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Research Paper

Challenges of Using Small Gantry Bore Computed Tomography in Simulation of Breast Cancer Patients for Teletheraphy in Resource Poor Environment

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Abstract

The radiation therapy simulator has been an integral component of the treatment planning process for over 30 years. Conventional radiotherapy simulators are currently being replaced by virtual computed tomography (CT) simulators in many centres across the world, and their demand is constantly increasing with the wider adoption of three-dimensional conformal and intensity-modulated radiation therapy. However, in Nigeria the story is not a successful one, because CT scanners with small gantry bores of 70 cm (for diagnostic procedures) were dedicated to linear accelerators in majority of centres across the country. This present an obstacle to the CT simulation process by limiting patient positions, compromising reproducibility and treatment setup errors. This study aim at finding errors that occurred due to change in standard positioning (midline laser alignment) of breast cancer patients during CT simulation. Data were retrospectively collected from treatment planning system (Render 99) of previously planned breast cancer patients. Off midline laser coordinate was redefined to midline on each previous planning CT image and lateral couch movements were determined on both plans (midline and off midline). Data obtained were analysed using SPSS version 20.0 (Chicago L). Sample -t- test was conducted to find any significant differences in couch positioning between the two plans during treatment setup. Mean, standard deviation and standard error of mean were also determined and presented in tabular form. Thirty CT scan images of breast cancer patients planned for chest wall radiotherapy were retrospectively reviewed. They comprise of 16 and 14 CT images of left and right breast respectively. The mean scores, standard deviations and mean standard error of the left lateral couch movements using standard midline coordinates were 7.7 cm (range of 5.8 cm to 9.7 cm), 1 cm and 0.3 cm respectively as against off midline coordinates of 1.6 cm (range of 0 to 6.1 cm), 1.9 cm and 0.5 cm. Similarly, the mean, standard deviation and standard error of mean for the right lateral couch movement using standard midline coordinates were 6.3 cm (range of 3.7 cm to 8.4 cm), 1.8 cm and 0.5 cm respectively, as against 1.4 (range of 0 to 4.3 cm), 1.5 cm and 0.4 cm for off midline coordinates. A highly significant difference was found in both left and right plans by comparing plans using midline coordinate and off midline coordinates. Small gantry bore (70 cm) CT-simulator dedicated to linear accelerators is a huddle to successful breast cancer patient simulation. It causes deviation from standard laser at midline simulation of breast cancer patients which results in to major treatment setup error.

Keywords: Small gantry bore; computed tomography; simulation challenges; breast cancer; SPSS

Introduction

After surgery, radiotherapy is the most successful and most frequently used treatment modality in breast cancer patients [1, 2]. It aims at delivering tumorocidal dose to target volume and tumour bed with minimal injury to organs at risk (heart and lungs). From physical and technical point of view this is a difficult task to

achieve, because malignant tumors are often close to organs at risk (OAR). Many scholars reported the risk of cardiac and lung toxicity post radiation therapy of breast cancer [3-5]. However, the advent of three dimensional conformal radiotherapy (3D-CRT) had significantly reduced toxicity to OAR by the use of virtual CT- simulators and computerized treatment planning system [6-8]. In 1983 Goitein and Abrams described multidimensional treatment planning based on CT images [9, 10] they showed how projection through the CT data from any desired origin provides an alignment film simulation which can be used to confirm accuracy of treatment, as well as help establish anatomical relationships relative to the margins of a treatment field. This was a description of major characteristics of a system known today as the CT-simulator [11]. Sherouse et al. [12] described a CT image based virtual simulation process as "software analog to conventional simulation", they also described the need to improve patient immobilization and setup reproducibility [11, 12]. The process of CT simulation was similarly reported by other numerous studies that outlined several problems associated with small gantry bore (70 cm) CT simulators [13-15], which includes restriction of large size patients from passing through the bore and asymmetric setups, slow transfer of volumetric CT data, difficulty with image analysis which requires diagnostic expertise and time consuming contouring [15]. Some of these have been overcome with scanner bore size, speed of data transfer, speed of DRR generation and hardcopy quality.

