

## REVIEW ARTICLE

---

# Review of the three-field techniques in breast cancer radiotherapy

John Kagkiouzis<sup>1</sup>, Kalliopi Platoni<sup>1</sup>, Ioanna Kantzou<sup>2</sup>, Maria Dilvoi<sup>1</sup>, George Patatoukas<sup>1</sup>, Efrosyni Kypraiou<sup>1</sup>, Efstathios Efstathopoulos<sup>1</sup>, George Sarris<sup>2</sup>, Nikolaos Trogkanis<sup>1</sup>, Vassilis Kouloulis<sup>1</sup>

<sup>1</sup>Radiotherapy Unit, 2nd Department of Radiology, Attikon Hospital, Medical School, National and Kapodistrian University of Athens, Athens, Greece; <sup>2</sup>1st Radiotherapy Department, Metaxa Cancer Hospital, Piraeus, Greece

## Summary

Breast cancer is often treated with radiotherapy (RT), with two opposing tangential fields. When indicated, supraclavicular lymph nodes have to be irradiated, and a third anterior field is applied. The junction region has the potential to be over or underdosed. To overcome this problem, many techniques have been proposed. A literature review of 3 Dimensional Conformal RT (3D CRT) and older 3-field techniques was carried out. Intensity Modulated RT (IMRT) techniques are also briefly discussed. Techniques are categorized, few characteristic examples are presented and a comparison is attempted. Three-field techniques can be divided in monoisocentric and two-isocentric. Two-isocentric techniques can be further divided in full field and half field techniques. Monoisocentric techniques show certain great

advantages over two-isocentric techniques. However, they are not always applicable and they require extra caution as they are characterized by high dose gradient in the junction region. IMRT has been proved to give better dosimetric results. Three-field matching is a complicated procedure, with potential of over or undredosage in the junction region. Many techniques have been proposed, each with advantages and disadvantages. Among them, monoisocentric techniques, when carefully applied, are the ideal choice, provided IMRT facility is not available. Otherwise, a two-isocentric half beam technique is recommended.

**Key words:** breast cancer, field matching, junction, radiotherapy, supraclavicular

## Introduction

Breast cancer is the second most common type of cancer worldwide (after lung cancer) and the most frequent cancer in women [1,2]. It is the second cause of cancer death in women both in Europe [2] and in the US [2,3]. Several therapeutic methods for breast cancer treatment are used, namely, surgery, systemic therapy and radiation therapy. RT is used supplementarily to surgery and/or systematic therapy or as a single treatment method. The role of adjuvant RT following lumpectomy or mastectomy is well defined. When treating with photons, breast or chest wall

is treated with tangential fields. For breast irradiation two opposing tangential fields are mainly used. In many cases not only breast but regional supraclavicular lymph nodes need to be irradiated [4-6]. In these cases, an extra anterior supraclavicular field is applied. The anterior field should be precisely matched with the two tangential fields in order to avoid cold and hot spots in the matching region (junction). Due to complex geometry of breast region, this matching can be appropriately achieved in three dimensions. The number of proposed techniques in this area indicates the

difficulty in accurate three-field matching. An appropriate Quality Assurance is therefore mandatory, whichever approach is used.

## Techniques in clinical practice

It is important to individualize RT planning and delivery. Computed tomography (CT) based treatment planning is encouraged to delineate target volumes and adjacent organs at risk. Greater target dose homogeneity and sparing of normal tissues can be accomplished using compensators, such as wedges, forward planning, using segments, and IMRT. Respiratory control techniques, including deep inspiration breath-hold, and prone positioning, may be used to try to further reduce dose to adjacent normal tissues, particularly the heart and lung.

In this work a literature review of three-field breast RT techniques was carried out. Two types of works were considered: papers describing new three-field techniques, and papers comparing some of these techniques. More complex techniques (IMRT) are briefly discussed, as 3D CRT is still the conventional treatment method in many parts of the world. The aim of this work was triple: three-field techniques evolution presentation, categorization and comparison.

