ISSN 2347-3487
Volume 13 Number 1
Journal of Advances in Physics

# Comparison between different boost dose delivery techniques to the tumor bed of right sided breast cancer patients.

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## ABSTRACT

Comparisons between three different techniques by which the boost dose was delivered to the tumor bed were carried out , aiming to present the best technique of treatment for right breast cancer patients.

In this study, ten right sided breast cancer computed tomography (CT) scans were selected for ten early right breast cancer patients. We made three different treatment plans for each patient CT using three different irradiation techniques to deliver a prescribed boost dose of 10 Gy in 5 fractions to the boost PTV. In the first technique, two tangential photon beams were used, in the second technique we, two oblique photon beams were used and in the third technique, a single electron beam was used. The comparative analyses between the three techniques were performed by comparing the boost PTV- dose volume histograms (DVHs), the ipsilateral breast (right breast) DVHs, the ipsilateral lung (right lung) DVHs and the heart DVHs of the three techniques for each patient. Furthermore the dose that covering 100% , 95% of the volume ($D_{100\%}$ , $D_{95\%}$) and the volume covered by 95% of the dose ($V_{95\%}$) of the boost PTV of all techniques, were calculated for each patient to investigate the dose coverage of the target.

Results showed that there were variations of the dose received by tumor bed, right breast and OARs depending on the technique used and the target location and size. A decrease of $D_{100\%}$ than 90% of the prescribed dose was observed with the 3rd technique for patients 8, 9 and 10, and was observed with the 2nd technique for patient 5. A reduction of right breast dose was observed when the 3rd technique was use in comparison with the 1st and the 2nd techniques for patients 1, 2, 3, 4, 6 and 8. Also reduction of right breast was observed when the 2nd technique used in comparison with 1st technique. An increase of lung dose was observed with the 3rd technique for patients 1, 2, 5 and 6, also was observed with 2nd technique in patient 3, 5 and 7. A decrease of lung dose was observed with the 1st technique for patients 2, 4, 5, 6, 7, 8 and 9

An individualized treatment, several plans using different irradiation techniques should be developed for each patient individually to reach the best boost PTV dose coverage with minimal OARs' dose.

## Indexing terms/Keywords

Boost dose, right breast cancer, dose volume histograms, electron beam, linear accelerator, photon beams.

## SUBJECT CLASSIFICATION

Physics.

## 1 INTRODUCTION

Breast cancer is considered as the second diagnosed type of cancer "after non-melanoma skin cancer" in women with about 23% of total new cancer cases. Also it represents about 14% of cancer death among women [1]. By the advances of the breast cancer treatment, the breast conserving therapy (BCT) became an accepted option for the treatment of most stage I or II invasive breast cancer in women instead of mastectomy. BCT is a technique of cancer treatment where the breast-conserving surgery (BCS) is used followed by adjuvant postoperative radiotherapy [2].the use of BCT improves the local control and the survival rate in early stage breast cancer patients [3], with decreasing of both cancer recurrence risk by 70% and death risk by 9%-12% [4].The two tangential fields is the most common and traditional technique used in the whole breast radiotherapy because of its technical simplicity, more over it has an advantage in sparing organs at risk (OARs). Over the last decade, this technique has evolved by the use of multi-leaf collimators (MLC) to deliver field-in-field (FIF) three-dimensional conformal therapy (3D-CRT) [5, 6] and intensity modulated radiation therapy (IMRT) variants [7, 8]. An additional boost dose of 10 to 16 Gy delivered to the tumor bed has shown an additional gain in decreasing local recurrence in patients [9]. The delivery of the boost dose to tumor bed has been performed sequentially following to the whole breast radiation therapy (RT). This Sequential boost reduces local recurrence [10] but increases the treatment duration. Alternatively, the simultaneously integrated boost (SIB) technique has also been involved to BCT with the use of IMRT in breast cancer. With this method, the whole breast and the boost PTV are integrated in a single treatment plan [11]. It was usual to deliver the boost dose to the tumor bed by using the electron beam. But today there are other boost techniques using the photon beam. Up till now, it is unclear which technique is recommended [9]. So investigations are needed to describe the differences between them and to modify a new techniques to irradiate breast with minimal side effects on heart, lungs, skin and normal breast tissues. In this work, we compare between three different techniques by which the boost dose is delivered to the tumor bed in right breast, aiming to present the best technique of treatment for breast cancer patients. Since the right lunge is larger than the left lung and the irradiated area of right lung is larger so more precaution should be taken to decrease the side effect on the right lung. In the first technique we used two tangential photon beams, in the second technique we used two oblique photon beams and in the third technique we used a single electron beam.

## 2 METHODS

Ten right sided breast cancer computed tomography (CT) scans were selected for ten early breast cancer patients treated at Ayadi Al-Mostakbal Oncology Center, Alexandria, Egypt. Patients were treated with BCT after BCS. The CT scans were performed by CT system Somatom Emotion Duo (Siemens, Munich, Germany). Patients were scanned according to the standard protocol with 5 mm slice thickness, in the supine position and arms above head [3]. Targets of different locations (upper, lower, medial, inner, outer, deep and superficial) and sizes were selected.

The contouring of target and OARs was done by experienced radiation oncologist. The boost clinical target volume (boost CTV) that included the tumor bed was recognized by the scar, visualized seroma and surgical clips. The boost planning target volume (boost PTV) that included boost CTV and safety margin of 7 mm in all directions except for the skin, was delineated. Also the ipsilateral breast (right breast), ipsilateral lung (right lung), heart and whole ipsilateral breast volume less boost PTV were delineated.

Three different treatment plans are made for each patient CT using three different irradiation techniques to deliver a prescribed boost dose of 10 Gy in 5 fractions to the boost PTV, and decrease the dose delivered to ipsilateral breast, contralateral breast and OARs. The planning aim was that the volume receiving 95% of the prescribed dose ($V_{95\%}$) of the boost PTV to be greater than 95% of the total boost PTV volume, and the volume that receiving 5 Gy of OARs except ipsilateral breast shouldn't exceed 5% of the total organ volume. All plans were performed by a 3D planning system CMS Xio v4.5 (Elekta AB, Stockholm, Sweden) employing the superposition algorithm.

All these plans were created for Siemens Artiste® Treatment System Linear Accelerator (Linac) machine with a dual energy X-rays of 6 and 10 MV and multi-electron beam energies of 10, 15, 16 and 21 MeV. The beams produced have high dose rates (up to 600 cGy per minute), small penumbras (an 80% to 20% penumbra of 6 mm for 6 MV beams), and minimal field edge divergence at 100 cm source-to-surface distance (SSD). The machine gantry, collimator and table can rotate about isocenter point at 100 cm SSD. Gantry and collimator have rotation range of 360º. The machine provides stationary and moving radiation (arc or rotation) clockwise or counter clockwise for X-ray or electron beam. The machine head is provided with conventional collimators in X-direction and two backup diaphragms in Y-direction. Multileaf collimator (MLC) has two opposing sets, having 160-leaf multileaf collimator (MLC) with leaf width of 5mm and leaf-positioning accuracy of 0.5 mm. The machine provides field sizes ranging from 1x1 to 40x40 $cm^2$ at 100 cm SSD within accuracy ±1 mm for fields less than 20x20 $cm^2$ and 1% for greater fields.

In the first technique, two tangential photon beams were used to deliver the boost dose to the boost PTV and reduce unnecessary dose to OARs. The isocenter located approximately in the center of boost PTV. In the second technique, two oblique photon beams with individual selected gantry angle were used to deliver boost dose to the boost PTV and reduce unnecessary dose to OARs. The isocenter located approximately in the center of boost PTV. In the third technique, a single direct electron beam with SSD =100 cm was used to deliver the boost dose to the boost PTV and reduce unnecessary dose to OARs.For all techniques, the beam energy was chosen for each case individually depending on the target location and volume aimed to cover the boost PTV with 95% of the prescribed dose.

