COMPRESSION FORCE VARIABILITY IN MAMMOGRAPHY IN GHANA – A BASELINE STUDY.

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1 Abstract

Introduction

Breast compression during mammographic examinations improves image quality and patient management. Several studies have been conducted to assess compression force variability among practitioners in order to establish compression guidelines. However, no such study has been conducted in Ghana. This study aims to investigate the compression force variability in mammography in Ghana.

Methods

This retrospective study used data gathered from 1,071 screening and diagnostic mammography patients from January, 2018-December, 2019. Data were gathered by seven radiographers at three centers. Compression force, breast thickness and practitioners' years of work experience were recorded. Compression force variability among practitioners and the correlation between compression force and breast thickness were investigated.

Results

Mean compression force values recorded for craniocaudal (CC) (17.2 daN) and mediolateral oblique (MLO) (18.2 daN), were within the recommended values used by western countries. Most of the mammograms performed – 80% – were within the National Health Service Breast Screening Programme (NHSBSP) range. However, 65% were above the Norwegian Breast Cancer Screening Programme (NBCSP) range. Compression forces varied significantly (p=0.0001) among practitioners. Compression forces increased significantly (p=0.0001) with the years of experience. A weak negative correlation (r= –0.144) and a weak positive correlation (r=0.142) were established between compression force and breast thickness for CC and MLO projections respectively.

Conclusion

This initial study confirmed that although wide variations in compression force exist among practitioners in Ghana, most practitioners used compression forces broadly within the range set by the NHSBSP. As no national guidelines for compression force currently exist in Ghana, provision of these may help to reduce the range of variations recorded.

Implications for practice

Confirmation of variations in compression will guide future practice to minimise image quality disparities and improve quality of care.

2 Introduction

Mammography is the most widely used medical imaging modality for breast cancer screening and detection.[1] To achieve a diagnostically acceptable mammogram, adequate compression of the breast is required. [2] To achieve uniform breast tissues, breast compression is applied to decrease the thickness of the breast. [3,4] Studies [5,6] have shown that breast compression and its impact on reducing breast thickness has a positive effect in reducing radiation exposure to the patient. Furthermore, compression of the breast improves image quality by reducing motion artifacts and image blurring due to the ability of the compression paddles to firmly hold the breast in a specific position. [7,8] The clinical benefits of breast compression are that it enhances breast cancer detection, thereby improving patient management. [9] However, the application of breast compression force varies across and within practitioners, [9,10] and in some cases may lead to pain, [11,12] and deter patients from attending future breast screening examinations. [13]

Several countries have produced breast compression guidelines for radiographers to apply during mammography examinations. The United Kingdom (UK) National Health Service Breast Screening Programme (NHSBSP) guidelines recommend that compression force should not exceed 20 decanewton (daN) and that compression should be applied slowly and gently to ensure that the breast is firmly held in position. [14] Similarly, the Norwegian Breast Cancer Screening Program (NBCSP) recommends a breast compression force range between 10.8-17.7 daN, [15] while the quality assurance guidelines for mammography in the United States (US) recommend a breast compression force between 11-20 daN. [16] The European guidelines recommend between 13-20 daN with the breast to be firmly compressed, yet tolerable for the patient.[17] Despite the existence of these recommendations, variations in the application of compression force by imaging professionals continues to be reported across studies [9,10,18,19], between centers [6,15,19] and across countries [20]. A common feature across studies is that the compression force which is applied tends to be practitioner dependent rather than patient dependent.

Currently, no specific compression force guidelines exist in Ghana. Neither have any previous studies been conducted to assess the breast compression force applied during mammography procedures by Ghanaian practitioners. The purpose of this study is to investigate the possible variations in compression force used among practitioners in Ghana to serve as a baseline data for future studies and contribute to the formation of national compression force guidelines.

3 Methods

Ethical approval was received from the Research and Ethics Committee of the University of Health and Allied Sciences, Ho, Ghana. Permission was also sought from the breast centers involved in the study. A purposive sampling technique was used to select three mammography centers for this study. In total, there are five digital mammography centers in Ghana. The absence of a national breast screening programme, coupled with limited data on national breast cancer screenings in Ghana [21–23], influenced the selection of these breast centers since they were the major breast screening centers with functional mammography machines at the time of data collection. Also, these centers were chosen because their quality control (QC) programmes were within the manufacturers' tolerances. Each breast center had one stationary Fujifilm FDR-2500DRLA digital mammography machine.

