THE DOSIMETRIC IMPACT OF BREAST TISSUE EXPANDER WITH METALLIC PORTS IN HELICAL TOMOTHERAPY: A RANDO-PHANTOM STUDY

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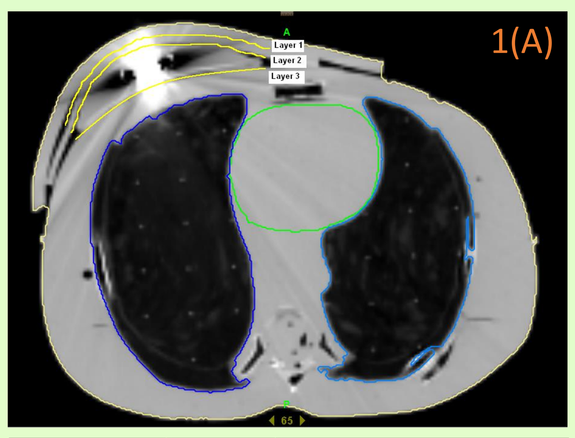
Purpose

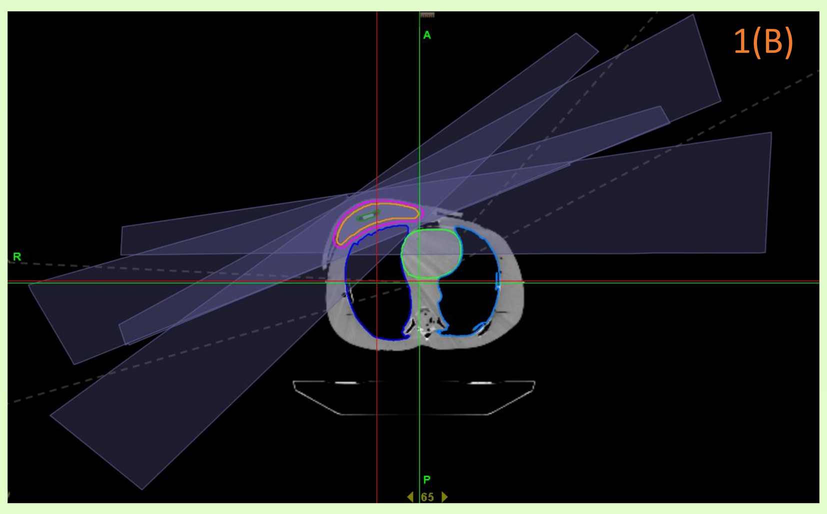
For breast cancer women with post-mastectomy radiation therapy (PMRT), the number of those who received immediate two-stage tissue expander (TE)/implant for breast reconstruction is increasing. TEs with metallic port become popular due to its convenience for saline injection. These high-density objects, however, cause streaking artifact on kilovoltage CT simulation image as shown in Figure 1 (A). Previous studies showed that high Z material can cause 10-30% actual dose reduction under tangential beam arrangement. This study was conducted to quantify the dosimetric effects in the region of the metallic ports using tomotherapy.

Methods

A bolus with 0.5cm thickness, which is defined as layer M, was placed on the surface of rando-phantom to simulate post mastectomy pectoralis major and skin beyond. TE with different amount of saline (100cc, 150cc, 200cc, 250cc, and 300cc) was placed under layer M simulating treatment condition. A 1 cm thick bolus was placed on layer M for routine PMRT technique. Artifact replacement : certain regions of the simulation image were replaced with electron density 1 with different approaches: 1) Image MP: only artifact was replaced (shown as Figure 2(A&B)), 2) Image Homo: both artifact and metallic port were replaced (shown as Figure 3(A&B)). Treatment planning was performed direct mode and helical mode for each image set. Direct mode used four beams arrangement with 60 degree and 273 degree as opposing beams and other two with 40 and 253 degrees, respectively, shown as Figure 1(B). A virtual ROI as direction block in whole lung was set for helical mode, shown as Figure 1(C). Same dose constrain and PTV coverage were demanded for all plans.

Radiochromic films (EBT3) were used for absolute dose measurement on three layers: Layer 1) surface of layer M; layer 2) interface between TE and layer M; Layer 3) bottom of TE, shown as Figure 1(A). Film QA was utilized for dose analysis. Each layer dose measurement was repeated for three times. Each measurement dose profile was collected and compared with treatment plan dose and prescribed dose.
The distance between TE top and metallic port (MT distance), and the distance between metallic port and TE bottom (MB distance) was recoreded. The correlation among measured dose difference, TE volume, image sets, and different technique was calculated and analyzed.