The isodose distributions and dose volume histograms (DVHs) of the three techniques for the boost PTVs and OARs, were obtained by using 3D planning system CMS Xio v4.5 (Elekta AB, Stockholm, Sweden) for each patient.

The comparative analyses between the three techniques were performed by comparing the boost PTV-DVHs, the ipsilateral breast (right breast) DVHs, the ipsilateral lung (right lung) DVHs and the heart DVHs of the three techniques for each patient. Furthermore the dose that covering 100% , 95% of the volume ($D_{100\%}$ , $D_{95\%}$) and $V_{95\%}$ of the boost PTV of all techniques, were calculated for each patient to investigate the dose coverage of the target. Also the volume receiving 5 Gy of OARs of all techniques were calculated for each patient.

## 3 RESULTS AND DISCUTIONS

Ten patients of right sided breast tumor with different sizes and position, as shown in table (1), were selected and assigned from patient 1 to patient 10. The dosemetric data of target and OARs for all patients are shown in tables (2), (3), (4), (5), (6), (7), (8) and (9).

**Table 1. The target position and dimension for right sided tumor.**

| Patient | Location | Volume | Target height | Distance | Target | Distance | Distance |
|---|---|---|---|---|---|---|---|
| 11 | Outer – Upper | 14.51 | 5.0x3.0 | 1.5 | 4.8 | 1.5 | 10.0 |
| 12 | Central – Lower | 24.41 | 4.0x3.0 | 1.2 | 4.1 | 1.8 | 9.3 |
| 13 | Outer – Lower | 12.95 | 3.5x2.5 | 1.4 | 3.0 | 1.5 | 9.5 |
| 14 | Central - medial | 30.71 | 4.0x6.5 | 1.5 | 3.0 | 3.5 | Far |
| 15 | Central - medial | 47.93 | 4.6x4.5 | 1.6 | 4.7 | 0.2 | 7.2 |
| 16 | Central - Medial | 12.45 | 1.8x3.4 | 1.0 | 3.0 | 0.8 | 6.7 |
| 17 | Outer – Medial | 4.61 | 1.2x2.2 | 4.0 | 6.1 | 1.0 | 9.5 |
| 18 | Outer – Upper | 39.83 | 4.3x6.9 | 3.2 | 5.4 | 1.6 | 6.6 |
| 19 | Outer – Upper | 11.63 | 2.4x2.8 | 4.2 | 6.2 | 1.2 | 8.5 |
| 20 | Central - Lower | 34.11 | 3.9x3.3 | 4.4 | 9.5 | 2.5 | 10.5 |

**Table 2. The global maximum doses, for right sided tumor patients.**

| Patient | Patient ID | Target volume | 1st technique (cGy) | 2nd technique(cGy) | 3rd technique(cGy) |
|---|---|---|---|---|---|
| 11 | 226815 | 14.51 | 1090 | 1026 | 1046 |
| 12 | 246315 | 24.41 | 1049 | 1055 | 1040 |
| 13 | 173915 | 12.95 | 1064 | 1024 | 1046 |
| 14 | 446915 | 30.71 | 1059 | 1059 | 1130 |
| 15 | o99515 | 47.93 | 1108 | 1023 | 1082 |
| 16 | 406915 | 12.45 | 1074 | 1029 | 1102 |
| 17 | o46416 | 4.61 | 1084 | 1022 | 1106 |
| 18 | 240315 | 39.83 | 1090 | 1045 | 1379 |
| 19 | 452515 | 11.63 | 1053 | 1072 | 1449 |
| 20 | 121215 | 34.11 | 1081 | 1027 | 1420 |

**Table 3. The minimum, mean and maximum doses of PTV.**

| Patient | Target volume | First technique (cGy) | | | Second technique (cGy) | | | Third technique (cGy) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mini. | Mean | Max. | Mini | Mean | Max. | Mini. | Mean | Max. |
| 11 | 14.51 | 949 | 984 | 1013 | 948 | 986 | 1018 | 911 | 979 | 1046 |
| 12 | 24.41 | 954 | 1002 | 1046 | 948 | 1007 | 1055 | 941 | 996 | 1040 |
| 13 | 12.95 | 962 | 999 | 1034 | 953 | 997 | 1021 | 958 | 1000 | 1046 |
| 14 | 30.71 | 850 | 998 | 1040 | 680 | 998 | 1049 | 850 | 992 | 1130 |
| 15 | 47.93 | 918 | 1055 | 1100 | 746 | 1000 | 1023 | 948 | 1027 | 1078 |
| 16 | 12.45 | 894 | 983 | 1042 | 841 | 979 | 1020 | 890 | 996 | 1102 |
| 17 | 4.61 | 960 | 992 | 1007 | 965 | 995 | 1045 | 911 | 990 | 1050 |
| 18 | 39.83 | 909 | 1004 | 1058 | 791 | 1005 | 1043 | 815 | 1014 | 1122 |
| 19 | 11.63 | 949 | 999 | 1032 | 975 | 1019 | 1072 | 870 | 1156 | 1314 |
| 20 | 34.11 | 962 | 998 | 1027 | 979 | 999 | 1027 | 292 | 964 | 1331 |

**Table 4. The doses covering 2%, 50%, 95%, 98% and 100% of PTV.**

| Patient | First technique (cGy) | | | | | Second technique (cGy) | | | | | Third technique (cGy ) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $D_{2\%}$ | $D_{50\%}$ | $D_{95\%}$ | $D_{98\%}$ | $D_{100\%}$ | $D_{2\%}$ | $D_{50\%}$ | $D_{95\%}$ | $D_{98\%}$ | $D_{100\%}$ | $D_{2\%}$ | $D_{50\%}$ | $D_{95\%}$ | $D_{98\%}$ | $D_{100\%}$ |
| 11 | 1011 | 988 | 988 | 959 | 950 | 1017 | 992 | 963 | 957 | 950 | 1030 | 989 | 950 | 935 | 918 |
| 12 | 1043 | 1006 | 971 | 966 | 941 | 1048 | 1013 | 969 | 960 | 931 | 1030 | 1003 | 968 | 959 | 919 |
| 13 | 1031 | 1030 | 978 | 972 | 951 | 1019 | 1004 | 974 | 967 | 951 | 1030 | 996 | 977 | 970 | 951 |
| 14 | 1032 | 1004 | 975 | 967 | 931 | 1041 | 1001 | 974 | 949 | 908 | 1050 | 999 | 959 | 942 | 932 |
| 15 | 1094 | 1064 | 1007 | 988 | 931 | 1022 | 1008 | 980 | 961 | 832 | 1067 | 1038 | 991 | 978 | 941 |
| 16 | 1039 | 985 | 947 | 939 | 901 | 1017 | 986 | 941 | 928 | 901 | 1060 | 1001 | 950 | 931 | 901 |
| 17 | 1006 | 998 | 980 | 975 | 961 | 1017 | 1000 | 978 | 975 | 961 | 1045 | 1000 | 950 | 940 | 933 |
| 18 | 1052 | 1006 | 980 | 975 | 951 | 1040 | 1011 | 979 | 968 | 901 | 1126 | 1026 | 930 | 912 | 829 |
| 19 | 1028 | 1005 | 975 | 969 | 951 | 1052 | 1024 | 995 | 987 | 971 | 1282 | 1178 | 1009 | 956 | 876 |
| 20 | 1023 | 1004 | 981 | 976 | 941 | 1013 | 1003 | 992 | 985 | 972 | 1282 | 1010 | 520 | 448 | 324 |