The study utilized retrospective data from a total of 1,071 patients, aged 35 years and above, who visited any of the three mammography centers for either screening or diagnostic mammography within the periods of January, 2018 to December, 2019. Parameters such as compression force in decanewton (daN) and compressed breast thickness in millimeters (mm), age of patients and practitioners' identity and years of work experience were obtained from the mammography information system. Data was entered manually into the Statistical Package for the Social Sciences (SPSS) version 23. Before the performance of each examination, the details of the patient were entered into the database alongside a unique identifier for the practitioner doing the examination. This facilitated easy identification of examinations conducted by each practitioner. Seven qualified practitioners (two from center one and two, and three from center three) performed the examinations. The practitioners were coded 1-7 and the mammography centers 1-3 for anonymity. The practitioners were all qualified radiographers, had additional training in mammography, and mammography was part of their normal job.

The study excluded 17 patients (68 mammograms) with incomplete data, three patients (12 mammograms) with breast implants, 18 patients (118 mammograms) with more than the four standard mammographic projections, and 54 patients (120 mammograms) with less than the four standard mammographic projections. In total, four-view mammography images (left craniocaudal, left mediolateral oblique, right craniocaudal, and right mediolateral oblique) from 979 patients, resulting in 3,916 mammograms were included in the study.

Compression forces between the right and left breast showed no statistical significance ($p = 0.913$). Therefore, the values of the right breast were used in the analysis to enable simplification of the results. The data was subjectively assessed for normality by visual observation using histograms, stem and leaf. It was objectively assessed using the Kolmogorov Smirnov (KS) test. The subjective analysis showed that the data was not normally distributed. Similarly, the KS test results showed a statistically significant p-value ($p= 0.0001$) indicating that the data was not normally distributed. Consequently, non-parametric statistics were conducted for inferential statistics. The mean compression force recorded was tabulated against recommended mammographic compression guidelines in other countries. The non-parametric Kruskal Wallis test was conducted to assess the breast compression forces applied between practitioners. Pairwise comparison using the Bonferroni confidence interval (CI) adjustment was also conducted to control for type 1 error. In instances where there was a statistically significant difference between the breast compression force among the practitioners, post-hoc Wilcoxon rank tests were conducted to determine exactly where the differences occurred. Spearman's rho correlation coefficient (r) was used to determine the correlation between the compression force and compressed breast thickness. The coefficient of determination (R^2) was calculated by multiplying *r* by itself and expressing it as a percentage. Cohen's[24] interpretation of *r* was used to interpret the strength of the correlation; r=0.1-0.29 (small), r=0.30-0.49 (medium), and r=0.50-1.0 (large).

4 Results

In all, four standard mammographic images each (left craniocaudal, left mediolateral oblique, right craniocaudal, and right mediolateral oblique) from 979 patients, resulting in 3,916 mammograms were used for data analysis. The patients were aged between 35 and 87 years [mean = 54 years; standard deviation (SD) = 10.0]. The years of work experience of the practitioners ranged between two to 10 years [mean = 6; SD = 2.8]. The number of cases per practitioner per center are indicated in table 1.

Table 1: The number of cases per practitioner per center

Centers	Practitioner ID	Frequency [Percent (%)] per practitioner	Frequency [Percent (%)] per center
Center one	Practitioner 1	122 (12.5)	204 (20.9)
	Practitioner 2	82 (8.4)	
Center two	Practitioner 3	172 (17.6)	310 (31.7)
	Practitioner 4	138 (14.1)	
Center three	Practitioner 5	103 (10.5)	465 (47.5)
	Practitioner 6	165 (16.9)	
	Practitioner 7	197 (20.1)	
	Total	**979 (100)**	**979 (100)**

The mean breast compression force values for craniocaudal (CC) and mediolateral oblique (MLO) and standard deviation were 17.24 ± 3.6 daN and 18.19 ± 3.1 daN respectively. The breast compression force values obtained in this study are compared with the recommended breast compression force ranges in other countries (table 2). The mean compressed breast thickness recorded was 36.06 ± 11.7 mm for CC and 44.64 ± 14.4 mm for MLO.

