EFFECT OF BREAST AUGMENTATION AFTER BREAST-CONSERVING SURGERY FOR BREAST CANCER ON RADIATION DOSE—SILICONE PROSTHESIS AND CHANGES IN RADIATION DOSE—

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(Received 11 March 2008, accepted 20 October 2008)

Abstract: The results of a study simulating postoperative radiation therapy of remaining breast tissue with a silicone bag prosthesis implanted to examine the effects of the prosthesis on radiation dosage and surrounding tissue are reported. The evaluation was conducted in two stages: 1) a water phantom was used to evaluate scattering effects of a prosthesis installed inside the phantom using GRD set around the prosthesis. Measurements were conducted on both entrance and rear sides of the prosthesis. 2) a Rand phantom was used to measure radiation doses around the prosthesis. The first evaluation resulted in a less than 5.4% reduction in dose at the rear side of the prosthesis whereas the second evaluation, for opposing portal irradiation used with breast-conserving surgical treatment, showed the effects of the prosthesis on radiation dosage being within ±2%, the permitted treatment range. In conclusion, for treating breast cancer, combining surgical treatment of the cancer with implanting of prosthesis for breast reconstruction followed by radiation treatment appears feasible as no effects on dosage were observed on treatment effectiveness.

Key words: Breast cancer, Augmentation & reconstruction, Silicone prosthesis

INTRODUCTION

Breast-conserving surgery is common for treating early stage breast cancer. Several types of operations are available including lumpectomy, partial resection and subcutaneous mastectomy to allow a wide-ranging patients' needs to be addressed. Previously, breast reconstruction was conducted after breasts were totally removed by mastectomy treatment for cancer. Now, increasingly more patients expect improved cosmetic reconstruction and augmentation after breast-conserving surgery. There are various issues related to cosmetic reconstruction. In postoperative radiation therapy of the remaining breast tissue to control recurrence of malignant tumors before cosmetic surgery, plastic surgeons have found that poor skin stretching being an obstacle for reconstruction. If silicone or other types of prosthesis are implanted for reconstruction at surgical treatment and postoperative radiation therapy is required, the effects on the body are unknown. As no established approach exists, it is not frequently used. This is our report on the results of a study investigating the effects of implanting a silicone bag prosthesis on radiation treatment including radiation doses and changes in the surrounding tissue, subcutaneous fat and peripheral.

MATERIALS AND METHODS

The prosthesis used in this study was a silicone bag prosthesis (McGhan Style 40, INAMED, USA, shell: silicone polymer, filler: poly di-methyl siloxane (DMPS), diameter ø11 cm, thickness: head side 1 cm, tail side 4 cm, weight 280 g). The therapeutic radiation source used was an ONCOR Impression PLUS (Siemens, USA) linear accelerator. Dose Ace GD-302M fluoroglass dosimeters (Asahi Technoglass Corp., Japan) were used. The fluoroglass dosimeter uses a glass rod detector (GRD) (composition: silver activated phosphate glass, cylindrical configuration: 1.5 mm diameter, 12 mm length) that is based on radiophotoluminescence (RPL). The detector is excited using a UV laser to measure the radiation level. Previously, we had reported that the precision of GRD was 1.81%. This study uses the findings of this note. GRD calibration conditions were in water phantom, using 4 MV x-ray, 10×10 cm field, source chamber distance (SCD) 100 cm, depth 10 cm, GRD is a calibrated farmer type ionization chamber (Applied Engineering Inc., C110 Farmer (JARP)). Measurements were conducted in two stages: Measurement 1—assessment of scattering effects of silicone prosthesis (Fig. 1)

In this study, we considered Klein report in preparation of prosthesis for single port irradiation and assessed effects of prosthesis on penetration rate.