**Table 5. The percentages of PTV volume covered with 95% and 100% of the prescribed dose.**

| Patient | 1st technique (%) | | 2nd technique(%) | | 3rd technique(%) | |
|---|---|---|---|---|---|---|
| | $V_{95\%}$ | $V_{100\%}$ | $V_{95\%}$ | $V_{100\%}$ | $V_{95\%}$ | $V_{100\%}$ |
| 11 | 100 | 22 | 100 | 31 | 95 | 24 |
| 12 | 99.9 | 61 | 99.8 | 66 | 99.5 | 56 |
| 13 | 99.9 | 57 | 99.9 | 58 | 99.9 | 38 |
| 14 | 99.8 | 62 | 98 | 53 | 98 | 49 |
| 15 | 99.9 | 99 | 98.9 | 69 | 99.9 | 90 |
| 16 | 91 | 31 | 91 | 25 | 95 | 51 |
| 17 | 100 | 39 | 100 | 50 | 95 | 50 |
| 18 | 100 | 61 | 99.5 | 73 | 91 | 70 |
| 19 | 100 | 60 | 100 | 90 | 98.5 | 95.5 |
| 20 | 99.9 | 62 | 100 | 67 | 59 | 51 |

**Table 6. The homogeneity indexes.**

| Patient | First technique | Second technique | Third technique |
|---|---|---|---|
| 11 | 5.2 | 6.0 | 9.5 |
| 12 | 7.7 | 8.8 | 7.1 |
| 13 | 5.9 | 5.2 | 6.0 |
| 14 | 6.5 | 9.2 | 10.8 |
| 15 | 10.6 | 6.1 | 8.9 |
| 16 | 10.0 | 8.9 | 12.9 |
| 17 | 3.1 | 4.2 | 10.5 |
| 18 | 7.7 | 7.2 | 21.4 |
| 19 | 5.9 | 6.5 | 32.6 |
| 20 | 4.7 | 2.8 | 83.4 |

**Table 7. The mean and the maximum doses of the left breast.**

| Patient | First technique (cGy) | | Second technique (cGy) | | Third technique (cGy) | |
|---|---|---|---|---|---|---|
| | Mean | Max. | Mean | Max. | Mean | Max. |
| 11 | 419 | 1090 | 307 | 1025 | 221 | 1028 |
| 12 | 452 | 1049 | 342 | 1040 | 229 | 1017 |
| 13 | 417 | 1064 | 337 | 1024 | 194 | 1030 |
| 14 | 482 | 1059 | 382 | 1059 | 278 | 1076 |
| 15 | 557 | 1108 | 454 | 1021 | 482 | 1081 |
| 16 | 395 | 1074 | 297 | 1029 | 212 | 1082 |
| 17 | 243 | 1084 | 183 | 1016 | 178 | 1106 |
| 18 | 495 | 1090 | 408 | 1045 | 343 | 1379 |
| 19 | 387 | 1053 | 290 | 1052 | 424 | 1449 |
| 20 | 286 | 1081 | 246 | 1005 | 214 | 1420 |

**Table 8. The mean and the maximum doses of the left lung.**

| Patient | First technique (%) | | Second technique (%) | | Third technique (%) | |
|---|---|---|---|---|---|---|
| | Mean | Max. | Mean | Max. | Mean | Max. |
| 11 | 48 | 1014 | 49 | 794 | 160 | 945 |
| 12 | 37 | 897 | 55 | 827 | 161 | 931 |
| 13 | 25 | 820 | 39 | 844 | 31 | 952 |
| 14 | 21 | 820 | 24 | 702 | 72 | 809 |
| 15 | 42 | 950 | 99 | 943 | 301 | 1082 |
| 16 | 44 | 971 | 58 | 891 | 169 | 983 |
| 17 | 42 | 988 | 61 | 621 | 21 | 425 |
| 18 | 28 | 946 | 65 | 916 | 77 | 711 |
| 19 | 42 | 935 | 78 | 915 | 56 | 840 |
| 20 | 20 | 710 | 17 | 308 | 7 | 121 |

**Table 9. The mean and the maximum doses of the heart.**

| Patient | First technique (%) | | Second technique (%) | | Third technique (%) | |
|---|---|---|---|---|---|---|
| | Mean | Max. | Mean | Max. | Mean | Max. |
| 11 | 6.5 | 15 | 9 | 32 | 17.5 | 135 |
| 12 | 6.6 | 18 | 5.9 | 11 | 22.6 | 210 |
| 13 | 0 | 0 | 6 | 14 | 10.2 | 16.7 |
| 14 | 0 | 0 | 6.9 | 14.9 | 24.4 | 85 |
| 15 | 6.8 | 15 | 12.8 | 189 | 71.5 | 518 |
| 16 | 8.3 | 50 | 8.1 | 100 | 73 | 550 |
| 17 | 8 | 114 | 8 | 255 | 8 | 49 |
| 18 | 7.8 | 24 | 43 | 378 | 10 | 128 |
| 19 | 9 | 79 | 80 | 392 | 21 | 89 |
| 20 | 6.9 | 14.9 | 5.8 | 15 | 3.1 | 45 |

### 3.1 Patient 1

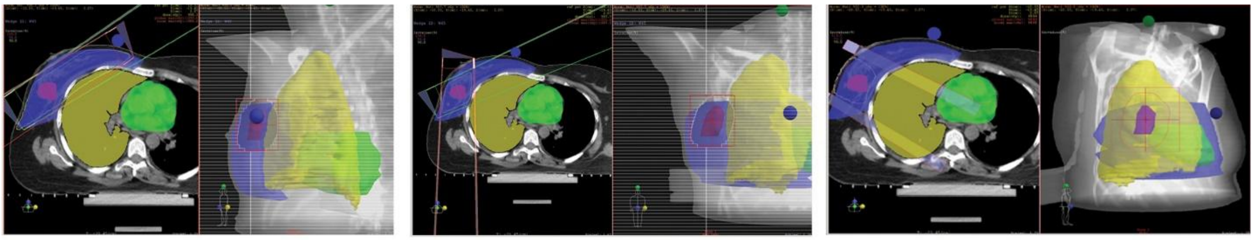
the isodose distributions using the three techniques are shown in “figure 1”. The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in “figure 2”.

From the boost PTV-DVHs of all treatment plans shown in “figure (2-a)”, we see similar boost PTV dose coverage. $D_{95\%}$ was greater than 950 cGy, $D_{100\%}$ was greater than 900 cGy and “$V_{95\%}$” was greater than 95% of the total volume of the target, for all techniques.

From the right breast DVHs shown in figure (2-b), it was clear that the 3rd technique presented the lowest breast dose. The volumes received doses (up to 900 cGy) were decreased by about 21% when the 3rd technique used in comparison with the 1st technique. The 3rd technique was better than the 2nd technique because it reduced the volumes received doses (up to 400 cGy) by 23%. In the region of doses greater than (400 cGy) the DVHs of the 2nd and the 3rd techniques were almost similar. The volumes received doses greater than (400 cGy) were decreased by about 17% when the 2nd technique used in comparison with the 1st technique. The mean right breast dose was 221 cGy with the 3rd technique while it was 307 cGy for the 2nd technique and 419 cGy for the 1st technique.

Figure (2-c) shows the right lung DVHs for all techniques. It was clear that the volumes received dose of 500 cGy ($V_{50\%}$) didn’t exceed 5% of total volume for the 1st and 2nd techniques, while it was 7.6% for the 3rd technique. Also increasing of “$D_{mean}$ = 160 cGy” was observed with the 3rd technique while it was “48 cGy” and “49 cGy” for the 1st and 2nd techniques respectively.

The analysis of heart DVHs for all techniques are shown in figure (2-d), there weren’t any significant differences between the three techniques.



