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Original Article

An evaluation of three tangential breast irradiation techniques in Hong Kong

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Abstract

Background and Purpose: Loco-regional radiotherapy after breast conserving surgery significantly reduces the risk of recurrence but may induce complications in the lungs. The complications are related to the lung volume irradiated and the lung dose delivered. The purpose of this study was to evaluate three tangential breast irradiation techniques i.e. conventional technique, gantry tilting technique and half-beam block technique in terms of the percentage of irradiated lung volume and high dose lung volume for patients of different sizes.

Materials and Method: Treatment planning of the three tangential breast irradiation techniques was performed using the CT scans of 20 patients with early-stage breast cancer after lumpectomy.

Results: When compared with conventional technique, both half beam block technique and gantry tilting technique irradiated a significantly smaller percentage of lung volume and delivered a smaller percentage of high dose (above 30 Gy) volume in the lung. Patients with large breasts had a significantly higher percentage of lung volume irradiated to above 30Gy than those patients with small and medium breasts. The combined effect of tangential separation and technique only produced significant effect on the percentage of total lung volume irradiated but not on the high dose volume.

Conclusions: Gantry tilting and half-beam block techniques can reduce a significant amount of lung volume and high dose lung volume. Half-beam block technique is recommended for small and medium breast size while for large breast size, gantry tilting technique is preferred.

Keywords

Breast cancer; radiotherapy technique; tangential irradiation

INTRODUCTION

Background

Breast conservative treatment (lumpectomy followed by radiotherapy) has become an accepted alternative to mastectomy for women with UICC stages I and II breast cancer.[1–3] It achieves equivalent long-term survival and local control as mastectomy but causes minimal psychological trauma.[4] As long-term survival can be expected in patients receiving breast-conserving radiotherapy, it is important to consider the risk of complications after the treatment. One major concern is radiation induced pulmonary complications.

Pulmonary complications

In tangential breast irradiation, 20–30% of the ipsilateral lung has been found to be irradiated.[5] Post-irradiation pneumonitis has also been reported in 1 to 16% of patients.[6,7] The incidence and severity of pneumonitis were shown to increase exponentially with the volume of lung irradiated, the total lung dose and the dose rate.[8] Although it is widely accepted that the incidence of pulmonary compli-

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cations from radiotherapy (20 samples for each technique) increases with the volume of lung irradiated, little literature can be found showing the volume of lung irradiated by various breast irradiation techniques.

Factors affecting irradiated volume

Patient anatomy, treatment position and radiation technique affect the volume of lung involved in the radiation treatment for breast cancer.[9,10] Patients with a very convex rib cage can have an increased volume irradiated in the ipsilateral lung as the thoracic contents protrude into the treatment volume.[11] Patients with large breasts are more likely to have higher incidence of lung fibrosis and poorer cosmetic effect due to larger irradiated lung volume and greater dose heterogeneity.[12] It has been suggested that the integral ipsilateral lung dose could be reduced by 70% using prone tangential breast radiotherapy.[13] It is, therefore, important to establish an optimal treatment for each patient.

Tangential breast techniques in Hong Kong

In Hong Kong, three tangential breast treatment techniques are commonly used for breast conserving treatment. The conventional technique (CON) (Fig. 1) makes no attempt to reduce the divergence of the tangential fields. Thus a relatively large volume of lung within the treatment field is irradiated. Gantry tilting technique (GTT) (Fig. 2) aligns the posterior border of both tangential fields to reduce the volume of lung included. If the lung tissue at 2 cm depth received dose greater than 90% of the prescribed dose, the gantry angle would be tilted 3–5° away from lung to minimize the inclusion of lung tissue within the treatment field. This technique could be modified using the asymmetric jaws or custom cerrobend blocks to create the half beam block technique (HBB) (Fig. 3). By applying half-beam block, the posterior half of the field is blocked off and the volume of lung irradiated is thus minimized. Using cerrobend blocks for half beam technique was found to increase the dose to the contralateral breast.[14] In Hong Kong, as many of the linear accelerators are now equipped with asymmetric jaws, cerrobend blocks are rarely needed.