Matching treatment of adjacent breast and supraclavicular target volumes represents the most complex clinical problem [7], mainly because of the irregular morphology of breast region (e.g. breast shape, chest slope, inhomogeneities) and the divergence of the fields [8]. Accurate matching is of great clinical importance: Field overlap will lead in overdosage in the junction region, which could result in tissue damage, e.g. fibrosis. On the other hand, an unexpected field gap will lead in underdosage in the junction region, which could result in failure of tumor control. To overcome this problem a number of techniques have been proposed. However, it is important to mention that in clinical practice, set up uncertainties [9] and jaw-positioning accuracy [10] affect the dose distribution in the junction region more than the used technique. Several techniques are used when three-fields must be applied, many of them aiming at the best dosimetric results in the junction region. Three-field techniques can be distinguished in two categories, depending on whether one or two isocenters are employed. The following classification is not all-inclusive list of three-field techniques; only some typical examples for each group have been selected. Moreover, some of the quoted techniques are no longer in use, due to technology developments.

The first category consists of techniques that use two isocenters, one for the tangential fields and a second for the anterior field. Two-isocentric techniques are further grouped to full beam and half beam techniques.

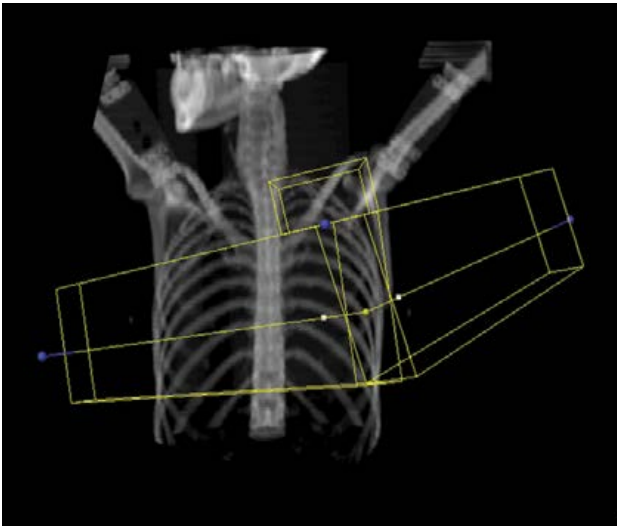
### *Full beam as two-isocentric technique*

The first group of two-isocentric techniques is characterized by the use of two full tangential and one full anterior beam. Beam divergence is handled using two approaches; geometric movements and/or a measured gap. Field modification is often accomplished using machine movements alone [11,12]. In other words, field borders are aligned and matched by applying couch, collimator and gantry rotations. The superior border of tangential fields is usually modified with couch and collimator rotation or couch rotation alone, whereas the inferior border of the anterior field is usually modified with couch and gantry rotation. An accurate angle calculation is therefore essential. In 1981, Siddon [13] presented a mathematical method which considers gantry, collimator and couch as coordinate systems. More recently Hernandez et al. [14,15] have published a more general solution which encompasses all the already known equations, assuming fixed field sizes or fixed isocenter positions. In our institution, full field techniques are mainly used. Determination of the angles is made either by the auto field alignment tool of TPS or manually, using "trial and error" method.

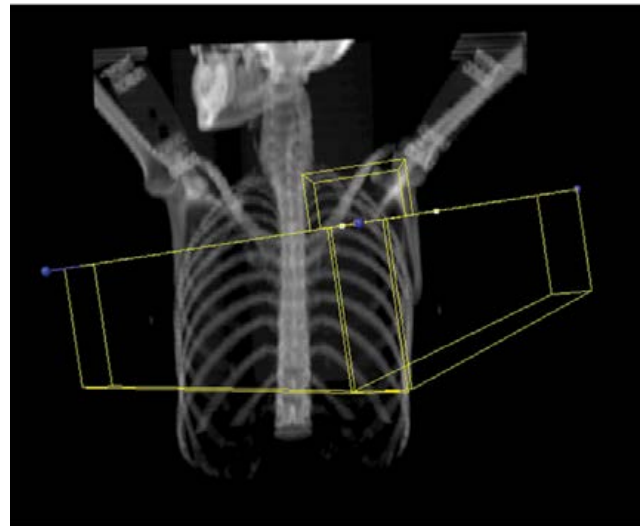
Another common approach is the use of a gap between the superior border of the tangential fields and the inferior border of the supraclavicular field [11,12,16]. Gap size may vary from 1 to 11 mm [11,16], when the most common size among UK radiotherapy centers is 5 mm [11]. Obviously, this approach is not a beam matching technique; however it is often used because field overlap is avoided. Gap technique is employed as a single modification method for the anterior field or in combination with machine movements for the modification of the tangential fields.