(a) (b) (c)

**Figure 1. The isodose distributions for patient 1. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

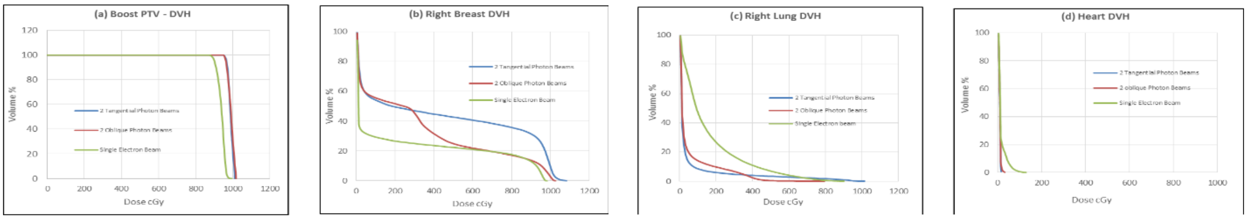



**Figure 2. The comparisons between DVHs of patient 1 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) right lung and (d) Heart.**

### 3.2 Patient 2

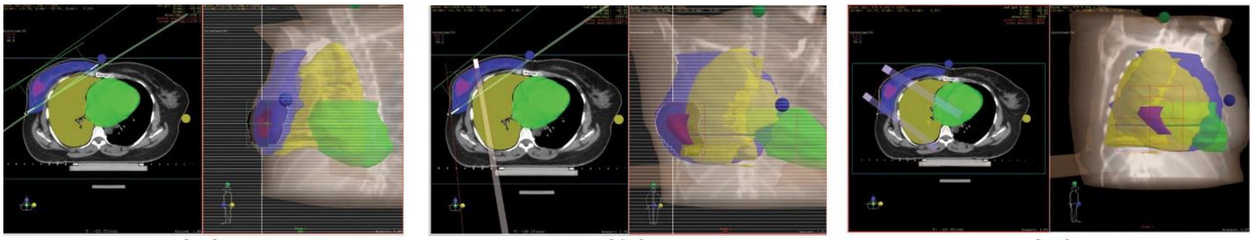
the isodose distributions using the three techniques are shown in “figure 3”. It’s clear that the boost PTV coverage for each technique was accepted. The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in “figure 4”.

From the boost PTV-DVHs for all techniques, shown in figure (4-a), we see similar boost PTV dose coverage. $D_{95\%}$ was greater than 950 cGy, $D_{100\%}$ was greater than 900 cGy and $V_{95\%}$ was greater than 95% for all techniques.

From the right breast DVHs shown in figure (4-b), it was clear that the 3rd technique presented the lowest breast dose. The volumes received doses (up to 900 cGy) were decreased by about 24.15% when the 3rd technique was used in comparison with the 1st technique. The 3rd technique was better than the 2nd technique that it reduced the volumes received doses (up to 400 cGy) and (>400-900 cGy) by 24% and 3.5% respectively. Also $D_{mean}$ was 229 cGy for the 3rd technique while it was 343cGy and 452cGy for the 2nd and 1st techniques respectively. These results indicated that the 3rd technique was favorable than the two other techniques, with respect to the right breast dose.

By the analysis of Lung for all techniques, shown in figure (4-c), increases of lung doses were observed for the 3rd technique that $V_{50\%}$ reached 9.9%. Also increasing of “$D_{mean}$ = 161 cGy” was observed with the 3rd technique while it was “37 cGy” and “55 cGy” for the 1st and 2nd techniques respectively.

The analysis of heart DVHs for all techniques are shown in figure (4-d), no significant differences between the three techniques were found.



(a) (b) (c)

**Figure 3. The isodose distributions for patient 2. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

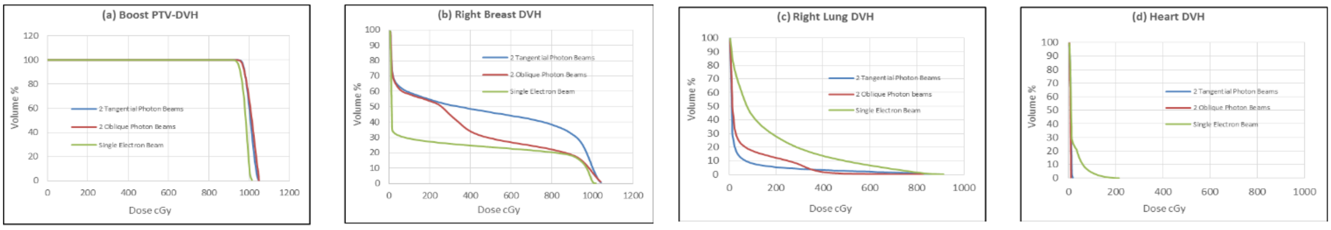



**Figure 4. The comparisons between DVHs of patient 1 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) Right lung and (d) Heart.**

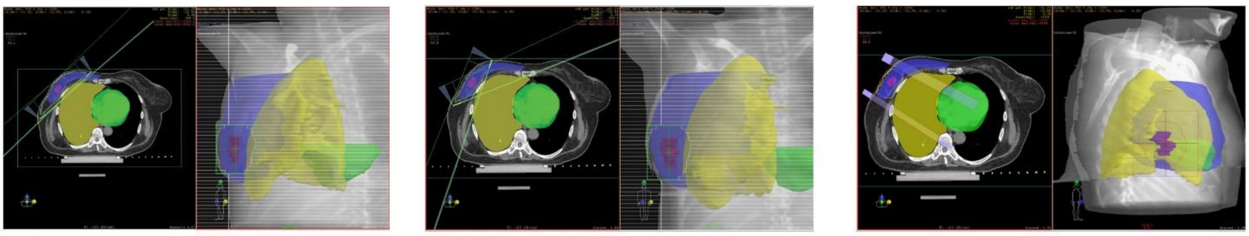
## 3.3 Patient 3

the isodose distributions using the three techniques are shown in "figure 5". It's clear that the boost PTV coverage for each technique was accepted. The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in "figure 6".

From the boost PTV DVHs for all treatment plans shown in figure (6-a), we see similar boost PTV dose coverage. $D_{95\%}$ was greater than 950 cGy and $V_{95\%}$ was greater than 95% for all techniques. Also $D_{100\%}$ was greater than 90% of the therapeutic dose for all techniques.

From the right breast DVHs shown in figure (6-b), it was clear that the 3$^{rd}$ technique presented the lowest right breast dose. The volumes received doses (up to 900 cGy) were decreased by about 22% when the 3$^{rd}$ technique used compared to the 1$^{st}$ technique. Also the volumes received doses (up to 400 cGy) and (>400-900 cGy) were decreased by 27% and 10% respectively when the 3$^{rd}$ technique used compared to the 2$^{nd}$ technique. The mean dose was 194 cGy for the 3$^{rd}$ technique, while it was 337cGy for the 2$^{nd}$ technique and was 417 cGy for the 1$^{st}$ technique.

By the analysis of Lung and heart DVHs for all techniques, shown in figures (6-c) and (4.26-d) respectively, we didn't find significant differences between the three techniques. Slight increases of lung doses were observed for the 2$^{nd}$ technique. ($V_{50\%}$) didn't exceed 5% of total volume for all techniques.