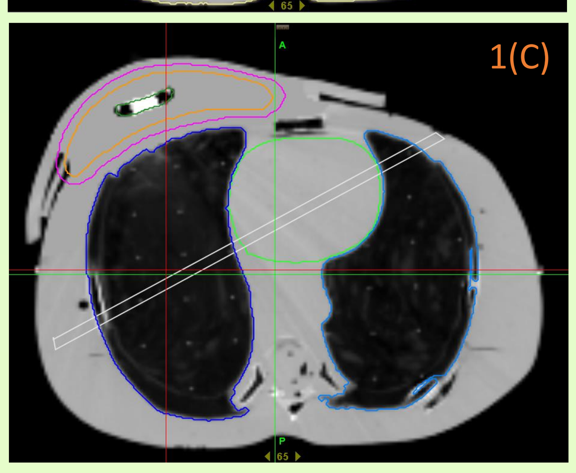


Figure1(A) CT simulation image with metallic port in tissue expander (TE) with artifact and position of radiochromic films (EBT3): layer 1) surface of layer M; layer 2) interface between TE and layer M; layer 3) bottom of TE.

Figure1(B) Beam arrangement of direct mode on Image MP.

Figure1(C) Contours of helical mode on Image MP.

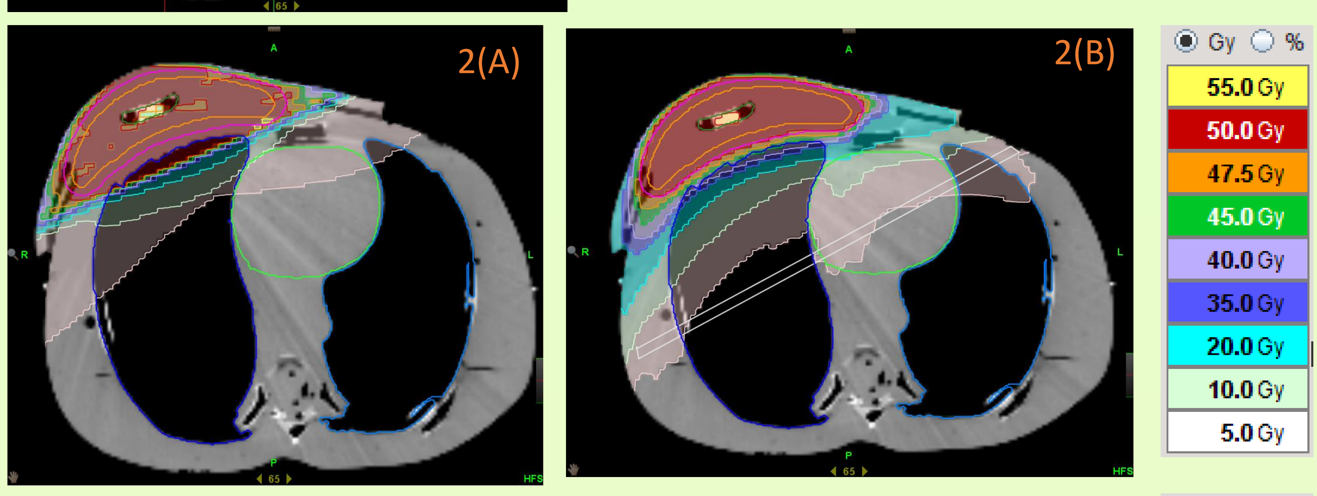


Figure2. Isodose distribution on Image MP with (A)Direct mode (B)Helical mode

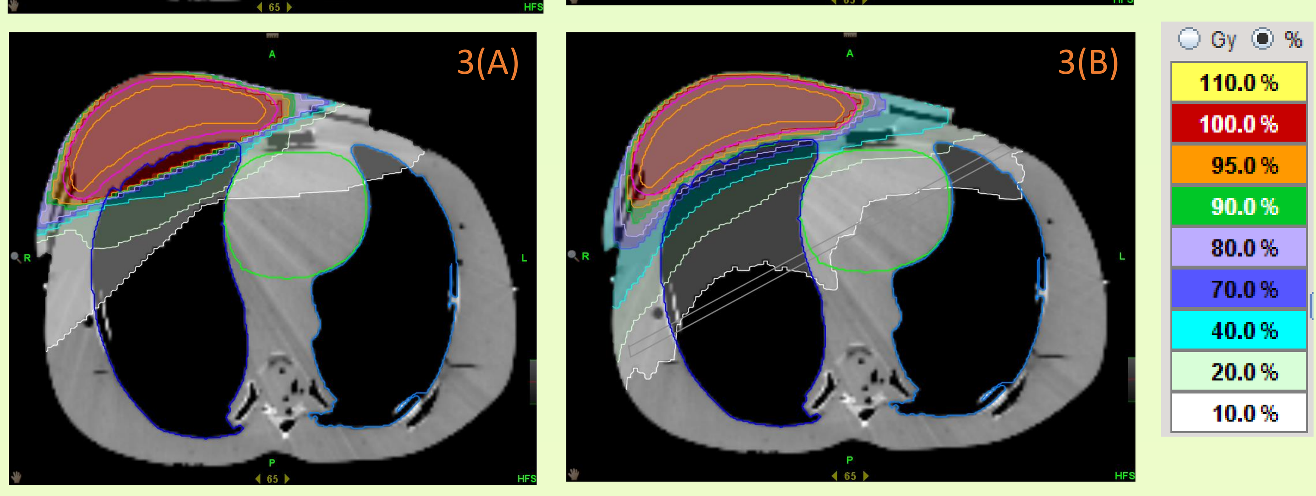


Figure3. Isodose distribution on Image Homo with (A)Direct mode (B)Helical mode

Results

•Capacity of TE volume

The position of TE metallic port changed with increase of TE volume. Among different TE volumes, the measured dose difference was lower with TE volumes 150, 200, and 250 cc in all layers.

Table 1 the change of MT distance and MB distance under different TE volumes

Capacity (cc)	100	150	200	250	300
MT distance (cm)	0.7	0.7	0.9	1.0	1.0
MB distance (cm)	0	0.1	0.5	1.0	1.4

•The dose difference from treatment plan

Treatment technique	Image mode	Measured dose difference(%)	