The silicone prosthesis was attached to an acrylic board that was installed inside a water phantom with the center of the silicone prosthesis 10 cm from the water surface. Radiation doses were measured with the prosthesis installed and removed. Fig. 1 shows the placement of the 3 GRD sets used in both cases at the front side of the prosthesis and at the rear of the prosthesis. 5 measurements each were made with and without the prosthesis installed. Radiation applied was AP single port irradiation 4 MV x-ray, 2 Gy/fraction. Each measurement value is normalized at 10 cm depth in water. Measurement 2—simulation of postoperative irradiation.
following breast-conserving surgery using a Rand phantom (Figs. 3-6)
The silicone prosthesis was placed on a Rand phantom as shown in Fig. 3. Similarly to Measurement 1, sets of 3 GRD were placed at 10 points in front of the prosthesis (corresponding to the front of the body) and 10 points behind the prosthesis (corresponding to the chest wall side of the body) for a total of 20 measurement points as shown in Fig. 4. The prosthesis was covered with a 1cm thick bolus (mixture of poly vinyl alcohol and sodium borate) with absorption similar to skin. Irradiation conditions of 4 MV x-ray opposing portal half beam irradiation, 15° wedge, half field, 2 Gy/fraction were used (Fig. 6). Inside the Rand phantom, additional dose measurements near the peripheral pleura were made to assess the effects on the peripheral lung areas (Fig. 5). Parametric comparisons used t-test of the Measurement 2.
Fig. 3 Measurements using human Rand phantom. Irradiation conditions were the same as used for postoperative treatment of breast tissue at 4 MV x-ray, half-beam, 2 Gy/fraction. Bolus was placed on silicone prosthesis surface as for human skin.

Fig. 5 GRD position (chest wall). One GRD placed in chest wall point in phantom.

Fig. 6 Treatment planning (silicone CT number: 110 HU).
RESULTS

Measurement 1—assessment of scattering effects of silicone prosthesis (Fig. 2)
As shown in Fig. 2, with the prosthesis installed, the 3 point values (high, median and low point) at the front of the prosthesis (x-ray incident side) were 1.06, 1.03 and 0.92, respectively. Without the prosthesis installed, the values were 1.07, 1.00 and 0.97, each. With the prosthesis installed, values at the backside of the prosthesis (x-ray exit side) were 0.83, 0.87 and 0.88, each. Without the prosthesis installed, the values were 0.92, 0.92 and 0.90, respectively. At the center point of the prosthesis (2 cm thickness), the x-ray dose on the rear side was 5.4% lower than those of the entrance side.

Measurement 2—simulation of postoperative irradiation following breast-conserving surgery with a Rand phantom (Table 1, Fig. 7)
Measurements of dose at the front side of the silicone prosthesis (corresponding to the human body surface) at locations corresponding to the head side, axilla, caudal side and mediastinum in clockwise order from Fig. 7 and Table 1 were 1: 1.901 Gy (SD 0.069), 2: 2.016 Gy (SD 0.091), 3: 1.997 Gy (SD 0.131), 4: 1.996 Gy (SD 0.133), 5: 1.993 Gy (SD 0.119), 6: 2.026 Gy (SD 0.079), 7: 2.186 Gy (SD 0.098), 8: 2.180 Gy (SD 0.141), 9: 2.097 Gy (SD 0.113), 10: 2.028 Gy (SD 0.072). For the backside of the silicone prosthesis (corresponding to the chest wall) results for measurements at the head side, mediastinum, caudal side and axilla in counterclockwise order were 1: 1.894 Gy (SD 0.063), 2: 1.843 Gy (SD 0.235), 3: 1.991 Gy (SD 0.092), 4: 2.038 Gy (SD 0.047), 5: 1.880 Gy (SD 0.105), 6: 1.922 Gy (SD 0.100), 7: 2.050 Gy (SD 0.119), 8: 1.989 Gy (SD 0.123), 9: 2.019 Gy (SD 0.052), 10: 1.969 Gy (SD 0.047). If parallel opposed irradiation is conducted in accordance with conventional radiation therapy after breast-conserving surgery, mean measured dose at the front side was 2.042 Gy (SD 0.027, CV 1.3%) and mean dose measured at the chest wall side was 1.960 Gy (SD 0.056, CV 2.9%). The mean measured doses at the front side of prosthesis and the backside differed by (t (17) =2.300, p<0.05). Mean dose inside the phantom assuming a peripheral pleural point dose was 2.066 Gy (SD 0.075, CV 3.8%).