(a) (b) (c)

**Figure 5. The isodose distributions for patient 3. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

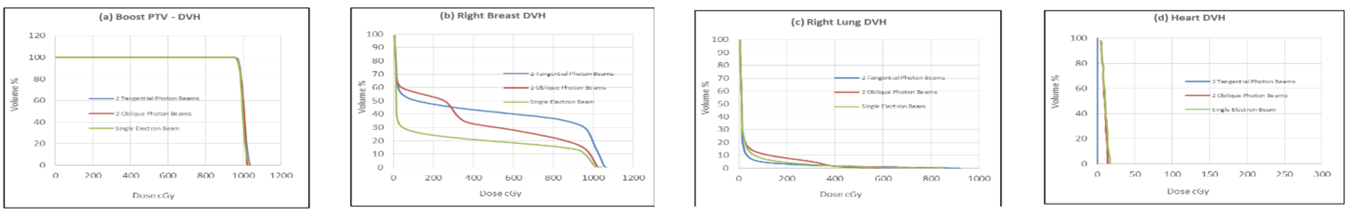



**Figure 6 . The comparisons between DVHs of patient 13 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) Right lung and (d) Heart.**

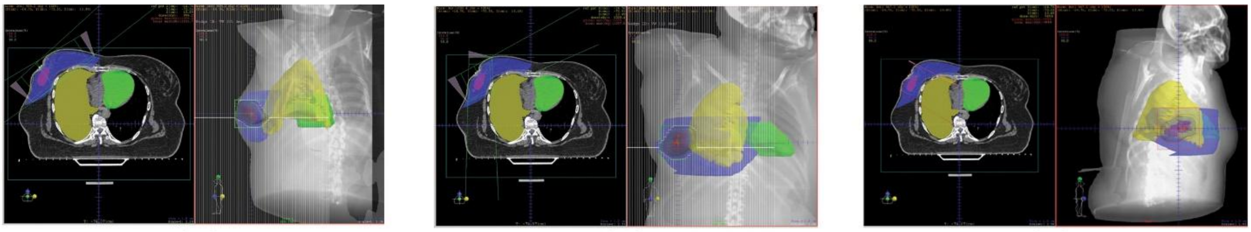
## 3.4 Patient 4

The isodose distributions using the three techniques are shown in “figure 7”. It’s clear that the boost PTV coverage for each technique was accepted. The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in “figure 8”.

From the boost PTV DVHs for all treatment plans shown in figure (8-a), $D_{100}$ of the boost PTV was greater than 900 cGy (90%of therapeutic dose). $D_{95\%}$ was greater than 950 cGy and $V_{95}$% was greater than 95% for all techniques.

From the right breast DVHs shown in figure (8-b), a significant decrease of breast dose was observed with the 3rd technique. The volumes received doses (up to 900 cGy) were decreased by about 22.5% when the 3rd technique was used in comparison with the 1st technique. Also the volumes received doses (up to 400 cGy) were decreased by 30% when the 3rd technique was used in comparison with the 2nd technique. And the volumes received doses (greater than 300 cGy) were decreased by 18% when the 2nd technique was used in comparison with the 1st technique.

By the analysis of Lung and heart DVHs for all techniques, shown in figures (8-c) and (8-d) respectively. ($V_{50\%}$) didn’t exceed 5% of total volume for all techniques.



(a) (b) (c)

**Figure 7. The isodose distributions for patient 4. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

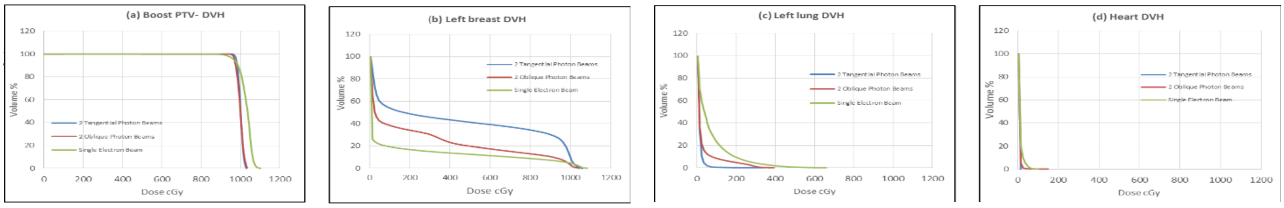



**Figure 8. The comparisons between DVHs of patient 4 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) Right lung and (d) Heart.**

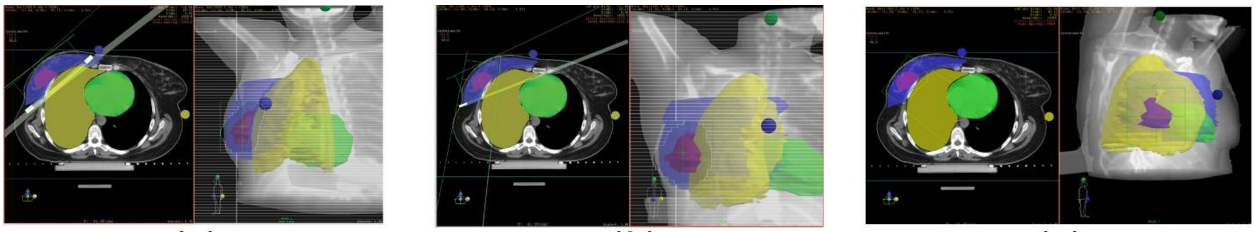
The isodose distributions using the three techniques are shown in “figure 9”. It’s clear that the boost PTV coverage for each technique was accepted. The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in “figure 10”.

From the boost PTV DVHs of all treatment plans, we see similar boost PTV dose coverage, as shown in figure (10-a). $D_{95\%}$ was greater than 95%of therapeutic dose and $V_{95\%}$ was greater than 95% for all techniques. A slight decrease of $D_{100\%}$ = 832 cGy was observed with the 2nd technique. The 2nd technique presented the lowest HI = 6.1% while it was 8.9% and 10.6% for the 3rd and 1st techniques respectively.

From the right breast DVHs shown in figure (10-b). The volumes received doses (up to 900 cGy) were decreased by about 7% when the 3rd technique was used in comparison with the 1st technique. Also the volumes received doses (>400cGy) were decreased by about 16% when the 2nd technique was used in comparison with the 1st technique.

By the analysis of Lung for all techniques, shown in figure (10-c), a significant increases of lung doses were observed for the 3rd technique that $V_{50\%}$ reached 26.5% and $D_{mean}$ =301cGy.

The analysis of heart DVHs for all techniques are shown in figure (10-d), slight increases were observed for the 3rd technique.



(a) (b) (c)

**Figure 9. The isodose distributions for patient 5. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

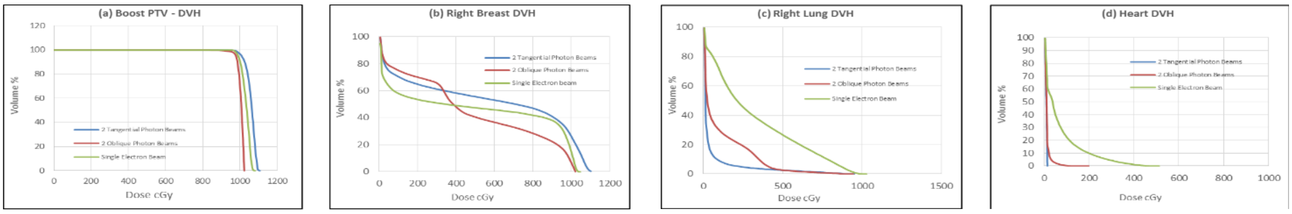



**Figure 10. The comparisons between DVHs of patient 5 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) Right lung and (d) Heart.**

## 3.6 Patient 6

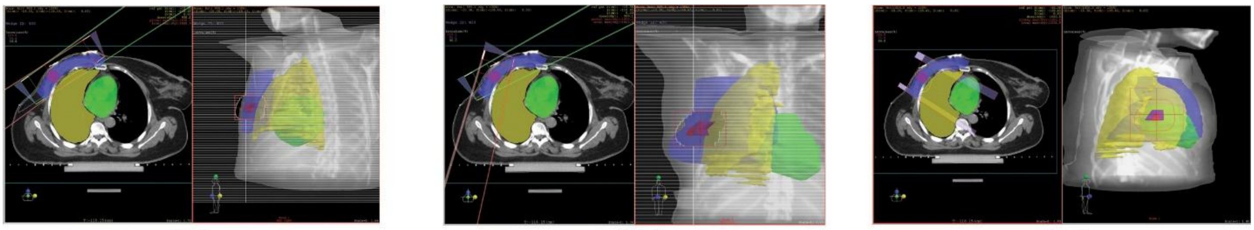
The isodose distributions using the three techniques are shown in “figure 11”. The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in “figure 12”.