### *Half beam as two-isocentric technique (Figure 1)*

In this group, not full but half beams are used for the geometric divergence to be removed. Using different methods the lower half of the supraclavicular field or the upper half of the tangential fields is blocked and thus made non divergent. By that means, matching line is defined by the sharp edge of the blocked field and beam divergence has to be dealt for the remaining field(s) only. Further



**Figure 1.** Half-field technique for irradiation of tangential breast fields and supraclavicular field.



**Figure 2.** Monoisocentric technique for irradiation of tangential breast fields and supraclavicular field.

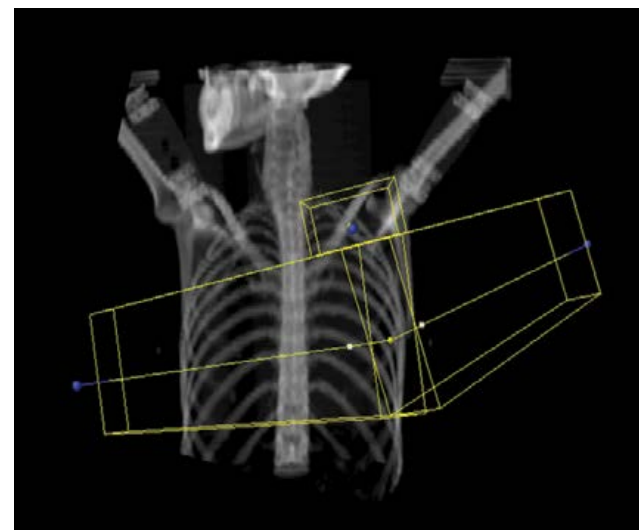
field matching is achieved by appropriate geometric movements. A variety of half beam techniques have been recorded in the literature and some of them are listed below. Svensson et al. [17] presented a technique where the anterior field is half-blocked and the tangential fields' upper edges become vertical with a hanging shielding block. With appropriate geometric movements, these three vertical edges are matched. Siddon et al. [18,19] modified Svensson technique, using a rotated half beam block to align the upper edges of the tangential fields. Later this technique was further improved, as the bulky rotatable block was replaced by small corner blocks [19]. In 1986, Lebesque [20] developed a general formula where angles block positions and field dimensions can be calculated, regardless of the used technique. In another technique [21] the appropriate set up is determined using a rod and a chain. More recently, a modern version of this technique was presented, where rod and chain are replaced by an external skin contour, created by the Treatment Planning System (TPS) [22]. Lu et al. [23], taking advantage of Multi Leaf Collimators (MLCs), developed a technique with a new set up routine and a mathematical formalism to calculate the required machine rotations. The general solutions proposed by Hernandez et al. [14,15] are also applicable in half beam techniques.

#### *Monoisocentric techniques (Figure 2)*

Use of a single isocenter for all three fields is the main characteristic of this group. The isocenter is placed in the junction of tangential and supraclavicular fields. The upper half of the tangential fields and the lower half of the anterior

field are half-blocked, using blocks or MLCs.

A monoisocentric technique for breast irradiation was first implemented at Mc Gill University, Montreal [24] as a modification of previous two-isocentric half beam techniques [17,25]. The vertical hanging block was replaced by a half block. Later Conte et al. [26] presented a monoisocentric technique using individualized shielding blocks. Rosenow et al. [27] applied a combination of asymmetric jaw and small blocks. The monoisocentric technique was further improved [28,29] and use of asymmetric jaws eliminated the need for blocks. Recently Romeo [16] developed a new technique, based on four independent asymmetric jaws that does not require additional shielding to protect the lung. Another approach is monoisocentric three-field technique without the use of half beam blocks by Zhang et al. [30]. This method eliminates the requirement that the supraclavic-



**Figure 3.** Full-field technique for irradiation of tangential breast fields and supraclavicular field.

ular field has to be half-beam blocked, so that the isocenter can be located inferior to the matching plane. Compared with approximate beam matching, the new approach always produces perfect geometric matching.