In Nigeria the problem of gantry bore size persists, CT simulators dedicated to linear accelerators in majority of centres were of small gantry bores (typically 70 cm). For CT simulation purposes, breast cancer patients are often in positions (ipsilateral arm is subtended at close to a 90° angle) that can prevent them from entering the 70 cm bore opening. Hence the need for a lateral shift of patients on breast board devices to either left or right side of the CT couch, depending on the side of the affected breast. This led to a laser shift away from the midline of the patients, and this deviation from the standard method (laser at the midline of the patient) resulted in wrong placement of puducial markers (reference coordinates), wrong tumour bed definition and treatment setup errors.

Materials and Methods

Data were retrospectively collected from breast cancer patients who were planned with treatment planning system (TPS) in radiotherapy department of Usmanu Danfodiyo University Teaching Hospital (UDUTH) Sokoto who were simulated with laser off midline using small 70 cm CT gantry bore. Lateral treatment couch position was determined on each off midline laser coordinates of the previously planned CT images (image A), and then redefined the coordinates to midline on each corresponding planning CT images (image B) and lateral couch movements were also determined. Data obtained were analysed using SPSS version 20 (Chicago L). Sample -t- test was employed to find any significant differences of couch positioning during treatment setup between the two plans. Mean, standard deviation and standard error of mean were also determined and presented in tabular form.

Results

We retrospectively reviewed 30 CT-Scan images of breast cancer patients that were planned for chest wall radiotherapy. The 30 CT-scan images comprises of 16 and 14 CT images of left and right breast respectively (table 1). The ages of patients ranged between 30 – 68 years, with mean age of 45 years (table 2). The mean scores, standard deviations and mean standard error of the left lateral couch movements using standard midline coordinates were 7.7 cm (range of 5.8 cm to 9.7 cm), 1 cm and 0.3 cm respectively as against off midline coordinates of 1.6 cm (range of 0 to 6.1 cm), 1.9 cm and 0.5 cm (table 3). Similarly, the mean, standard deviation and standard error of mean for the right lateral couch movement using standard midline coordinates were 6.3 cm (range of 3.7 cm to 8.4 cm), 1.8 cm and 0.5 cm respectively, as against 1.4 (range of 0 to 4.3 cm), 1.5 cm and 0.4 cm for off midline coordinates (table 4). A highly significant difference was found in both left and right plans by comparing plans using midline coordinate and off midline coordinates with p-value of 0.000 (table 5 and 6).

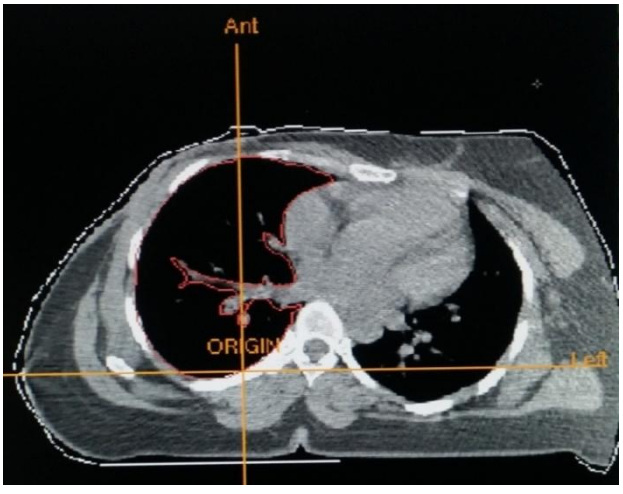

Figure 1. Off midline anterior chest wall coordinate.

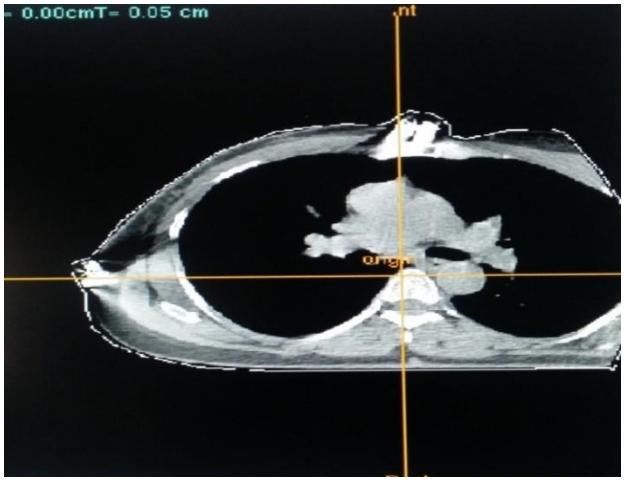

Figure 2. Midline anterior chest wall coordinate.