The purpose of this study was to compare the three tangential breast techniques so that an optimal technique can be identified for patients with different breast sizes. The dependent variables in the study are: (i) the percentage volume of lung irradiated, (ii) the percentage of lung receiving >30 Gy (60% of the prescribed dose for a total dose of 50 Gy). The effects of different breast sizes on the two variables above and the combined effect of technique and breast size on the two variables will also be evaluated.

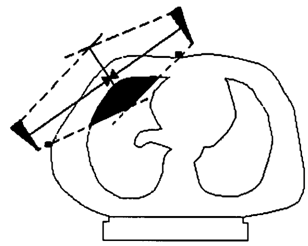

Figure 1. Conventional technique of breast tangential opposed fields. No attempt is made to minimize the beam divergence.

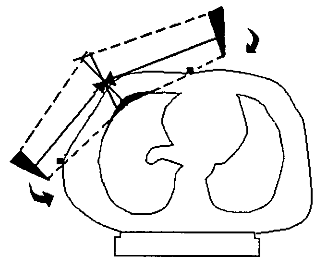

Figure 2. Gantry tilting technique. The two tangential beams are tilted away from lung to minimize dose to lung.

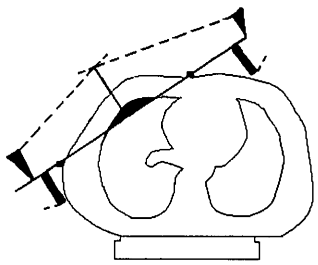

Figure 3. Half beam block technique. The posterior half of the tangential beam is blocked off to minimize lung dose.

METHOD AND MATERIALS

Sample selection

The computed tomographic (CT) scans of 20 patients who had received lumpectomy followed by radiotherapy were retrieved at random. Their CT images were used to determine the body contour and the lung contour for treatment planning.

Equipment

For each patient, a full set of CT scans of the chest region were downloaded into the Focus Treatment Planning System. This system was equipped with 3-D planning facilities and used the true three-dimensional dose calculation algorithm, thus, more precise dose distributions could be computed.

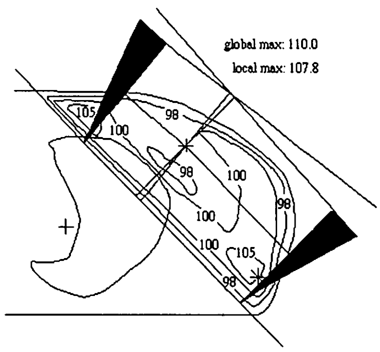

Figure 4. The isodose distribution of a typical tangential pair in the principal treatment plane.

Treatment planning

Tangential fields were constructed on the patient's contour from the CT images with the medial border at the midline of the body and the lateral border at the mid-axillary line. The superior and inferior borders were 1–2 cm beyond the visible breast tissue as assessed from the CT scans. Three separate treatment plans – the conventional technique, gantry tilting technique and half beam block technique were planned for each patient and optimized on the same set of patient outlines and lung contours. A 6 MV photon beam was used with 0.2 g/cm^3 lung density correction. All treatment plans were optimized based on the following set of planning criteria: (a) 105% isodose level should not appear on the skin. (b) 98% isodose level runs parallel to the skin surface at a depth of 0.5 to 1 cm. (c) Hot spot should be less than 110% of the prescribed dose. (d) The maximum depth of lung tissue irradiated should not exceed 3 cm (Fig. 4). For each plan, the dose volume histogram for lung tissue was obtained.

Data collection

The volume of lung encompassed by the 50% isodose line and 60% isodose line, i.e. 30 Gy for a prescribed dose of 50 Gy, was assessed. The 50% isodose line corresponds to the geometric boundary of photon fields. It could provide an accurate measurement of total lung volume irradiated within the tangential fields.[15] 30 Gy was chosen because it has been reported as critical in terms of radiation induced lung damage.[9,16] To estimate the volumes as a percentage of the whole lung, the cumulative dose volume histograms for lung tissue were used. At 50% and 60% of the prescribed dose, two perpendicular lines were drawn from the X-axis to meet the curve. The intersection points correspond to the respective percentage of the total volume of lung irradiated (Fig. 5).