DISCUSSION
According to our assessment, conducted with high energy x-rays of the effect of silicone prosthesis on radiation dose due to scattering of x-rays by the prosthesis, AP single port irradiation had no effects on the x-ray entrance surface (silicone prosthesis surface, front side of human body). However, there were differences observed between the cases with and without the prosthesis installed on x-ray exit side (chest wall side). These results suggest that radiation treatment using single portal to control recurrence after
Augmentation with silicone prosthesis may provide inadequate dosage that should be taken into account when conducting treatment. From the experimental planning images, the CT number of silicone at 110 HU was higher than for water. We had expected that the silicone prosthesis would absorb x-rays and the results showed that the x-ray dose on the rear side was 5.4% lower than those of the entrance side. Also, if the parallel opposing portal irradiation method, commonly used for postoperative irradiation after breast-conserving surgery, is used, the 5.4% reduction in dose using single port irradiation became a +2% increase at the front surface of the silicone prosthesis and -2% reduction at the chest wall. This shows that for the treatment plan, the dose is within the permissible range of ±2%. Klein reported that measurements of the effect of prosthesis made using a thermo luminescent dosimeter (TLD) and a

<table>
<thead>
<tr>
<th>Point</th>
<th>Chest wall side mean (Gy)/SD mean (Gy)</th>
<th>Surface side mean (Gy)/SD mean (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1 (Axillary side)</td>
<td>1.894 0.063</td>
<td>1.901 0.069</td>
</tr>
<tr>
<td>2</td>
<td>1.843 0.235</td>
<td>2.016 0.091</td>
</tr>
<tr>
<td>3</td>
<td>1.991 0.092</td>
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<td>4</td>
<td>2.038 0.047</td>
<td>1.996 0.133</td>
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<tr>
<td>5</td>
<td>1.880 0.105</td>
<td>1.993 0.119</td>
</tr>
<tr>
<td>6</td>
<td>1.922 0.100</td>
<td>2.026 0.079</td>
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<tr>
<td>(Mediastinal side)</td>
<td></td>
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<tr>
<td>7</td>
<td>2.050 0.119</td>
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<tr>
<td>10</td>
<td>1.969 0.047</td>
<td>2.028 0.072</td>
</tr>
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</table>

Compare with weight point dose 2 Gy
Chest wall side: 1.960 Gy, SD 0.056, CV 2.9%
Surface side: 2.042 Gy, SD 0.027, CV 1.3%