Table 1. Affected chest wall sites and CT-images reviewed

Affected chest wall site	Number of CT images reviewed		Percentage
	Off midline coordinate	Midline coordinate	
Left chest wall	16	16	53.3
Right chest wall	14	14	46.7
Total	30	30	100

Table 2. Ages of patients who were simulated using small gantry bore CT-scan simulator for chest wall teletherapy

Age range	Number of patients	Percentage
30-39	10	33.3
40-49	12	40.0
50-59	5	16.7
60-69	3	10.0
Total	30	100

Table 3. Mean scores, standard deviations and standard error of mean for the left lateral couch movements using midline and off-midline coordinates

Position of left chest wall coordinates on planning CT-image	Number of CT-images	Mean score of lateral treatment couch movements in cm	Standard deviation	Standard error of mean
Midline	16	7.7	1	0.3
Off midline	16	1.6	1.9	0.5

Table 4. Mean scores, standard deviations and standard error of mean for the right lateral couch movements using midline and off midline coordinates

Position of right chest wall coordinates on planning CT-image	Number of CT-images	Mean score of lateral treatment couch movements in cm	Standard deviation	Standard error of mean
Midline	14	6.3	1.8	0.5
Off midline	14	1.4	1.5	0.4

Table 5. Sample t test for mean difference between the two plans on the left chest wall

Position of left chest wall coordinates on planning CT-image	Number of CT-images	Mean score of lateral treatment couch movements in cm	Sample-t-test		
			t	df	p-value
Midline	16	7.7	11.410	30	0.000
Off midline	16	1.6			

Table 6. Sample t test for mean difference between the two plans on the right chest wall

Position of left chest wall coordinates on planning CT-image	Number of CT-images	Mean score of lateral treatment couch movements in cm	Sample-t-test		
			t	df	p-value
Midline	14	6.3	7.876	26	0.000
Off midline	14	1.4			

Discussion

Inability to simulate patients in an optimal treatment position due to restricted bore opening has often been cited as the major weakness of the CT simulation process that can result into treatment setup errors [15-18]. This is in accordance with our finding which shows significant errors in left lateral treatment couch movement of patients simulated in off midline laser position, with mean lateral couch movements of 1.6 cm, standard deviation of 1.9 cm and standard error of 0.5 cm as against 7.7cm, 1 cm and 0.3 cm respectively when using midline laser coordinates. Similar treatment setup errors were found on the right lateral treatment couch movement, with mean right lateral couch movement of 1.4 cm, standard deviation of 1.5 cm and standard error of 0.4 cm when using off midline laser position compared to 6.3 cm, 1.8 cm and 0.5 cm respectively when laser was at the midline. Apart from the significant disparities seen between the standard errors of left and right lateral couch movements with respect to their mean scores using off midline laser position, it also revealed a significant difference between the two methods of simulations (off midline laser alignment and laser at midline) with p-value of 0.000. This indicates that simulation of breast cancer patients using off midline lesser coordinates can result into significant error in lateral couch movement for location of an iso-centre during treatment setup. The end result of these errors is inappropriate tumour coverage and exposure of OAR to high radiation doses. Garcia-Ramirez JL et al. [19] also reported similar challenges encountered by using small gantry bore CT simulators in breast cancer patients' simulation. One of the limitations of this study is that only lateral movement of the couch was

considered at the planning CT image (not central) selected by the planning medical physicist. Many errors (along y, x and z planes) would had been pointed out if central planning CT images were used previously by the planning medical physicist.

Conclusions

Computed tomography simulator of small (70 cm) gantry bore poses a great hurdle to successful implementation of breast cancer teletherapy. It necessitate the asymmetrical positioning of breast cancer patients during simulation, which results into treatment setup errors associated with uncertainty in tumour bed coverage and exposure of OAR to high radiation dose. We therefore recommend their immediate replacement with standard wider bore (85 cm) CT simulators for accuracy and precision in delivery of radiation to breast cancer patients.

Abbreviations

CT: Computed Tomography; OAR: Organs at Rsik; 3D-CRT: Three Dimensional Conformal Radiotherapy.

Author Contributions

H. I. and R. I. Contributed equally to this study. All authors gave their final approval.

Competing Interests

The authors have declared that no competing interest exists.

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