Direct mode	Image MP	-1.56% ± 2.10%	P=0.000
	Image Homo	-2.75% ± 2.52%	
Helical mode	Image MP	-1.32% ± 2.17%	P=0.000
	Image Homo	-2.75% ± 1.74%	
Image mode	**Treatment technique**		
Image MP	Direct mode	-1.56% ± 2.10%	P=0.637
	Helical mode	-1.32% ± 2.17%	
Image Homo	Direct mode	-2.75% ± 2.52%	P=0.165
	Helical mode	-2.75% ± 1.74%	

•Underdose proportion from prescribed dose

Treatment technique	Image mode	Underdose proportion (%)	
Direct mode	Image MP	11.5%	P=0.000
	Image Homo	27.9%	
Helical mode	Image MP	5.7%	P=0.001
	Image Homo	11.5%	
Image mode	**Treatment technique**		
Image MP	Direct mode	11.7%	P=0.000
	Helical mode	5.9%	
Image Homo	Direct mode	27.2%	P=0.000
	Helical mode	11.2%	

•Cold area in Image Homo-Direct mode

Compared with treatment plan dose, lower measurement dose was noted at bilateral sides of TE metallic port. The measurement dose profile with Image Homo-Direct mode had two lowest cold areas in all TE volumes, as shown in Figure 4(C). . There was no significant correlation between measured dose difference and TE volume (p=0.316).The average dose reduction of the measured cold areas dose comparing with treatment plan was 6.05% ± 1.94%.

