ORIGINAL ARTICLE

QUANTIFICATION OF SCATTERED RADIATION TO ADULT FEMALE BREASTS DURING LUMBOSACRAL X-RAY AND HEAD COMPUTED TOMOGRAPHY IN A NEGROID POPULATION

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ABSTRACT

BACKGROUND: Deterministic and stochastic effects deleterious side effects arising from the use of ionizing radiation in diagnostic radiology, radiation therapy, and nuclear medicine. The breast is a radiosensitive organ that is often 'shielded' with a simple cotton gown when contiguous or fairly distant anatomical regions are imaged radiographically. **OBJECTIVE:** To quantify the amount of scattered radiation to breasts during x-ray and CT investigations with a view to finding evidence for apparel shielding during such procedures in the locality. **METHODS:** Thermoluminescent dosimeters were used to quantify scattered radiation dose in fifty patients each for computed tomography (CT) and computed radiography (CR). Absorbed dose (mGy) were subjected to statistical analysis. Central tendencies and dispersion were noted. Furthermore, a paired-sample t-test was done to test for statistically significant difference in mean absorbed dose by both breasts. Difference found justified the necessity for shielding during radiographic examinations. **RESULTS:** Scattered radiation reached the breasts in both procedures, and with a range of 1.28 - 12.6 mGy (CT) and 1.02 - 3.63 mGy. There was enormous reduction in dose between unshielded and shielded breasts in CT (113 %) and CR (32.2 %), with the difference being statistically significant ($p < 0.05$). **CONCLUSION:** Scattered radiation to the breasts were greatly and significantly reduced when shielding was applied. We strongly urge radiographers to practice shielding of contiguous and distant organs during procedures involving ionizing radiation.

Keywords: Scattered radiation, computed tomography, computed radiography, head, lumbosacral spine, x-ray

Introduction

Deterministic and stochastic effects deleterious side effects arising from the use of ionizing radiation in diagnostic radiology, radiation therapy, and nuclear medicine.[1] The breast is a radiosensitive organ that is often 'shielded' with a simple cotton gown when contiguous or fairly distant anatomical regions are imaged radiographically.[2,3] In view of the enormous amount of scattered radiation that reach the breasts during procedures involving ionizing radiation,[4,5] shielding with a gown may be grossly inadequate. Exposure to scattered radiation has lifetime attributable cancer risks which varies according to patient age and gender, with risk doubling in individuals 20 years or younger and 2.22 times higher in women.[6,7] In addition, this low-dose radiation deteriorates image quality which may necessitate repeats and concomitant increase in radiation dose to patients.[8,9]

It is reported that that lumbosacral x-ray and head CT are anatomical regions with frequent requisition for medical imaging. Due to high anatomical density, multiple surrounding structures and higher exposure settings, the tendency to induce scattered radiation

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is high during examinations of these regions.[1,7,10] Although both hardware and software modifications in x-ray and CT technology have helped to lower radiation dose,[7,11,12] scattered radiation still remains a challenge. Apparel shielding of radiosensitive organs is now being recommended and practiced.[3,9,13,14]
Our facility is a tertiary hospital with multiple x-ray, fluoroscopic and mammographic machines as well as computed tomography, magnetic resonance imaging and ultrasound scanners. Annual throughput of patients is in tens of thousands. As part of examination protocol at the centre and locality, breast shielding is not carried out during examination of contiguous or distant organs. This work aims to quantify scattered radiation to breasts during x-ray and CT procedures in order to find justification for a proposed adoption of breast shielding.