Breast size is an important variable in dose distribution and can be reliably represented using tangential separation.[11,12] Tangential separation is the linear distance between the lateral and medial tangential field entry points.[12] In the CT slice that contained the principal plane, the ruler function in the planning system was used to measure the distance between the entry points of the medial and lateral fields (Fig. 6).

Data analysis

The percentage lung volume irradiated to above 50% of the prescribed dose and the percentage volume of lung irradiated to above 30 Gy were the

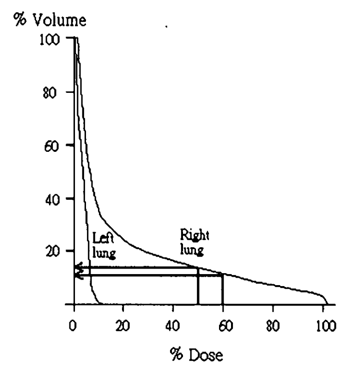

Figure 5. Cumulative dose volume histogram to determine the volume of lung encompassed by the 50% and 60% isodose lines.

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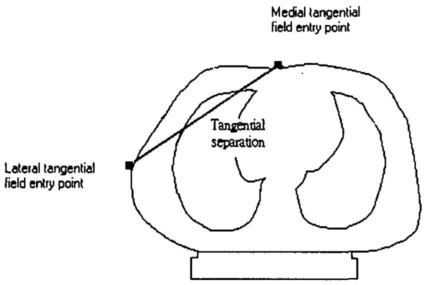

Figure 6. Definition of tangential separation

dependent variables to be investigated. To study the simultaneous effects of two independent variables on repeated samples, two-way ANOVA with one repeated factor was used. The two independent variables are tangential separation (with three groups) and irradiation techniques (a repeated factor with three types). In this design, the effect of each independent variable was also examined separately. A post-hoc test, Bonferroni method was then used to compare pairs of group means.

RESULTS

Samples

All the 20 patients recruited for this study are Chinese females. Eleven (55%) patients had cancer of the left breast and 9 (45%) of the right breast. Their tangential separations range from 17.5 cm to 24 cm. According to the tangential separations, the patients were divided into three groups. The separations <20cm, 20–22cm and >22cm were classified as small, medium and large breast sizes respectively.

Percentage of lung volume above 50% of prescribed dose

The mean percentage of ipsilateral lung volumes above 50% of the prescribed dose, according to the three irradiation techniques and tangential separation, are shown in Table 1. Significant difference was found among the three tangential techniques ($p<0.0001$). Post-hoc multiple comparison using Bonferroni test showed that the conventional technique irradiated a significantly higher percentage of lung when compared with the other two techniques. No significant difference between the gantry tilting and half beam block techniques was demonstrated. Neither was any significant difference found among the three separation groups ($p>0.05$). However, as shown in Fig. 7, a statistical interaction was detected between the tangential separation and technique (tangential separation × technique: $p<0.05$). That is to say, the percentage lung volume irradiated to above 50% of the prescribed dose does not only vary with the tangential separation, but also with the technique used. All techniques showed an increase in the percentage of lung volume above 50% of prescribed dose from medium separation to large separation, but the increase was more marked for the conventional technique than the other two techniques. The gantry tilting technique resulted in the smallest amount of lung irradiated across the three groups of tangential separation, though the result was not statistically significant.

Table 1. Effect of irradiation techniques and tangential separation on the percentage lung volume above 50% of the prescribed dose

Irradiation technique [a]	Tangential separation [b]			
	<20 cm	20–22 cm	>22 cm	All tangential groups
CON	12.50 ± 8.07	11.57 ± 6.19	21.29 ± 4.23	15.25 ± 7.27
GTT [c]	9.38 ± 8.44	9.36 ± 7.16	15.71 ± 5.56	11.48 ± 7.18
HBB [de]	10.42 ± 7.95	11.57 ± 6.02	17.00 ± 5.00	13.13 ± 6.52
All technique groups	10.77 ± 7.56	10.86 ± 6.09	18.00 ± 5.17	

