cm³) | $D_{mean}$ | 12.99 Gy | 14.54 Gy |
| | Volume > 20 Gy | 26.08% | 31.47% |
| | Volume > 40 Gy | 18.45% | 16.05% |
| Heart (411 cm³) | $D_{mean}$ | 5.43 Gy | 7.22 Gy |
| | Volume > 20 Gy | 8.67% | 9.41% |
| | Volume > 40 Gy | 3.94% | 4.38% |
| | HI | 0.936 | 0.906 |
| | CI | 0.674 | 0.763 |
| | Number of MU for 2 Gy dose | 211 MU | 298 MU |

## RESULTS

We compared values of dose volume histograms, maximum PTV doses, ipsilateral lung volume which gets dose more than 20Gy, 40Gy respectively, heart volume which gets dose more than 20Gy, 40Gy respectively, median dose for lung and the other breast, dose homogeneity index, radiation dose conformity index, and the time estimated for radiation procedure.

Forward IMRT and inverse IMRT plans comparison is shown in the Table 1. There was no significant difference for PTV's and organs at risk doses between plans. It was possible to achieve better CI with iIMRT plan, while better HI was obtained by fIMRT plan. Longer treatment time was needed for iIMRT plan. Comparison of the dose volume histograms is shown on the Figure 6.

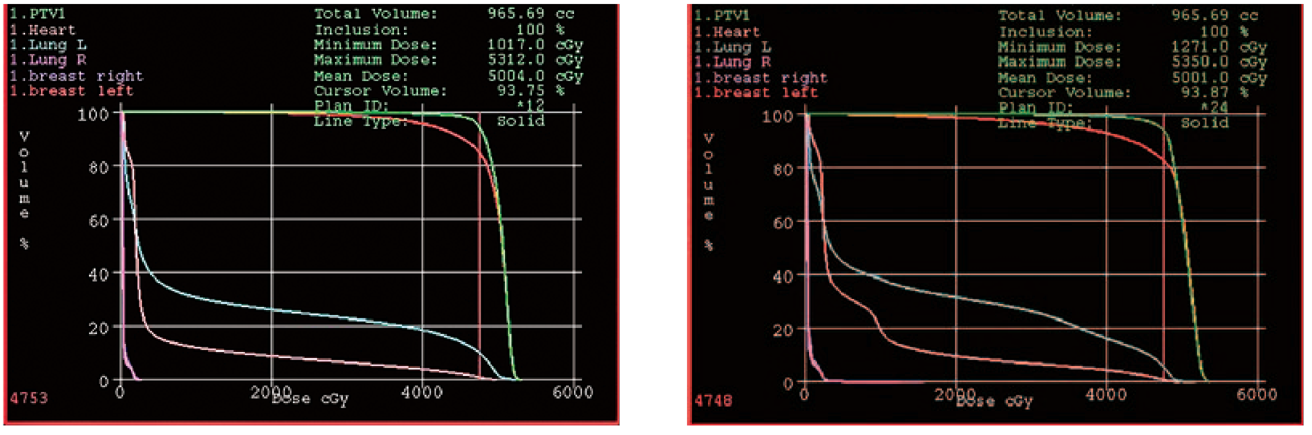


*Figure 6. Dose Volume Histograms (DVH) for forward IMRT (left) and inverse IMRT (right)*

## CONCLUSION

It was possible to compare forward IMRT and inverse IMRT results in the treatment of breast cancer patient. Forward IMRT was easier to plan, good homogeneity was achieved (HI) and it was easier to control maximal absorbed dose ($\mathbf{D}_{max}$). Inverse IMRT was more complicated for planning, bigger number of beamswere needed, irradiation time was longer, but it was possible to achieve better conformity index (CI). Because of the treatment plan simplicity, shorter irradiation time and better $\mathbf{D}_{max}$ control, forward IMRT remains a method of choice for the treatment of breast cancer patients at the University Hospital for Tumors.