The tangential breast fields are geometrically matched with the supraclavicular field by rotating the collimator and couch. Similar to the dual-isocenter approach, the full-field length can be utilized for the tangential fields (Figure 3). With a single isocenter, the treatment delivery requires only one setup, thereby treatment time is significantly reduced. More importantly, without manual matching using a light field, the new method reduces dose variation in the matching region due to setup uncertainties.

### Advantages and disadvantages (Table 1)

Three main technique groups are regularly used when three fields must be applied in the breast region: three full fields with geometric or gap modification, two full tangential fields and a half blocked supraclavicular field (or, more rarely, two half blocked tangential fields and a full supraclavicular field) or three half blocked fields with a common isocenter. Among these three, monoisocentric techniques are believed to be the most efficient, as they offer a number of advantages. Firstly, satisfactory dosimetric results can be obtained i.e. accuracy in dose delivery, dose homogeneity in the junction region (cold and hot spots avoidance) and reproducibility between the treatment sessions. In a study involving 18 patients carried out by Banaei et al. [31], two plans were designed for each patient using single and two-isocentric full field technique respectively. Two-isocentric techniques resulted in higher values of:  $V_{105}\%$ , maximum dose in the junction region and level 2 lymph nodes mean dose. Overlap of the treatment beams is the reason for these results. Similarly, Assaoui et al. [32] compared dose volume histograms (DVHs) of 30 patients. Dose distribution in

PTV was similar in both techniques but hot spots were lower using the monoisocentric technique. Specifically, the maximum dose in the junction region was 52 Gy (two-isocentric) and 46 Gy (monoisocentric) while the prescribed dose was 42 Gy. Another important finding is that monoisocentric technique has been demonstrated to protect organs at risk such as lung and the heart. In another study [33] 18 patients were treated with monoisocentric technique. No enhancement of skin reaction at the field junctions was observed. Additionally, no recurrences and no serious side effects connected with irradiation were observed in a 10-month period. Urbańczyk et al. [34] described the implementation of a monoisocentric technique to 68 patients. Dose delivery accuracy was checked by *in vivo* dosimetry and portal images. Using this technique, hot spots were avoided. Diamantopoulos et al. [35] compared dose delivery accuracy in the junction region between a two-isocentric technique in breast cancer patients and a monoisocentric technique in head and neck cancer patients. Dose in the breast junction region exceeded ICRU recommended range (95-105%) several times, whereas this limit was not exceeded at all in head and neck junction region. Two-isocentric half beam techniques have also been reported to give sufficient dosimetric results. START trial QA team visited 36 radiotherapy centers in the UK in order to document and verify *in vitro* the techniques in use [11]. Two centers used monoisocentric technique, 7 centers used two-isocentric half beam techniques, 16 centers used two-isocentric full beam techniques, 9 of them applied 0.5 cm gap, while the rest used combinations that were not examined. Best results in terms of uniformity and dosimetry were produced by two-isocentric half beam and monoisocentric techniques, while full beam techniques did not give satisfactory results. Half beam techniques produced a more homogeneous dose distribution in the junction region and daily reproducibility was achieved; therefore their use is recommended. A half beam

**Table 1.** Advantages and disadvantages of techniques for breast radiodioterapy

Techniques	Advantages	Disadvantages
full-beam as two-isocentric	no tangential field size limitation	not-satisfactory dosimetric results high-dose gradient in junction region
half-beam as two-isocentric	more homogenous dose distribution in junction region daily reproducibility	greater treatment time no set up simplicity
monoisocentric	satisfactory dosimetric results reproducibility greater protection of organs at risk set up simplicity total treatment time is shortened	tangential field size limitation high-dose gradient in junction region

technique described by Lu et al. [24] was verified *in silico*, using geometrical simulation, and *in vitro*, using film dosimetry in a solid phantom. Both methods demonstrated perfect match and dose homogeneity between the anterior and tangential fields. Dose to contralateral breast and ipsilateral lung was lower compared to a previously used technique.