From the boost PTV DVHs of all treatment plans shown in figure (12-a). $D_{100\%}$ of the boost PTV was greater than 900 cGy (90%of therapeutic dose) for all techniques. $V_{95\%}$ was 91% for the 1$^{st}$ and 2$^{nd}$ techniques while it was 95% for the 3$^{rd}$ technique.

From the right breast DVHs shown in figure (12-b). The volumes received doses (up to 900 cGy) were decreased by about 20% when the 3$^{rd}$ technique was used in comparison with the 1$^{st}$ technique. The 3$^{rd}$ technique was better than the 2$^{nd}$ technique that it reduced the volumes received doses (up to 400 cGy) and (>400-900 cGy) by 24.5% and 4% respectively. $D_{mean}$ was 212 cGy for the 3$^{rd}$ technique while it was 297 cGy and 395 cGy for the 2$^{nd}$ and the 1$^{st}$ techniques respectively.

By the analysis of Lung DVH for all techniques shown in figure (12-c), Significant increases of lung doses were observed for the 3$^{rd}$ technique that $V_{50}$ reached 13%. $D_{mean}$ was 169 cGy for the 3$^{rd}$ technique while it was 58 cGy and 44 cGy for the 2$^{nd}$ and the 1$^{st}$ techniques respectively.

The analysis of heart DVHs for all techniques are shown in figure (12-d), slight increases were observed for the 3$^{rd}$ technique. $D_{mean}$ was 71.5 cGy for the 3$^{rd}$ technique while it was 12.8 cGy and 6.8 cGy for the 2$^{nd}$ and the 1$^{st}$ techniques respectively.



(a) (b) (c)

**Figure 11. The isodose distributions for patient 6. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

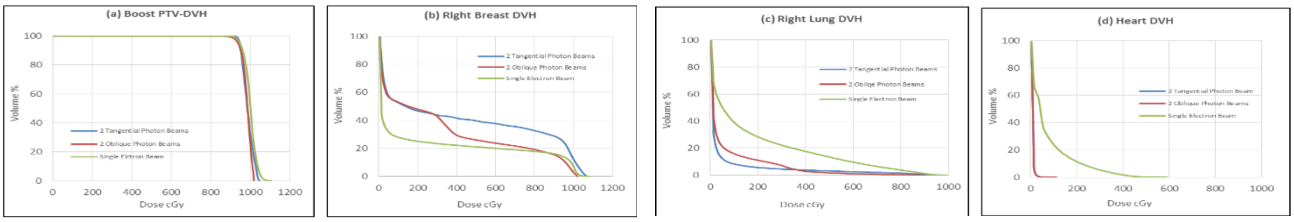


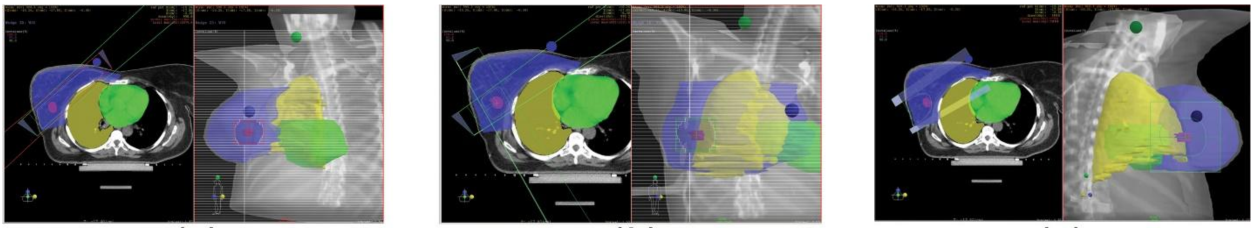

**Figure 12. The comparisons between DVHs of patient 6 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) Right lung and (d) Heart.**

## 3.7 Patient 7

the isodose distributions using the three techniques are shown in “figure 13”. It’s clear that the boost PTV coverage for each technique was accepted. The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in “figure 14”.

From the boost PTV DVHs of all treatment plans, we see similar boost PTV dose coverage, as shown in figure (14-a). $D_{100\%}$ of the boost PTV was greater than 900 cGy (90%of therapeutic dose), $D_{95\%}$ was greater than 950 cGy and $V_{95\%}$ was greater than 95% for all techniques. HI was 10.5% for the 3$^{rd}$ technique while it was 4.2% and 3.1 % for the 2$^{nd}$ and 1$^{st}$ techniques respectively.

By the analysis of boost PTV, right breast, right lung DVH and heart DVHs for all techniques, shown in figures (14-b), (14-c) and (14-d) respectively, we didn't find any effective differences between the three techniques. ($V_{50\%}$) for heart and lung didn't exceed 5% of total volume for all techniques.



(a) (b) (c)

**Figure 13. The isodose distributions for patient 7. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

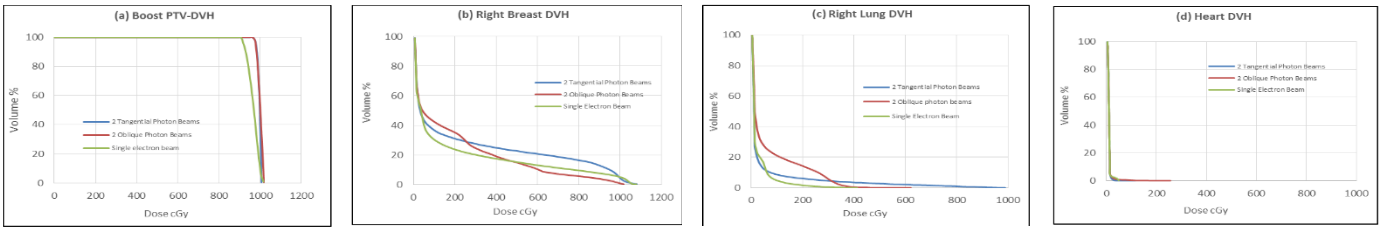



**Figure 14. The comparisons between DVHs of patient 7 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) Right lung and (d) Heart.**

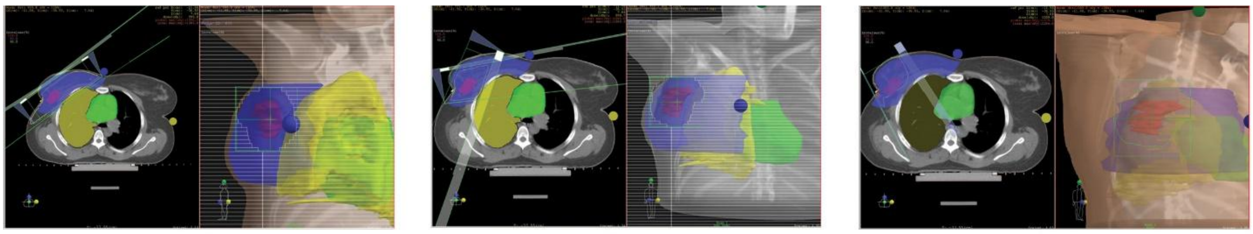
## 3.8 Patient 8

The isodose distributions using the three techniques are shown in "figure 15". The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in "figure 16".