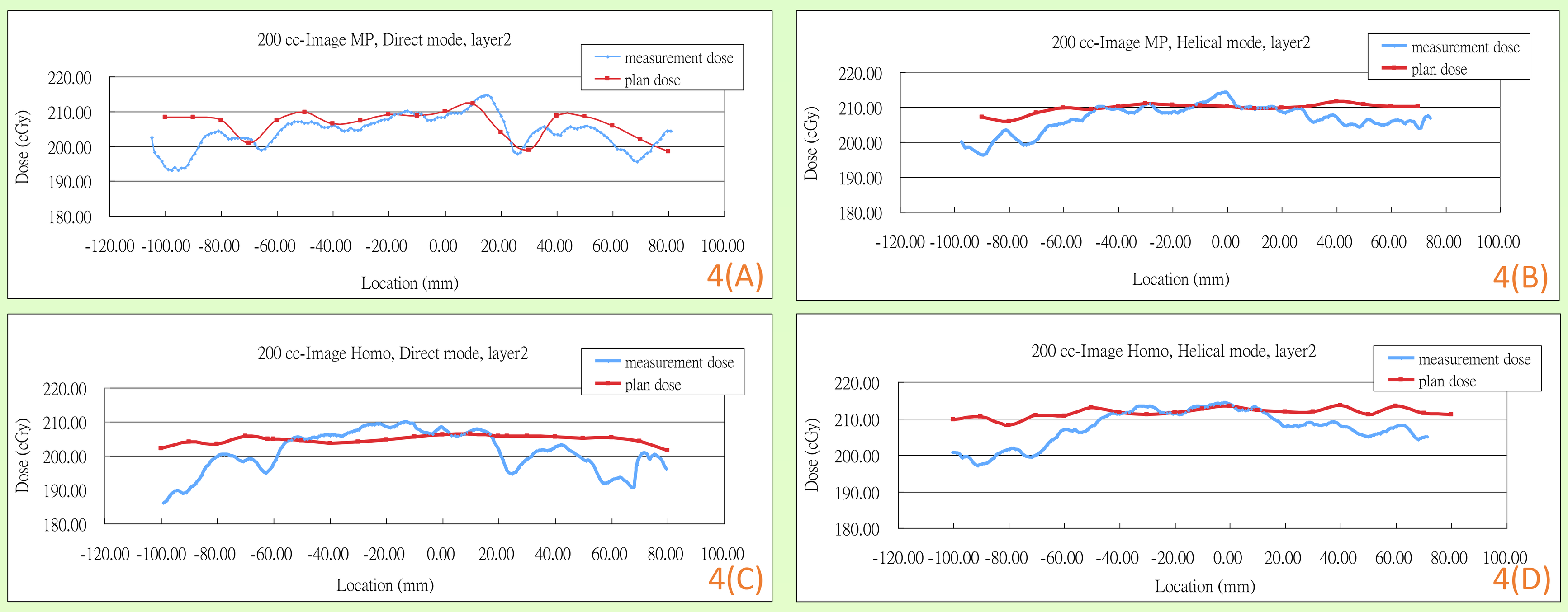


Figure 4 (A)-(D). Dose profiles of two image sets and technique modes for 200cc of TE volume.

Discussions and Conclusions

According to our result, TE volume with 150 to 250 cc are recommended during radiotherapy treatment course, while more or less TE volume may lead to increase of measured dose difference. Previous studies also showed oversize breast volume will reduce the daily patient set up reproducibility.

The algorithm of tomotherapy planning uses mass attenuation coefficient for mass density attenuation calculation. Also, the algorithm uses density of water and bone for interpolation. The metallic port of TE is a high Z material, and the density is 9.18 g/cc which is much more than bone density. The algorithm calculation based on above assumption is the source of the main deviation of the measured dose from the treatment plan. For lung tissue protection, most of radiation beam will delivered from nearly tangential angles and the dose deviation mentioned above mostly will locate at bilateral side of metallic port.

In order to study possible backscatter effect caused by metallic port, dose of layer 2 was analyzed and the result showed no obvious dose increase of region above metallic port. There are two possible reasons. First, the space between TE top and metallic port is at least 0.7 cm among all TE volumes. The material within such space may absorb the backscatter caused by the metallic port. Second, the beam direction tends to be arranged more from tangential angle for lung protection instead of from above the metallic port. Tangential incident angle beam causes backscatter mainly on tangential directions which can be absorbed by surrounding saline instead of to the tissue above the metallic port.

For patient planning to receive radiotherapy with metallic port TE, replacement of only artifact instead of both artifact and metallic port is suggested for CT simulation image correction and modification. Helical technique mode is recommended for treatment technique. Helical mode delivered radiation through multiple angles which can smear the dose attenuation effect caused by metallic port without sacrifice tumor coverage, tumor homogeneity and lung protection. Helical tomotherapy is a suitable treatment technique for patient with breast tissue expander with metallic port.

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