Set up simplicity is another benefit of monoisocentric techniques. Comparing to two-isocentric techniques where a repositioning step is required, in single isocenter techniques dose can be delivered at once without couch motion. In this way, errors connected to patient misplacement because of couch motion, are avoided. Additionally, the total treatment time is shortened, so errors from unmeant patient movements are minimized [32-36]. A mean reduction from 16.8 to 8.3 min has been reported [35]. However, it should be mentioned that planning time is longer compared to two-isocentric techniques [32,34]. Finally, angles determination is easier, compared to complicated calculations demanded, especially, in full field techniques [15].

On the other hand, monoisocentric techniques come with two noticeable drawbacks. The most significant one is the tangential field size limitation. As only the half field is used and the maximum field size available is 40 x 40 cm<sup>2</sup>, it can be easily understood that the maximum curable breast length is 20 cm. This restriction is the main reason why two-isocentric techniques are in use. There are many cases where a 20 x 20 cm<sup>2</sup> field size is not enough to cover the whole breast. Then, either a full field or a half supraclavicular field technique must be used. Another issue, common to mono-isocentric and two isocentric half beam techniques, is the high dose gradient in the junction region [11,37]. This is of great importance, as a small inaccuracy in field matching could result in a high dose delivering error both to targeted and contralateral breast [11,38]. Sub-millimetre accuracy and careful jaws calibration

is therefore required [11,37,39]. IMRT includes modern, more complex techniques than 3D CRT where inverse planning algorithms are used to optimize beam intensities. Several studies have been carried out comparing IMRT with 3D CRT efficiency in breast or chest wall cancer treatment, especially when supraclavicular lymph nodes had to be irradiated. A study held by Morganti et al. [40] showed significant reduction of  $V_{107\%}$  and  $D_{max}$  and increase of  $D_{min}$  to irradiated volume between patients treated with IMRT and patients treated with a standard 3D technique. The homogeneity of dose distribution was also significantly improved with IMRT. In another study [41] IMRT plans displayed better dosimetric characteristics (uniformity, homogeneity, conformity) to the target, particularly at the field junction, compared to 3D CRT plans. Superior dosimetric results were also noticed in an investigation by Yang et al. [42] both in the chest wall and in the supraclavicular region, as dose distribution was improved using IMRT compared to a 3-field technique. Finally, O'Donnell et al. [43] mark that by using tomotherapy IMRT, breast and regional nodes can be treated in continuity; this way overlaps and gaps are avoided and improved coverage can be achieved.

## Conclusion

An accurate field matching in breast RT is not a simple task when an anterior field has to be applied. A number of techniques have been recorded but none comes without major disadvantages. Techniques that apply a single isocenter are recommended as they offer good dosimetric results and convenient patient set up, but they are not always applicable. In these cases two isocentric half beam techniques can be used. Anyhow, IMRT has been proved to be the optimal treatment method.

## Conflict of interests

The authors declare no conflict of interests.

## References

1. Coleman MP, Quaresma M, Berrino F et al. Cancer survival in five continents: a worldwide population-based study. *Lancet Oncol* 2008;9:730-756.
2. Ferlay J, Soerjomataram I, Ervik M et al. GLOBOCAN 2012 v1.0, Cancer Incidence and Mortality Worldwide: IARC CancerBase No.11 [Internet]. Lyon, France: International Agency for Research on Cancer; 2013. Available from: <http://globocan.iarc.fr>, accessed on 15/12/2014
3. Siegel R, Ma J, Zou Z, Jemal A. Cancer Statistics, 2014. *CA Cancer J Clin* 2014; 64:9-29.
4. Overgaard M, Hansen PS, Overgaard J et al. Postoperative radiotherapy in high-risk premenopausal women with breast cancer who receive adjuvant chemotherapy. Danish Breast Cancer Cooperative Group 82b Trial. *N Engl J Med* 1997;337:949-955.
5. Vicini FA, Horwitz EM, Lacerna MD et al. The role of regional nodal irradiation in the management of

