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Optimization of Radiation Protection of Patients in Mammography Examinations using compression analysis

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ABSTRACT

Compression force, compression alignment and compression thickness have been studied on thirteen (13) mammography systems in Ghana to help in the optimization of the mammography process. The objective of this study was to check that the mammography system provides adequate compression in manual and automatic (power) mode; to check the accuracy of the compression force indicator, if present on the equipment and to check the accuracy (or deviation) of the compression thickness indicator. The alignment of the compression device at maximum force was also visualized and measured. The tests were conducted using the International Atomic Energy Agency Human Health Series 2 and 17 and the European guidelines for quality assurance in breast cancer screening and diagnosis protocols. Results from the test shows that systems A - C, E, H - M, all passed the compression force (both Manual and Power) test. System G failed the Power compression force test. The test was not performed on systems D and F. System F failed manual compression test. It was realised that even though system I passed the test, it was observed that the compression plate lacked the needed force to compress the breast. System G failed the compression thickness test completely whiles system H failed the test for the 45mm thick PMMA phantom. Values from the compression alignment test, Left Difference (rear - front) and Right Difference (rear - front) for system E were outside the tolerance limit of ≤ 5mm. Their values represents misalignment of the compression plate. It is recommended that the compression force system for system F must be replaced. The compression plate for systems E, G and H must be changed since they are misaligned and do not offer the best for the patient.

Keywords : Mammography, Breast, Compression, Force, Thickness, Alignment

I. INTRODUCTION

Compression, which has to be firm, causes the various breast tissues to be spread out, minimizing superposition from different planes and thereby improving the conspicuity of structures. This effect may be accentuated by the fact that different tissues (fatty, fibroglandular and cancerous) have different elasticities, resulting in the various tissues being spread out by different amounts and potentially making a cancer easier to see. Compression decreases the ratio of scattered to directly transmitted radiation reaching the image receptor. It also decreases the distance from any plane within the breast to the image receptor, and in this way reduces geometric unsharpness [1]. The compressed breast provides lower overall attenuation to the incident X - ray beam, allowing the radiation dose to be reduced. The

compressed breast also provides more uniform attenuation over the image which reduces the exposure range that must be recorded by the imaging system. It also provides a clamping action, which reduces anatomical motion during the exposure, thereby reducing this source of image unsharpness. It is important that the breast be compressed as uniformly as possible and that the edge of the compression plate at the chest wall be straight and aligned with both the focal spot and image receptor to maximize the amount of breast tissue that is included in the image. The mechanical properties of the breast are non-linear; after a certain reduction in thickness, application of additional pressure provides little benefit in terms of improved image quality [2]. An important disadvantage of compression is the pain and discomfort that women experience during and after the examination [3]

Adequate compression is essential for high quality mammography [4]. The objective of the compression test was to check that the mammography system provides adequate compression force in manual and automatic (power) mode; to check the accuracy of the compression force indicator, if present on the equipment; and to check the accuracy (or deviation) of the compression thickness indicator. The alignment of the compression device at maximum force was also visualized and measured [5].

II. METHODS AND MATERIAL

A. Materials

A total of thirteen (13) mammography systems (A – L), four (4) in public/government hospitals, two (2) in private hospitals and seven (7) in private diagnostic imaging centres, were chosen for the study. The four (4) systems in the public hospital were full-field digital mammography (FFDM) systems whiles the remaining nine (9) were computed radiology (CR) systems. Five (5) of the systems were located in the Greater Accra region, three (3) in Ashanti, two (2) in Western region, one (1) in the Eastern Region, one (1) in the Volta Region and one (1) in Central region. Other materials used for the work included a lawn tennis ball, analog bathroom scale, bathroom towel and semi – circular polymethylmethalcrylate (PMMA) slabs.

Methods

Experiment 1

Compression force

Power compression mode

The bathroom towel was placed on the breast support and the bathroom scale was placed on it centrally directly under the compression paddle. A lawn tennis ball was placed on the scale to protect the compression plate and such that it does not obscure the reading on the scale. The reading on the scale was adjusted to point "Zero". The compression paddle was activated so that it operated and stopped at the maximum available powered force of 150 N. The compression foot pedal was activated for a second time to secure the compression plate. The deflection on the bathroom scale and the value of the displayed compression force were both recorded in kilogrammes (Kg) and Newton's (N) respectively. The compression plate was released. Displayed value accuracy should be within ±20 N. Results are presented in Table 1.