REFERENCES


1. Halperin EC, Wazed DE, Perez CA, Brady LW, eds. Principles and Practice of Radiation Oncology, Sixth Edition. Lippincott Williams and Wilkins, 2013.
2. Barret A, Dobbs J, Morris S, Roques T, eds. Practical Radiotherapy Planning, Fourth Edition, Hodder Arnold Comp, 2009.
3. International Commission on Radiation Units and Measurements: Prescribing, Recording and Reporting Electron Beam Therapy. ICRU Report 71, ICRU, Bethesda, Maryland, USA, 2004.
4. Bhatnagar AK, Beriwal S, Heron DE, Flickinger JC, Deutsch M, Huq MS, et al. Initial outcomes analysis for large multicenter integrated cancer network implementation of intensity modulated radiation therapy for breast cancer. Breast J. 2009;15(5):468-74.
5. Selvaraj RN, Bhatnagar A, Beriwal S, etal. Breast skin doses from brachytherapy using MammoSite HDR, intensity modulated radiation therapy, and tangential field techniques. Technol Caner Res Treat. 2007;6(1): 17-22.
6. Selvaraj RN, Beriwal S, Pourarian RJ, etal. Clinical implementation of tangential field intensity modulated radiation therapy (IMRT) using sliding window technique and dosimetric comparison with 3D conformal therapy (3D-CRT) in breast cancer. Med Dosim. 2007; 32(4):299-304.
7. Rusthoven KE, Carter DL, Howell K, et al. Accelerated partial-breast intensity-modulated radiotherapy results in improved dose distribution when compared with three-dimensional treatment-planning techniques. Int J Radiat Oncol Biol Phys. 2008;70(1):296-302.
8. Oliver M, Chen J, Wong E, et al. A treatment planning study comparing whole breast radiotherapy against conformal, IMRT and tomotherapy for accelerated partial breast irradiation. Radiother Oncol. 2007;82(3): 317-23.
9. Leonard C, Carter D, Kerscher J, etal. Prospective trial of accelerated partial breast intensity-modulated radiotherapy. Int J Radiat Oncol Biol Phys. 2007;67(5): 1291-8.
10. Hooning MJ, Botma A, Aleman BM, et al. Long-term risk of cardiovascular disease in 10-year survivors of breast cancer. J Natl Cancer Inst. 2007;99(5):365-75.
11. Harmon M, Mihailidis, DM. TomoTherapy Versus Conventional Planning for Left-Sided Breast Cancer With Lymph Nodes—Dosimetric Comparison: In Regard to Goddu et al. Int J Radiat Oncol Biol Phys. 2009;73:1243–51.
12. Correa CR, Litt HI, Hwang WT, et al. Coronary artery findings after left-sided compared with right-sided radiation treatment for early-stage breast cancer. J Clin Oncol. 2007;25(21):3031-7.
13. Chao KSC ed., Practical Essentials of Intensity Modulated Radiation Therapy. Third Edition, Lippincott Williams and Wilkins, 2014.
14. Beckham WA, Popesscu CC, Patenaude VV, et al. Is multi-beam IMRT better than standard treatment for patients with left-sided breast cancer? Int J Radiat Onc Biol Phys. 2007;69(3):918-24.
15. Borghero YO, Salehpour M, McNeese MD, et al. Multileaf field-in-field forward planned intensity modulated dose compensation for whole-breast radiation is associated with reduced contralateral dose: a phantom model comparison. Radiother Oncol. 2007;82(3): 324-8.
16. Donovan E, Bleakley N, Denholm E, et al. Randomized trial of standard 2D radiotherapy (RT) versus intensity modulated radiotherapy (IMRT) in patients prescribed breast radiotherapy. Radiother Oncol. 2007;82(3):254-64.
17. Haffty BG, Buchholz TA, McCormick B. Should intensity-modulated radiation therapy be the standard of care in the conservatively managed breast cancer patient? J Clin Oncol. 2008;26(13):2072-4.
18. Harsolia A, Kestin L, Grills I, et al. Intensity-modulated radiotherapy results in significant decrease in clinical toxicities compared with conventional wedge-based breast radiotherapy. Int J Radiat Oncol Biol Phys. 2007;68(5):1375-80.
19. Pignol JP, Olivotto I, Rakovitch E, et al. A multicenter randomized trial of breast intensity-modulated radiation therapy to reduce acute radiation dermatitis. J Clin Oncol. 2008;26(13)2085-92.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