- patients with early-stage breast cancer treated with breast-conserving therapy. *Int J Radiat Oncol Biol Phys* 1997;39:1069-1076.
6. Poortmans P, Struikmans H, Collette S et al. ESTRO 33 Congress Report, 2014. Available from: <http://www.astro.org>, accessed on 20/01/2015
  7. Jane Dobbs H. Radiation therapy for breast cancer at the millennium. *Radiother Oncol* 2000;54:191-200.
  8. Mahmoud A, Somayeh N, Mahbod E, Mehdi A, Vahid C, Ghazale G. Optimization of three dimensional planning dosimetric in breast phantom for match region of supraclavicular and tangential fields. *J Cancer Res Ther* 2013;9:64-70.
  9. Idzes MH, Holmberg O, Mijnheer BJ, Huizenga H. Effect of set-up uncertainties on the dose distribution in the match region of supraclavicular and tangential breast fields. *Radiother Oncol* 1998;46:91-98.
  10. Han T, Taylor R, Melancon A, Howell R, Mourtada F, Salehpour M. A Comprehensive Investigation of Dosimetric Uncertainties in Junction Region of Breast Superclavicular and Tangential Fields. *Med Phys* 2013;40.
  11. Miles EA, Venables K, Hoskin PJ, Aird EG; START Trial Management Group: Dosimetry and field matching for radiotherapy to the breast and supraclavicular fossa. *Radiother Oncol* 2009;91:42-48.
  12. Landau DB, Laing RW. An Audit of Indications and Techniques for Supraclavicular Fossa Irradiation in Early Breast Cancer in the UK. *Clin Oncol (R Coll Radiol)* 2000;12:172-178.
  13. Siddon RL. Solution to treatment planning problems using coordinate transformation. *Med Phys* 1981;8:766-774.
  14. Hernandez V, Arenas M, Pons F, Sempau J. Clinical applications of geometrical field matching in radiotherapy based on a new analytical solution. *Med Dosim* 2011;36:160-165.
  15. Hernandez V, Arenas M, Sempau J. A general analytical solution to the geometrical problem of field matching in radiotherapy. *Med Phys* 2009;36:4191-4196.
  16. Romeo N. A new isocentric technique for exact geometric matching in the radiotherapy of the breast and ipsilateral supraclavicular fossa using dual asymmetric jaws. *Phys Med* 2012;28:281-287.
  17. Svensson GK, Bjärngård BE, Larsen RD, Levene MB. A modified three-field technique for breast treatment. *Int J Radiat Oncol Biol Phys* 1980;6:689-694.
  18. Siddon RL, Tonnesen GL, Svensson GK. Three-field technique for breast irradiation using a rotatable half-beam block. *Int J Radiat Oncol Biol Phys* 1981;7:1473-1477.
  19. Siddon RL, Buck BA, Harris JR, Svensson GK. Three field technique for breast irradiation using tangential field corner blocks. *Int J Radiat Oncol Biol Phys* 1983;9:583-588.
  20. Lebesque JV. Field matching in breast irradiation: An exact solution to a geometrical problem. *Radiother Oncol* 1986;4:47-57.
  21. Chu JCH, Solin IJ, Hwang CC, Fowble B, Hanks GE, Goodman RI. A nondivergent three field matching technique for breast irradiation. *Int J Radiat Oncol Biol Phys* 1990;19:1037-1040.
  22. Strauss JB, Kirk MC, Chen SS et al. A virtual matching technique for three-field breast irradiation using 3-D planning. *Phys Med* 2009;25:212-215.
  23. Lu XQ, Sullivan S, Eggleston T et al. A three-field breast treatment technique with precise geometric matching using multileaf collimator - equipped linear accelerators. *Int J Radiat Oncol Biol Phys* 2003;55:1420-1431.
  24. Podgorsak EB, Gosselin M, Kim TH, Freeman CR. A simple isocentric technique for irradiation of the breast, chest wall and peripheral lymphatics. *Br J Radiol* 1984;57:57-63.