Manual mode

Using the same set-up as the powered compression mode, the compression plate was moved downwards manually until it stopped. The deflection on bathroom scale and the value of the compression force were both recorded on the data collection sheet in Kilogrammes (Kg) and Newton's (N) respectively. The compression plate was released. Displayed maximum manual compression force should be less than 300 N. Displayed value accuracy should be ± 20 N. Results are presented in Table 1. Set – up for measuring compression force in Power mode and Manual mode is presented in figure 1.

Figure 1: Set – up for measuring Compression force in Power and Manual Mode

Experiment 2

Compression thickness

The PMMA slabs (20 mm, 45 mm and 70 mm) was aligned with the chest wall edge of the breast support platform The compression paddle was activated so that it operated and stopped at the maximum available powered force. The measurement of the thickness of the slabs was taken centrally. The measured thickness and the displayed thickness were all recorded and inputted into the data sheet. Tolerance limit is for the displayed thickness to be within ±5 mm of phantom thickness. Results are presented in Table 2. Set – up for measuring compression thickness is presented in figure 2.

Experiment 3

Compression alignment

The alignment of the compression device at maximum force was visualized and measured when the lawn tennis ball was compressed. The distance between breast support surface and compression device on each corner was measured. The compression device was released. Minimal misalignment of the compression plate is allowed, the difference between the measured distances at the left and the right side of the compression paddle should be ≤ 5 mm for symmetrical load. Results are presented in Table 3. Set – up for measuring compression alignment is presented in figure 3.

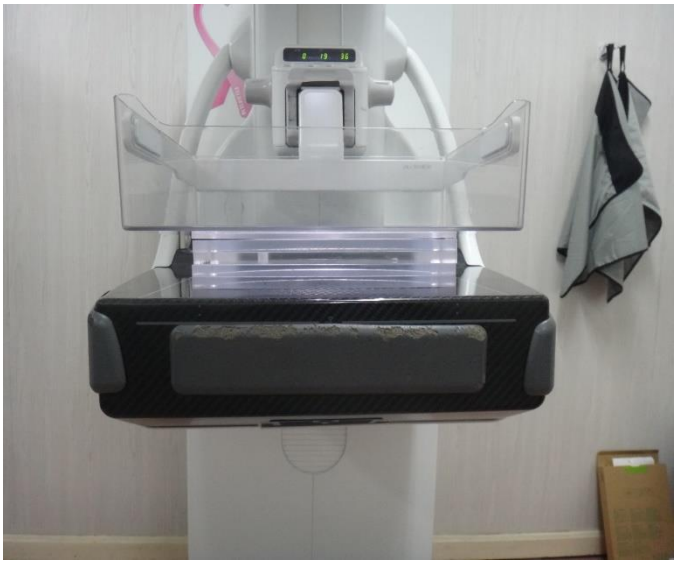

Figure 2: Set –up for measuring compression thickness

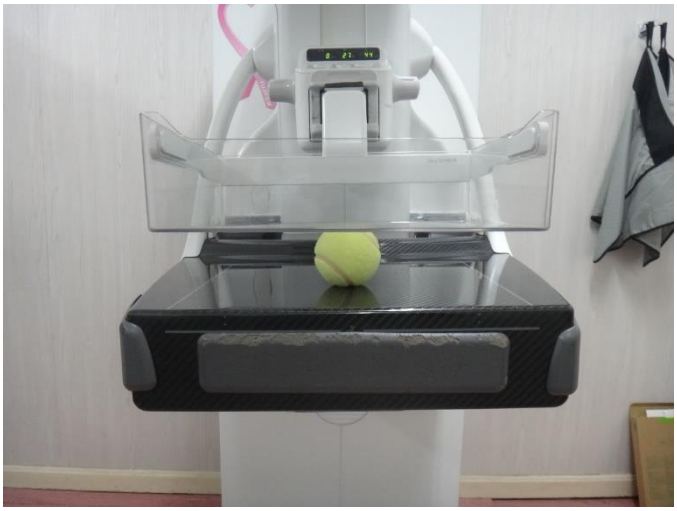

Figure 3: Set –up for measuring compression alignment

III. RESULTS AND DISCUSSION

Results from the compression force test is presented in Table 1. Systems A - C, E, and H – M passed both Power and Manual compression force test performed

on them according to the tolerance level (displayed value accuracy ± 20 N) set by IAEA Human Health Series 2 and 17 protocols [4,6].