Materials and Methods

Ethical approval was obtained from institutional research ethics subcommittee (GUU/DRRS/EC/RADM.03 of 28th June, 2019). The prospective, cross sectional work involved adult female subjects aged ≥ 18 years and was undertaken in July and August, 2019. It had multiple stages, involved two study locations, and two modalities (x-ray & CT). Computed tomography aspect of the work was carried out in southeast Nigeria while computed radiography (x-ray) aspect was undertaken in southsouth Nigeria. Computed tomography was used to ascertain the likelihood and significance of scattered radiation to breasts during head imaging while x-ray assessed likelihood and significance of scattered radiation to head during lumbosacral investigations. Gravid and very ill patients who found it difficult to remain stable during examinations were excluded.
A GE Brightspeed, 8 slice scanner manufactured in 2007 and installed in the centre in 2012 was involved in the assessment of scattered radiation. The scanner had a maximum tube potential, tube current and gantry rotation time of 140 kVp, 350 mA and 4 seconds, respectively. Calibration was done daily using installed calibration software. X-Ray machine was a GE silhouette VR, high frequency, 3-phase, static equipment with a maximum rating of 140 kVp (tube potential), 600 mA (tube current), and 2.7 mmAl (total filtration). It was manufactured in 2003 and installed in 2012. Other equipment and accessories were a computed radiography digitizer (model CR 12-x) made by Agfa healthcare, Belgium in December 2013. A 25cm x 30 cm (10” x 12”) and 35cm x 43 cm (14” x 17”) photostimulable phosphor imaging plates (model CR MD4.0T General) also by Agfa Healthcare, Belgium were available.
For each modality, fifty ambulant, seemingly healthy, consenting female patients were prospectively and consecutively enlisted. Body mass index (kg/m^2) was calculated from weight (kg) and height (m) which were read off to the nearest 0.5 kg and 0.1cm (1mm), respectively. One hundred thermoluminescent dosimeter chips (TLD-100 LiF: Mg, Ti) with multidirectional energy response and which were calibrated and annealed at a regional dosimetric centre were used as dose detectors for computed tomography. In computed radiography, there were two hundred of those chips. The TLD chips were enclosed in small, black radiolucent polythene sachets before and after CT and CR irradiation to shield them from background radiation. In CT, each breast had a TLD chip affixed at its mid-craniocaudal point and held in place by transparent adhesive tapes. In addition, a 30 x 30 cm gonad shield with 0.35mm lead equivalent was used to shield the left TLD cum breast all through the investigations.
Computed tomography procedure was carried out as according to standard protocols. Anonymity of digital data was guaranteed with ‘image anonymity’ feature on the screen. Subjects were positioned for the CT examination supine, with orbito-meatal (OM) baseline at 90 degrees to headrest, and with azimuth of 90 and 180 degrees for lateral and postero-anterior scout images Axial (x-axis) centring was coincident with OM line at the level of infra-orbital margin. Subjects were scanned in axial mode with 120 kVp, 200 - 250 mA, 1 second gantry rotation time, pitch of 1.5, and scan duration of 14 - 20 seconds. Computed radiography procedure for lumbosacral x-ray was carried out using standard procedure as described by Adejoh, et. al.[3] This involved supine positioning with upper limbs raised above the head, lower limbs extended, 90 - 100 cm focus-detector-distance (FDD), grid, and breath-hold technique.
The TLDs were carefully retrieved after pre-contrast series, carefully packed and then sent for reading at

the centre where they were initially annealed and calibrated. Data were analyzed with statistical packages for social sciences, version 20.0 (SPSS Incorporated, Chicago, Illinois, USA). Absorbed dose (mGy) were subjected to statistical analysis. Central tendencies and dispersion were noted. Furthermore, a paired-sample t-test was done to test for statistically significant difference in mean absorbed dose by both breasts. Difference found justified the necessity for shielding during radiographic examinations.

Results

From (Tab.1), both computed tomography and computed radiography equipment were manufactured by General Electronics (GE) within the same decade, and also installed by end user in a different decade. The 50 enlisted patients for each modality have a summary of their anthropometric parameters shown in (Tab.2). Radiation reached breasts in both procedures with significant difference between shielded and unshielded breasts (Tab.3).

Parameters	**CT**	**CR**
Model	GE Brightspeed, 8 slice	GE silhouette VR
Manufactured	2007	2003
Installation	2012	2012
Maximum tube current (mA)	350	600
Maximum tube potential (kVp)	140	140
Maximum gantry rotation time (second)	4	Not applicable

Table 1: Machine properties

Parameters	**Computed tomography** (n = 50)		**Computed radiography** (n = 50)	
	Range	Mean ± SD	Range	Mean ± SD
Age (years)	18 - 60	38 ± 6.0	25 - 78	55.30 ± 12.40
Height (cm)	149 - 176	159 ± 3.4	147 - 179	160 ± 6.30
Weight (kg)	55 - 95	76.2 ± 5.0	48 - 125	78.10 ± 16.30
Body Mass Index (kg/m^2)	19.6 - 34.3	29.70 ± 2.10	16.2 - 57.5	32.00 ± 8.26