From the boost PTV DVHs of all treatment plans shown in figure (16-a), $D_{100\%}$ of the boost PTV was greater than 900 cGy (90%of therapeutic dose) , $D_{95\%}$ was greater than 950 cGy and $V_{95}$ was greater than 95% for the 1$^{st}$ and 2$^{nd}$ techniques while they were 829 cGy, 930 cGy and 91% for the 3$^{rd}$ technique. Increasing of HI=21% was observed with the 3$^{rd}$ technique, while it was 7.2% and 7.7 % for the 2$^{nd}$ and 1$^{st}$ techniques respectively.

From the right breast DVHs shown in figure (16-b). The volumes received doses (up to 900 cGy) were decreased by about 17.5% when the 3$^{rd}$ technique was used in comparison with the 1$^{st}$ technique. The volumes received doses (up to 400 cGy) were decreased by about 22% when the 3$^{rd}$ technique was used in comparison with the 2$^{nd}$ technique. And the volumes received doses (greater than 300 cGy) were decreased by 13% when the 2$^{nd}$ technique was used in comparison with the 1$^{st}$ technique.

By the analysis right lung and heart DVHs for all techniques, shown in figures (16-c) and (16-d) respectively, we didn't find any significant differences between the three techniques. ($V_{50\%}$) didn't exceed 5% of total volume for all techniques. A slight increases of lung doses were observed with the 2$^{nd}$ and 3$^{rd}$ techniques.



(a) (b) (c)

**Figure 15. The isodose distributions for patient 8. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

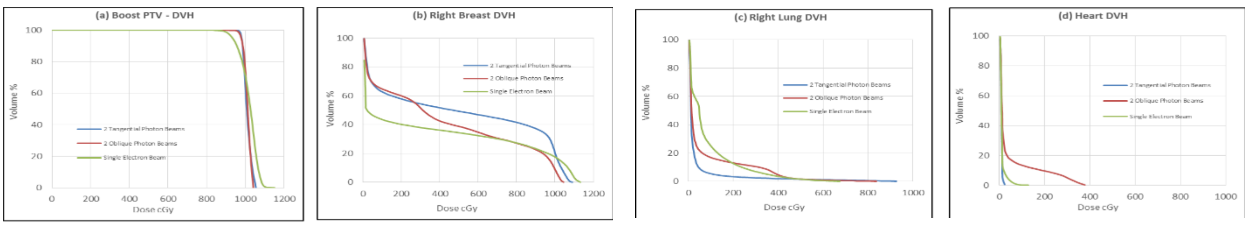



**Figure 16. The comparisons between DVHs of patient 8 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) Right lung and (d) Heart.**

## 3.9 Patient 9

The isodose distributions using the three techniques are shown in “figure 17”. The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in “figure 18”.

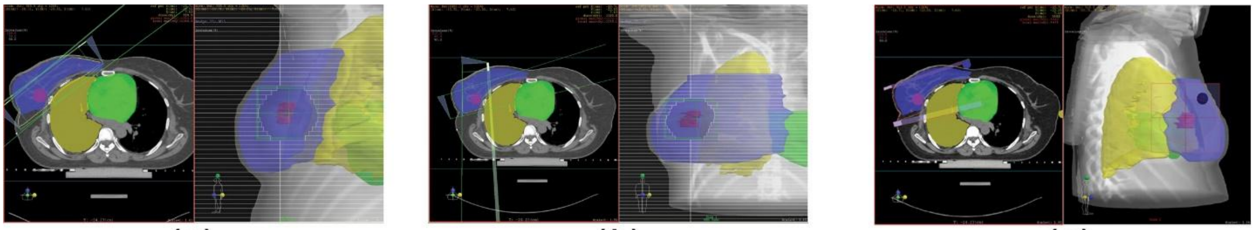
From the boost PTV DVHs of all treatment plans, we see similar boost PTV dose coverage for the 1st and the 2nd techniques and Decrease of $D_{100\%}$ = 876 cGy was observed for the 3rd technique, as shown in figure (18-a).

Increasing of HI= 32.6% was observed with the 3rd technique while it was 5.9% and 6.5% for the 1st and the 2nd techniques. Also increasing of the global maximum value was observed with the 3rd technique “GM=1449 cGy”.

From the right breast DVHs shown in figure (18-b), there were no effective differences between the 1st and the 2nd techniques. For the 3rd technique we observed that the maximum dose received by right breast increased to about 144% of therapeutic dose.

By the analysis right lung and heart DVHs for all techniques, shown in figures (18-c) and (18-d) respectively, we didn’t find any significant differences between the three techniques. ($V_{50\%}$) didn’t exceed 5% of total volume for all techniques. But it was clear that the lowest heart and right lung dose was obtained with the 1st technique. An increase of heart dose was observer with the 2nd technique.

It is clear that the 3rd technique wasn’t preferable for this case.



(a) (b) (c)

**Figure 17. The isodose distributions for patient 9. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

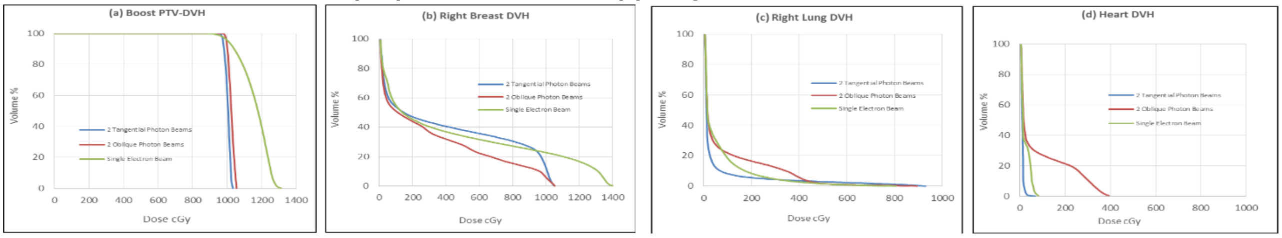



**Figure 18. The comparisons between DVHs of patient 9 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) Right lung and (d) Heart.**

## 3.10 Patient 10

the isodose distributions using the three techniques are shown in “figure 19”. The DVHs of boost PTV, ipsilateral breast, right lung and heart using the three techniques are shown in “figure 20”.

Increasing of HI= 83.4% was observed with the 3rd technique while it was 4.7% and 2.8% for the 1st and the 2nd techniques. Also increasing of the global maximum value was observed with the 3rd technique “GM=1420 cGy”

From the boost PTV DVHs of all treatment plans, we see similar boost PTV dose coverage for the 1st and the 2nd techniques and poor coverage for the 3rd technique, as shown in figure (20-a). Decreases of $D_{100\%}$ = 324 cGy, $D_{95\%}$ =520 cGy and $V_{95\%}$ = 58% were observed for the 3rd technique.

From the right breast DVHs shown in figure (20-b), there were no effective differences between the 1st and the 2nd techniques. For the 3rd technique we observed that the maximum dose received by right breast increased to about 142% of therapeutic dose.

By the analysis right lung and heart DVHs for all techniques, shown in figures (20-c) and (20-d) respectively, we didn’t find any significant differences between the three techniques. ($V_{50\%}$) didn’t exceed 5% of total volume for all techniques.

It is clear that the 3rd technique wasn’t preferable for this case.