Even though system "I" passed the test it was observed that the compression plate lacked the needed force to compress the breast. The compression was not firm enough hence during breast examinations, breast will not receive the maximum compression they require. System D has no display screen hence the compression force test could not be carried out on it. However under maximum compression, a force of 170 N and 200 N was calculated during Power compression and Manual compression respectively. This results can be used as baseline data for further studies. Power compression test was not performed on system F due to malfunctioning of the compression paddles. The system also failed the manual compression test recording a difference in value between the measured and displayed force of +630 N. Apart from results of Manual compression of system M, the FFDM systems recorded a relatively lower compression force difference than the CR systems.

Table 1: Results of compression force test

Mammography systems	Compression force accuracy (N)	
	Power Compression	Manual compression
A	+10.00	+10.00
B	+7.04	+3.04
C	+15.00	+15.00
D	-	-
E	+15.00	+15.00
F	-	+630.00
G	+30.00	+10.00
H	+6.00	+10.00
I	+10.00	+10.00
J	+2.00	+3.00
K	+5.00	+6.00
L	+5.00	+4.00
M	+9.00	+17.00

Results from the compression thickness test is presented in Table 2. For the system to be passed, the displayed thickness must be within ± 5 mm of phantom thickness. System G failed the compression thickness test completely whiles system H failed the compression thickness accuracy test for the 45 mm PMMA phantom. This indicates that the breast are not being compressed efficiently to the right thickness and hence can't achieve best image quality.

Table 2: Results of compression thickness test

Mammography systems	Compression thickness accuracy (mm)		
	PMMA thickness		
	20 mm	45 mm	70 mm
A	4	3	3
B	2	4	1
C	5	5	1
D	0.5	1	2
E	3	3	2
F	4	1	0
G	11	10	11
H	2	6	5
I	3	3	1
J	4	4	3
K	4	2	3
L	3	4	3
M	2	2	3

Results from the compression alignment test is presented in Table 3. Results from system C shows that it failed the compression alignment test "Right Diff. (r-f)" which is the difference on the right side of the compression plate between the rear and front. Values obtained from system E's compression alignment tests - Left Diff. (r-f) and Right Diff. (r-f) was 9 mm and 9 mm respectively. The values were more than the tolerance limit of ≤ 5 mm according to the European Quality Control of Physical and Technical Aspects of Mammography Screening protocol. The values measured indicates that the compression plate is misaligned for systems C and E

which means patient breast is not optimally compressed during imaging.

Table 3: Results of compression alignment test

Mammography systems	Compression alignment accuracy (mm)			
	Rear Diff. (l-r)	Front Diff. (l-r)	Left Diff. (r-f)	Right Diff. (r-f)
A	1	0	2	3
B	1	0	2	1
C	0	1	5	6
D	1	1	1	3
E	0	0	9	9
F	1	2	1	2
G	4	3	5	4
H	3	0	4	3
I	1	1	1	1
J	0	0	0	2
K	4	0	3	1
L	1	1	1	1
M	1	1	2	0

IV. CONCLUSION

The compression force, compression thickness and compression alignment have been accessed. Systems A – C, E, H – M, all passed the compression force (both manual and Power) test. System G failed the Power compression force test. The test was not performed on systems D and F. System F failed manual compression test. It was realised that even though system I passed the test, it was observed that the compression plate lacked the need force to compress the breast. System G failed the compression thickness test completely whiles system H failed the test for the 45mm thick PMMA phantom. Values from the compression alignment test Left Difference (rear – front) and Right Difference (rear – front) were outside the tolerance limit of ≤ 5mm. Their values represents misalignment of the compression plate.

It is recommended that the compression force system for system F must be replaced. The compression plate for systems E, G and H must be changed since they are misaligned and do not offer the best for the patient.

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