Table 2: Demographic characteristics of subjects

Parameters	**Computed tomography** (n = 50)		**Computed radiography** (n = 50)	
	Range	Mean ± SD	Range	Mean ± SD
Left breast (shielded), mGy	1.28 - 4.40	3.00 ± 0.60	1.02 - 2.43	1.74 ± 0.40
Right breast (unshielded), mGy	3.05 - 12.6	6.40 ± 3.45	1.05 - 3.63	2.30 ± 0.50
Mean dose difference (mGy)	3.00 - 6.40	3.4 (113 % dose difference)	1.74 - 2.30	0.56 (32.2 % dose difference)
Student's t-test for shielded & unshielded breast dose	T = 11.731; p = 0.001 (Significant)		T = 5.524; p = 0.001 (significant)	

Table 3: Mean scattered radiation to breast

Discussion

Contiguous and distant radiosensitive organs receive low-dose irradiation often referred to as scattered radiation during radiographic examinations. This adverse outcome tend to increase the risk to cancer in exposed persons and gene mutation in descendants of exposed persons.[15] To mitigate these hazards, apparel shielding for patients to absorb scattered radiation has become a growing countermeasure in radiography practice.[1,11] Despite this advancement, only a single work from a search of the literature in our locality recommended apparel shielding during radiographic investigations.[3] The implication is grim, as the intention for adopting this evidence-based practice in the locality may also not have fully crystallized. This work was an attempt to provide evidence to support a campaign for an introduction of shielding during radiographic examinations.

Evidence sought by us was whether scattered radiation reached breasts procedures involving distant anatomical regions. Doses were trapped using TLD chips. Head and lumbosacral were examined with high-dose (CT) and lower-dose (CR) modalities, respectively. Our findings revealed that scattered radiation reached the breast from both CT (range: 1.28 - 12.6 mGy) and CR (range: 1.02 - 3.63 mGy). There was a further reduction in these doses for shielded breasts in CT/CR (3.00 ± 0.60 mGy /1.74 ± 0.40 mGy) compared to unshielded breasts (6.40 ± 3.45 mGy / 2.30 ± 0.50 mGy). Further interrogation of these differences using Student's t-test revealed that the differences between shielded and unshielding breast were significant ($p < 0.05$). The implication is that shielding will mitigate scattered radiation in practically meaningful ways.

A fairly similar one carried out on cervical spine in United Arab Emirates showed that absence of shielding on breasts exposed them to scattered radiations (0.98 µGy, left breast; 0.61 µGy, right breast). When shielding was however applied, there was considerable, and significant ($p < 0.05$) reduction of dose by as much as 23% and 99% for the left and right breast, respectively.[1] Their findings on scattered radiation getting to the breasts as well as the efficacy of apparel shielding is in tandem with ours. Although they got a higher level of dose reduction in one instance in comparison with our 32.2 %, both results were significant ($p < 0.05$). In another related work by Revel (2015), a reduction of 42.1% was achieved. Similar study in computed tomography of the head have equally reported reduction in radiation dose following shielding16 with as much as 62 %.[14] Despite these strong evidences, some authors discouraged apparel shielding, insisting instead on dose optimization.[11,12] Notwithstanding, we would suggest that dose optimization go hand in hand with shielding.

This work suffers some limitations. We lacked anthropomorphic phantoms to enable us carefully plan our work and control extraneous variables like patients dislodging our TLDs from original positions. In addition, the TLDs were read a regional radiation laboratory hundreds of kilometer away, and we have no means of ascertaining veracity of returned results. Notwithstanding, since this is a pioneering work in our locality, we are optimistic that future works will address identified flaws in this study.

Conclusion

In conclusion, we observed that scattered radiation did not only get to the breasts from lumbosacral spine (x-ray) and head (CT), but that the quantity was much. Further, when a breast was shielded there was enormous and significant reduction in radiation dose. We strongly urge radiographers to practice shielding of contiguous and distant organs during procedures involving ionizing radiation.

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