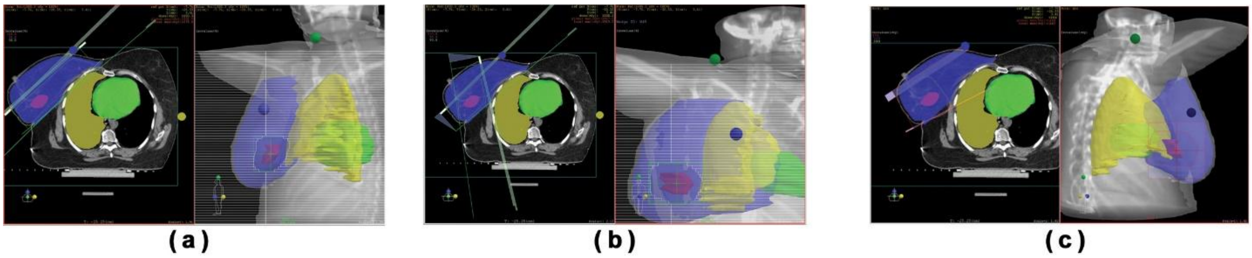



**Figure 19. The isodose distributions for patient 10. (a) Two opposite tangential photon beams, (b) Two oblique photon beams and (c) Single electron beam.**

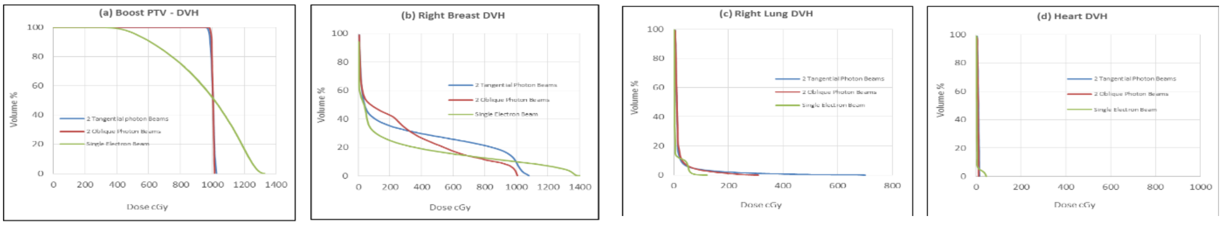



**Figure 20. The comparisons between DVHs of patient 20 using two opposite tangential photon beams, two oblique photon beams and single electron beam for (a) Boost PTV, (b) Right breast, (c) Right lung and (d) Heart.**

## 4 CONCLUSIONS

This work aimed to compare between three different techniques by which a prescribed dose delivered to the right breast boost PTV. Our goal was to determine the best technique in terms of dose delivery to the boost PTV while maintaining acceptable dose distributions in normal breast tissues and the OARs.

Ten early-stage right breast cancer patients with different tumor sizes and locations were selected and the data was collected and analyzed.

By the comparison of DVHs of boost PTV, ipsilateral breast and OARs for each patient using the three different techniques we concluded that:

1- The 3rd technique presented the lowest dose delivered to the normal breast tissues, however it delivered a high doses to the heart and the right lung in some cases.

2- The 1st technique presented the lowest dose delivered to the heart and the right lung, however it delivered a high doses to the normal breast tissues, and so it could be the technique of choice for young patient or patient with medical back ground showing disorders in heart or right lung.

3- When the lung was closed to the tumor bed, the 3rd technique presented the largest dose deliver to the lung and the volume receiving 500 cGy might reached 5%.

4- For small size breast (that meaning the distance between the lung and the skin is small), the 3rd technique presented the largest dose deliver to the lung and the volume receiving 500 cGy might reached 5%.

5- As the thickness of breast decrease in the upper part , the lung becomes closer to the skin.so if the target located upper the 3rd technique may deliver a high dose to the lung (except for large size breast).

6- For superficial tumor bed, the 3rd technique presented the accepted boost PTV dose coverage. So it considered as the best technique in delivering boost dose to tumor bed for cancer patient with superficial target.

7- For large and/or deep tumor bed, the 1st technique provided the beast boost PTV coverage with minimal dose delivered to OARs. So it considered as the technique of choice in delivering boost dose to tumor bed for cancer patient with large deep tumor bed. The 3rd technique was unfavorable for this case because of its poor dose coverage to boost PTV.

8- For inner boost PTV located close to the heart, the 2nd technique was unfavorable because it delivered a high dose to the heart, while the 1st technique presented the largest lung dose.

Finally, we did not find a definite irradiation technique that could sufficiently deliver the boost dose to the boost PTV and totally spare the OARs, as the treatment planning is multifactorial process affected by multiple factors including radiation type and energy, technique of irradiation, target size, target location, target depth, breast size, distance between target and OARs, distance between the skin and OARs.

So we recommended that there was no standard procedures could be considered as the best technique to deliver the boost dose to tumor bed while maintaining acceptable dose distributions in normal breast tissues and the OARs, and an individualized treatment, several plans using different irradiation techniques should be developed for each patient individually to reach the best boost PTV dose coverage and with minimal OARs' dose.

## 5 REFRENCES

1. Jemal, A., Bray, F., Center, M., Ferlay, J., Ward, E., and Forman D.2011. Global cancerstatistics. CA Cancer. J. Clin. 61,69–90.

2. Tachian A. , Kozak K., Doppke K., KatzA., Smith B., Gadd M., Specht M., Hughes K., Braaten K., Kachnic L., Recht A., and Powell S. 2006 . Initial dosimetric experience using simple three-dimensional conformal external-beam accelerated partial-breast irradiation. Int. J. Radiation Oncology Bio Phys., 64,1092–1099.

3. Aly M., Glatting G., Jahnke L., Wenz F., and Abo-Madyan Y.2015. Comparison of breast simultaneous integrated boost (SIB) radiotherapy techniques. Radiation Oncology, 10-139.

4.Van Parijs H., Miedema G., Vinh-Hung V., Verbanck S., Adriaenssens N., Kerkhove D., Reynders T., Schuermans D., Leysen K., Hanon S., Van Camp G., Vincken W., Storme G., Verellen D.and De Ridder M. 2012. Short course radiotherapy with simultaneousintegrated boost for stage I-II breast cancer, early toxicities of a randomized clinical trial. Radiation Oncology, 7-80.

5. Hamza H., Aly M., and Soliman M. 2011. Asymmetric open field-in-field can replace wedged fields in tangential whole breast irradiation. GB. Cancer , 10-250

6. Vaegler S., Bratengeier K., Beckmann G., Flentje M., 2015. Conformal breast irradiation with the arm of the affected side parallel to the body. Strahlenther Onkol.

7. Farace P., Deidda M., Lamundo De Cumis I., Deiana E., Farigu R., and Lay G., 2013. Bi-tangential hybrid IMRT for sparing the shoulder in whole breast irradiation. Strahlenther Onkol.,189, 967–71.

8. Abo-Madyan Y., Polednik M., Rahn A., Schneider F., Dobler B., and Wenz F. 2008. Improving dose homogeneity in large breasts by IMRT: efficacy and dosimetric accuracy of different techniques. Strahlenther Onkol., 184, 86–92.

9. Van Parijs H., Reynders T., Heuninckx K., Verellen D., Storme G., and De Ridder M. 2014. Breast conserving treatment for breast cancer: dosimetric comparison of different non-invasive techniques for additional boost delivery. Radiation Oncology. 9-36.

10. Bartelink H., Horiot J., Poortmans P., Struikmans H., Bogaert V., and Fourquet A. 2007. Impact of a higher radiation dose on local control and survival in breast conserving therapy of early breast cancer: 10-year results of the randomized boost versus no boost., J. Clin. Oncol., 25, 3259–65.

11. Bahadur Y., Constantinescu C., Fawzy E., and Ghasal N. 2009. 3D-CRT techniques for simultaneously integrated boost in breast conserving radiation therapy. Med. J. Cairo Univ., 77,179-185.

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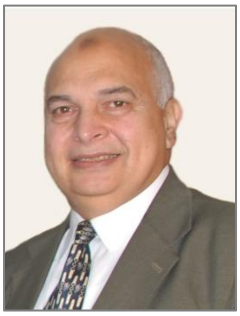

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