Table 2: Comparison of mean breast compression force to international recommended values

TOTAL		Mean±SD (in daN)			
Craniocaudal (CC) projection		17.24 ± 3.6 daN			
Mediolateral oblique (MLO) projection		18.19 ± 3.1 daN			
		NHSBSP – UK (< 20 daN)	**NBCSP – Norway (10.8–17.7 daN)**	**US (11– 20 daN)**	**Europe (13–20 daN)**
Total	Mammograms below range	-	4.7 % (186/3916)	5% (195/3916)	8.1 % (316/3916)
	Mammograms within range	80 % (3131/3916)	37.5 % (1469/3916)	75 % (2936/3916)	71.9 % (2815/3916)
	Mammograms above range	20 % (785/3916)	57.7 % (2261/3916)	20 % (785/3916)	20 % (785/3916)
Center one	Mammograms below range	-	0.9 % (7/816)	0.9 % (7/816)	0.9 % (7/816)
	Mammograms within range	28.2 % (230/816)	5.1 % (42/816)	27.3 % (223/816)	27.3 % (223/816)
	Mammograms above range	71.8 % (586/816)	94 % (767/816)	71.8 % (586/816)	71.8 % (586/816)
Center two	Mammograms below range	-	3 % (37/1240)	3.1 % (39/1240)	6.1 % (76/1240)
	Mammograms within range	89.6 % (1111/1240)	46.4 % (575/1240)	86.5 % (1072/1240)	83.5 % (1035/1240)
	Mammograms above range	10.4 % (129/1240)	50.6 % (628/1240)	10.4 % (129/1240)	10.4 % (129/1240)
Center three	Mammograms below range	-	7.6 % (142/1860)	8.0 % (149/1860)	12.5 % (233/1860)
	Mammograms within range	96.2 % (1790/1860)	45.8 % (852/1860)	88.2 % (1641/1860)	83.7 % (1557/1860)
	Mammograms above range	3.8 % (70/1860)	46.6 % (866/1860)	3.8 % (70/1860)	3.8 % (70/1860)

The Kruskal-Wallis test results revealed a statistically significant difference (p = 0.0001) in the breast compression forces applied in the CC projection among the seven practitioners. Similarly, the Kruskal-Wallis test results revealed a statistically significant difference (p = 0.0001) in the breast compression forces applied in the MLO projection among the seven practitioners. The median values of each practitioner per the CC and MLO projections are shown in figures 1 and 2 respectively. Figure one is a box plot indicating variability in the compression force applied across the practitioners for the CC projection; practitioner two recorded the highest median compression force (21.9 daN) and practitioner six recorded the least median compression force (16.5 daN).

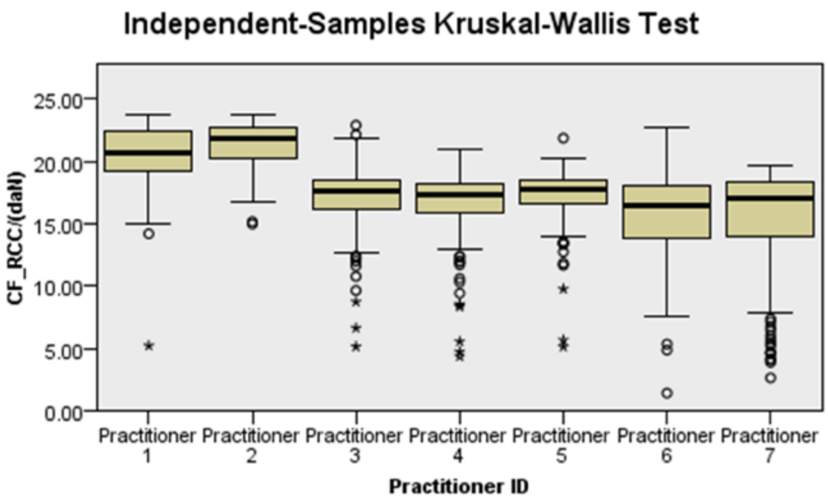

Figure 1: The median values recorded for the Kruskal Wallis test for each practitioner for the CC projection

Figure two is a box plot indicating variability in the compression force applied across the practitioners for the MLO projection; practitioner two recorded the highest median compression force (22.6 daN) and practitioners three, four, five, six and seven recorded similar median compression forces (17.9 daN).