Fig. 7 Results of Measurement 2.
thin window parallel-plate chamber, for parallel opposed irradiation showed similar effects on silicone prosthesis to skin tissue. Also, the presence of the silicone prosthesis causes the build-up on the surface for single port port irradiation that was reported by Klein13 to be 10%. In the same paper results of measurements using TLD were reported to be +17 – 19% on the proximal side and -1 +4.5% on the distal side. The results of our study using GRD had differed. McGinley reported changes in dose of -8 +5% at the proximal and distal interface between the skin and silicone for single port irradiation13, 14. Our results differed from these studies because it may be related to the use of TLD versus GRD. Klein13 reported that the dose was affected but not the dose distribution, which corresponds to our results. Additionally, when planning the radiation field setting for irradiation of the breast requires attention to the effect on the peripheral lung directly below the pleura near the breast. The central irradiation 2 Gy dose resulted in a dose of 2.066 Gy/SD: 0.075 (coefficient of variation: CV 3.8%). This dose is not of a level that would result in acute reactions such as radiation pneumonia or delayed responses such as lung fibrosis and it can be inferred that it would not be a deleterious factor. There were no reports found addressing this point. The results of this study demonstrated that the irradiation treatment with implanted silicone prosthesis would result in changes in therapeutic dose and exposure to surrounding organs within permissible ranges. The main objective for the use of silicone prosthesis in breast reconstruction is improvement of cosmetic aspects. Thus, in addition to tumor control, assessment of visual and tactile aspects is important. Silicone prosthesis is frequently used because of the hardness of silicone similar to that of the original breast14. Moreover, there have been reports that there have been differences on where to place top priority relating to the timing of implanting prosthesis: oncologists claim tumor control as the top priority vs. plastic surgeons cosmetic improvement the highest priority. A consensus on this issue has not been reached. Evans et al.3 reviewed the 6-month follow-up for more than 300 cases and found no significant differences in complication rates between radiation and non-radiation groups. Complications occurred more rapidly for the radiation group with complications including pain and shifting of silicone due to poor fixing. Mori et al.3 found complications in 60% of cases with implants including atrophy, deviation and pain. However, as implants for breast reconstruction are not permanent, it is possible to remove prosthesis if complications occur. Mark et al.6 reported that 86% of cases had no problem related to cosmetic evaluation compared with whether adjuvant therapy but contraction was found in 14% of cases. However, no correlation was reported in these studies between the results of the cosmetic assessment, radiation dose, age at the time of radiation treatment, cancer type, prosthesis position and type and systemic chemotherapy7, 9. Faucher et al.5 discussed the need for high precision in radiotherapy. Various types of complications have been reported including contraction, infection and damage for cases using synthetic prosthesis and atrophy and fat necrosis caused by poor blood flow for cases using auto tissue with depressions similar to those with artificial implants5. Furthermore, smoking, diabetes mellitus (DM), and chemotherapy have been reported as risk factors for complications9. About half of the cases using TRAM, latissimus dorsi muscle flap and other tissues for auto-reconstruction and auto-transplantation reported necrosis and other complications10, 11. While about 44% of these reconstruction cases had chemotherapy after mastectomy, there are others reporting that auto-transplantation provided better results12. One paper on tumor control reported that for early stage cancer and recurring cancer case that had been treated with surgery and radiation therapy, review of the cases at 35-84 months found that the presence of prosthesis did not affect treatment outcomes and that cosmetic evaluation was excellent as well10. The overall impression of the reports reviewed was that the cosmetic evaluation was higher than expected. However, there were also reports where the cosmetic evaluation was low as well. Negative factors include age over 50 years and the use of bolus during irradiation. The use of bolus tended to result in excess dosage with occurrence rate being 60% for silicone prosthesis versus 23% for saline solution prosthesis. Complications included heavy fibrosis, necrosis, excess doses and rupture of prosthesis bags11, 15. There are also reports of severe reaction in normal tissue in cases where bolus were used with 400-600 kV middle voltage14. With regards to radiation dose, for 44-62 Gy about 30% of cases had fibrosis surrounding the prosthesis but cosmetic assessment was reported to be good16. Caffee et al.17 reported that for an experiment conducted using rabbits (about 3000 rad using parallel opposed Cobalt-60 source), after 6 months the prosthesis had partially degenerated and hair re-growth on the irradiated area had been delayed. Based on the papers reviewed, a consensus on applicable cases types has not been reached. In case of wide surgical resection and localized aggressive cases, rupture of silicone prosthesis have been experienced18 that resulted in rheumatoid arthritis, scleroderma and other collagen diseases with worsening of the primary disease over 1-4 months and turning into fibrosis with increasing pain after 8-11 months19. There are also reports regarding degeneration of silicone including change in color to yellow due to effects on preservatives and impurities13, color change at 60 Gy, changes in color and size at 100 Gy19. There are other reports of discoloration of silicone and/or stiffening at about 60 Gy20. However, others have reported no effects at 100 Gy19, 20.

CONCLUSION

For radiation therapy following breast-conserving surgery combined with breast reconstruction using silicone prosthesis, no deleterious effects of the presence of silicone prosthesis on surrounding tissue due to changes in dosage were found. Thus, it is concluded that from the standpoint of radiation dosage, there were no significant issues with procedures combining treatment with breast augmentation.


References