Values are mean %± SD; Abbreviations: CON = conventional technique; GTT = gantry tilting technique; HBB= half beam block technique

Tangential separation × technique: $p<0.05$

[a] Technique-effect: $p<0.0001$; [b] Tangential separation-effect: $p>0.05$;

Post-hoc test: [c] vs CON $p<0.001$; [d] vs CON $p<0.01$; [e] vs GTT $p>0.05$

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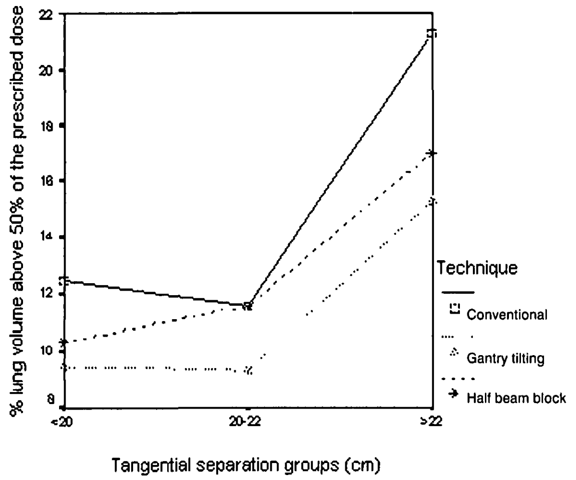

Figure 7. Relationship between percentage lung volume above 50% of the prescribed dose and the tangential separation in the three irradiation techniques (Tangential separation × technique: $p<0.05$)

Percentage of lung volume above 30Gy

The mean and standard deviations of percentage of lung volumes above 30 Gy among the three irradiation techniques and tangential groups are shown in Table 2 and significant difference was found among the three techniques ($p<0.0001$). Post-hoc analysis demonstrated that for half beam block and gantry tilting techniques, significantly smaller percentages of lung volumes received dose above 30 Gy when compared to the conventional technique. No significant difference was found between gantry tilting and half beam block techniques.

Significant difference was also found among the three tangential separation groups ($p<0.05$). The largest separation group had a significantly higher percentage of lung volume receiving a dose above 30 Gy when compared with the other two smaller separation groups. There was no significant difference between small and medium tangential separation groups. The interaction between technique and tangential separation was not statistically significant (tangential separation × technique: $p>0.05$). This means that the variation in the percentage of lung volume receiving a dose above 30 Gy is similar for all techniques in the three tangential separation groups.

DISCUSSION

Percentage of lung volume irradiated and lung complications

The volume of lung irradiated is a factor affecting the severity of radiation-induced lung injury.[17] The results of this study showed that half beam block and gantry tilting techniques could significantly reduce the percentage of irradiated lung volume to 13.13% and 11.48% respectively when compared with 15.25% in conventional technique (Table 1). Comparable results were obtained by Mallik and colleagues[18] who found that the mean percentage of lung volume irradiated was 16.2% within the breast tangential fields. Lind and colleagues[19] illustrated that 26% of the ipsilateral lung was irradiated when the internal mammary nodes were included within the tangenital fields. In the techniques of this study, the IMC was excluded and the medial tangenital field edge was at the midline of the patients. This clearly shows that the exclusion of the IMC from the tangenital field could reduce the

Table 2. Effect of irradiation techniques and tangential separation on the percentage lung volume above 30 Gy

Irradiation technique [a]	Tangential separation [b]			
	<20 cm	20–22 cm[f]	>22 cm[gh]	All tangential groups
CON	11.33 ± 8.04	9.43 ± 6.02	19.29 ± 4.15	13.45 ± 6.79
GTT [c]	8.17 ± 7.65	8.43 ± 5.83	15.29 ± 4.89	10.75 ± 5.47
HBB [de]	9.00 ± 7.75	9.21 ± 5.64	15.21 ± 4.79	11.25 ± 4.77
All technique groups	9.50 ± 12.58	9.02 ± 13.15	16.6 ± 11.86	

Values are mean %+ SD; Abbreviations: CON = conventional technique; GTT = gantry tilting technique; HBB= half beam block technique

Tangential separation technique: $p>0.05$

[a] Technique-effect: $p<0.0001$; [b] Tangential separation-effect: $p>0.05$;

Post-hoc test: [c] vs CON $p<0.01$; [d] vs CON $p<0.01$; [e] vs GTT $p>0.05$; [f]vs<20cmp>0.05; [g]vs<20cmp<0.05; [h]vs 20–22 cm $p<0.05$

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irradiated lung volume by over 10% and is now the trend for tangenital fields.