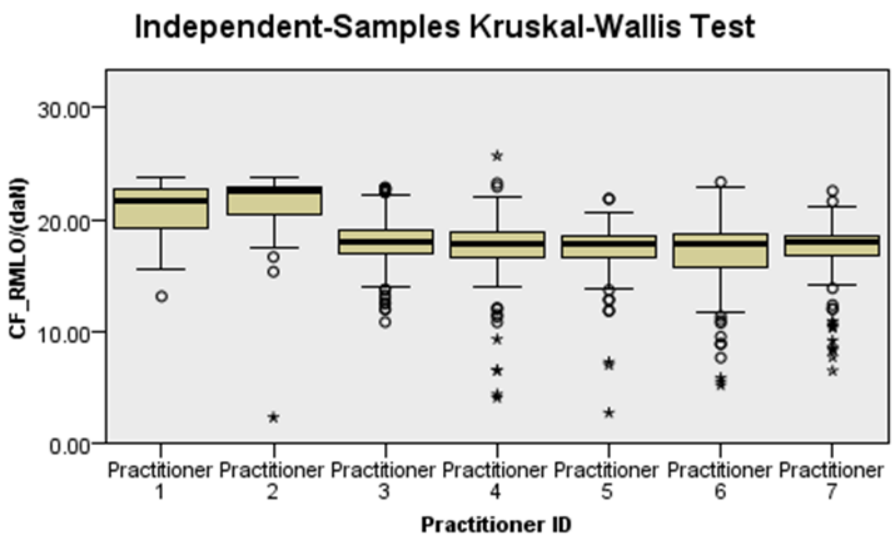

Figure 2: The median values recorded for the Kruskal Wallis test for each practitioner for the MLO projection

The results of the post-hoc pairwise comparison using the Bonferroni confidence interval (CI) adjustment, indicated that there were statistically significant differences (p=0.001) in the breast compression force applied among the seven practitioners for both the CC and MLO projections (table 3).

Table 3: Results of post-hoc pairwise comparison indicating inconsistencies in the breast compression force applied among seven practitioners for both the CC and MLO projections

Practitioner vs. Practitioner		**Significance level**		**Significance level**
P1-P3		0.001		0.001
P1-P4		0.001		0.001
P1-P5		0.001		0.001
P1-P6	**CC**	0.001	**MLO**	0.001
P1-P7		0.001		0.001
P2-P3		0.001		0.001
P2-P4		0.001		0.001
P2-P5		0.001		0.001
P2-P6		0.001		0.001

P2-P7		0.001		0.001
P3-P6		0.011		0.001
P3-P7		0.020		0.047
P4-P6		0.001		0.010
P5-P6		0.020		0.003

*P = practitioner

Spearman’s rho correlation coefficient indicated a weak negative correlation between the breast compression force and compressed breast thickness for the CC projections (r = –0.144), and a weak positive correlation between breast compression force and compressed breast thickness for the MLO projection (r = 0.142). The coefficient of determination showed 2.1 % and 2.0 % shared variance between breast compression force and compressed breast thickness for the CC and MLO respectively. Similarly, there was a weak positive correlation between the breast compression force and practitioners’ years of work experience (r = 0.247 for CC and r = 0.171 for MLO). There was no correlation between the compression force and age of patients (r = 0.077 for CC and r = 0.009 for MLO).