  25. Lichter AS, Fraass BA, van de Geijn JA. Technique for field matching in primary breast irradiation. *Int J Radiat Oncol Biol Phys* 1983;9:263-270.
  26. Conte G, Nascimben O, Turcato G et al. Three-field isocentric technique for breast irradiation using individualized shielding blocks. *Int J Radiat Oncol Biol Phys* 1988;14:1299-1305.
  27. Rosenow UF, Valentine ES, Davis LW. Technique for treating local breast cancer using a single set-up point and collimation. *Int J Radiat Oncol Biol Phys* 1988;14:1299-1305.
  28. Marshall MG. Three-field isocentric breast irradiation using asymmetric jaws and a tilt board. *Radiother Oncol* 1993;28: 228-232.
  29. Klein EE, Taylor M, Michaletz-Lorenz M, Zoeller D, Umfleet W. A mono isocentric technique for breast and regional nodal therapy using dual asymmetric jaws. *Int J Radiat Oncol Biol Phys* 1994;28:753-760.
  30. Zhang T, Dilworth JT, Marina O, Chen P, Benedetti, Liu Q. A three-field monoisocentric inverse breast treatment planning technique without half-beam blocking. *J Appl Clin Med Phys* 2015;16:5494.
  31. Banaei A, Hashemi B, Bakhshandeh M. Comparing the monoisocentric and dual isocentric techniques in chest wall radiotherapy of mastectomy patients. *J Appl Clin Med Phys* 2015;16:5069.
  32. Assaoui F, Toulba A, Nouh M et al. Mono-Isocentric Technique in the Breast Cancer and Organ at Risk Tolerance. *J Nucl Med Radiat Ther* S2:010. DOI: 10.4172/2155-9619.S2-010.
  33. Galecki J, Grudzien-Kowalska M, Hicer-Grzenkiewicz J et al. Experiences with the mono isocentric irradiation technique in breast cancer patients after conservative surgery. *Nowotwory* 2004;54:474-480.
  34. Urbańczyk H, Hawrylewicz L, Ganowicz M et al. The "one-isocenter-quarter-beam" technique as a radiotherapy of breast cancer patients. *Rep Pract Oncol Radiother* 2005;10:307-312.
  35. Diamantopoulos J, Thalassinou S, Efstathopoulos E et al. In vivo dosimetry in the field junction area for 3D-conformal radiation therapy in breast and head & neck cancer cases. A quality assurance study. *JBUON* 2016;21:1104-1112.
  36. Wiant D, Wentworth S, Maurer J, Vanderstraeten C, Terrell J, Sintay B. Surface imaging-based analysis of intrafraction motion for breast radiotherapy patients. *J Appl Clin Med Phys* 2014;15:4957.
  37. Kron T, Barnes K, O'Brien P. Multicentre dosimetric comparison of photon-junctioning techniques in head and neck radiotherapy. *Australas Radiol* 2003;47:289-

- 294.
38. Brooks PS. Dose to contralateral breast--a comparative study. *Med Dosim* 1995;20:301-307.
  39. Kron T. The potential for systematic field placement errors when using asymmetric collimation for photon field junctions. *Australas Phys Eng Sci Med* 2000;23:58-60.
  40. Morganti AG, Cilla S, de Gaetano A et al. Forward planned intensity modulated radiotherapy (IMRT) for whole breast postoperative radiotherapy. Is it useful? When? *J Appl Clin Med Phys* 2011;12:3451.
  41. Yao W. A two-point scheme for optimal breast IMRT treatment planning. *J Appl Clin Med Phys* 2013;14:4525.
  42. Yang B, Wei XD, Zhao YT, Ma CM. Dosimetric evaluation of integrated IMRT treatment of the chest wall and supraclavicular region for breast cancer after modified radical mastectomy. *Med Dosim* 2014;39:185-189.
  43. O'Donnell H, Cooke K, Walsh N, Plowman PN. Early Experience of Tomotherapy-based Intensity-modulated Radiotherapy for Breast Cancer Treatment. *Clin Oncol* 2009;21:294-301.