Incidence of pneumonitis has not been reported when less than 18% of lung volume was irradiated.[20] After averaging, the mean percentage of lung volume irradiated appears to be within the safe limit in terms of radiation pneumonitis. However, when the maximum percentage of lung volume irradiated is considered, all techniques produced a percentage that is above the 'complication-free' percentage of 18; 26% for HBB and GTT, and 27% for CON. Nevertheless, out of the 20 samples for each technique, the number of samples having their lung volume irradiated to over 18% is: 7 (35%) for CON, 6 (30%) for HBB and 4 (20%) for GTT. This shows that individual patients are still at risk of suffering from radiation pneumonitis. In view of this, the technique chosen needs to be individualized and techniques that irradiate the least volume of lung should always be opted for.

Floyd and colleagues[9] suggested that only the high-dose region in the lung is relevant to the radiation induced lung changes. McDonald and colleagues[16] showed no pulmonary function impairment at doses of less than 30 Gy. In this current study, the percentage of irradiated lung volume receiving doses above 30 Gy using conventional technique, gantry tilting technique and half beam block technique were 13.45% (ranged 3% to 26%), 10.75% (ranged 2% to 23%) and 11.25% (ranged 3% to 20%), respectively (Table 1). This shows that a substantial amount of lung still receives a high dose and the risk for pulmonary function impairment still exists.

Optimal treatment technique

Gantry tilting technique resulted in slightly less volume of lung irradiated than half beam block technique, but the difference was statistically not significant. The lack of significant difference was due to the elimination of beam divergence in both techniques. By applying half beam block technique, the asymmetric jaws were used to block off the posterior half of the beam. While for gantry tilting technique, the divergence of the tangents into the lungs was minimized by tilting the gantry for a few degrees away from the lung.

Technically, half beam block technique is superior to the gantry tilting technique because the latter requires the upward shift of the isocenter to match the field border during computer planning, which is more time consuming and produces a less homogeneous dose distribution. On the contrary, half beam block technique does not require the shifting of the field and is more simple and easy in the set-up.

Large-breasted patients receive a significantly higher percentage volume of high dose to the lung than small- or medium-breasted patients. Gantry tilting technique could irradiate the smallest percentage of total lung volume for all breast sizes. Figure 7 shows that for the large tangential separation group, gantry tilting technique results in 30% less total lung volume being irradiated when compared to the conventional technique. Therefore, gantry-tilting technique with proper selection of beam angle should be considered for large-breasted women and women with a high risk of development of radiation-induced complications, such as smokers.[17]

Some forms of compression to the breast during treatment could help reduce the tangential separation and thus minimize the lung volume.[1] The lung tissue can be spared when a special breast holding mask is shaped for each patient. In addition, treatment in the prone position has also been found to reduce the lung volume being irradiated.[11] Recently, intensity-modulated radiotherapy (IMRT) has been tried on the irradiation of breast cancer with a further reduction in the dose to the lung tissue.[21]

CONCLUSION

Although it is well known that conventional technique results in a larger amount of lung being irradiated than half beam block and gantry tilting techniques, no information is available in the literature to quantify such difference with various breast irradiation techniques. This study found that conventional technique resulted in a 14% increase in the percentage of total lung volume irradiated and a 16% increase in the percentage of irradiated lung volume receiving more than 30Gy when compared with half beam block tilting technique. This study provides further support for the replacement of conventional technique by half beam block technique for centres with linear accelerators that are equipped with asymmetric jaws.

Until IMRT can be implemented, half beam block technique is an optimal irradiation technique for the small and medium breast size patients. For patients with large breast size and those with a high risk of developing radiation-induced pulmonary complications, gantry-tilting technique should be considered.

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