5 Discussion

This study compared breast compression force and compressed breast thickness applied during four-view mammography by practitioners across three test centers in Ghana. All the study participants were females and their mean age mean (54 ± 10.0) was within the common age for breast cancer screening. [25] This was similar to the age range reported by a study profiling Ghanaian mammography patients (51 ± 8.9). [21] In the current study, the mean compressed breast thickness recorded for the craniocaudal (CC) was 36.06 ± 11.7 mm, and the mediolateral oblique (MLO) was 44.64 ± 14.4 mm; these values were lower than those recorded by Moshina et al. [26] in Norway [56.9 ± 12.0 mm (CC); 60.0 ± 13.7 mm (MLO)]. The differences in the recorded compressed breast thickness could be due to differences in breast characteristics/composition such as density and size [27] among black African women compared to predominantly Caucasian women. The mean breast compression force applied for the CC and MLO projections in this study were within the recommended values detailed by guidelines published in the UK and USA [14–17] . The MLO value was, however, above the NBCSP range set by Norway, as shown in table 2. The highest percentage (80%) of mammograms within the recommended guidelines of other countries were recorded for the NHSBSP (UK). In contrast, the NBCSP recorded the highest percentage (62.5%) of mammograms outside the recommended range, as evident in table 2. This indicates that the breast compression forces applied by practitioners in Ghana were more aligned to UK rather than Norwegian protocols. Ghana currently lacks national mammographic compression force guidelines. However, the values from this baseline study, alongside international guidelines, could serve as reference data to guide the formation of national recommended breast compression guidelines to guide the practice of mammography in Ghana.

The findings of this study confirmed that variations in compression force existed among mammography practitioners in Ghana. This finding is consistent with the results of previous studies. [9,15,18,19,28] Mercer et al. [9] attributed variations in the compression force to three factors: practitioner, equipment and the patient. Variations stemming from patients could be due to differences in their tolerance of pain [11,12], breast density, size, stiffness and compressibility. [27,29] The study by Mercer et al. [9] categorized the breast compression force among practitioners as high, intermediate and low in relation to breast volume and density. To minimise the variations in breast compression force and reduce unnecessary pain, the use of pressure controlled paddles, taking into account compression force and breast size, to compress breasts to achieve the required pressure for varying breast sizes has been recommended. [5,8] Factors relating to the practitioner include their age, years of work experience and adherence to protocols. This study recorded a statistically significant difference ($p = 0.0001$) in the practitioners' years of work experience and the amount of breast compression force applied. Practitioners may rely more on their experience when applying breast compression due to the absence of Ghanaian protocols. This may contribute to the wide range of variations recorded. Consistent with the results of this current study, a previous study by Waade et al. [15] recorded a statistically significant difference ($p < 0.05$) between the practitioners' years of work experience, age and compression force. It is in line with this that Branderhorst et al. [6] recommended the use of pressure standardization in the production of mammogram images. This can help to both minimise significant variations among practitioners, and enable the production of reproducible images. A further finding of this study was the variation between data across study centers. Center one had the least compliance with western protocols whilst center three had the greatest. This may be related to the fact that center one had older practitioners with several years of work experience compared to center three.

Studies [28,30] have reported that increased compression force decreases the compressed breast thickness. This is supported by the negative correlation ($r = –0.144$) recorded in this study for the CC projection. However, the MLO projection recorded a weak positive correction ($r = 0.142$) supporting the findings of Waade et al. [15]. It is likely that the patient positioning during the acquisition of the MLO projection could have impacted on this positive correlation. Patient positioning during MLO projection includes the juxtathorax which are mostly thicker and stiffer than the breast tissues and could be visualized on a typical MLO projection. This position is comparable to findings by Dustler et al. [31] and Förnvik et al. [2] Although there is evidence to show that increased breast compression reduces breast thickness, over compression (the use of excessively high pressure) of the breast has little clinical benefit, in that, it has minimal effect on breast thickness reduction. [32] Over compression could cause pain/discomfort and could induce the development of pressure ulcers in the breast. Further analysis recorded a slight increase in the compression force in tandem with an increase in the practitioners' years of work experience. It can be inferred from the results that, as the practitioners' years of work experience increase, higher compression forces are applied. This, in turn, decreases the compressed breast thickness, motion blurring and radiation exposure to the patient and the radiographer. It also improves uniform distribution of the breast tissues to achieve optimum image quality. Förnvik et al. [2] suggested that optimum breast compression force is essential for producing diagnostically acceptable images, detecting possible lesions and facilitating accurate diagnosis, thereby improving patient management. However, high levels of breast compression force could be painful to patients. The clinical implication of this is that patients could be deterred from attending future breast screening examinations. Only three mammography centers had functional digital mammography machines that met manufacturer QC recommendations at the time of the study so the results of this study should be generalized with caution.

6 Conclusion

This baseline study investigated the breast compression force applied in mammography examinations in Ghana. Statistically significant differences were measured in the levels of breast compression force applied. This was due to variations in compression force used among practitioners. The years of work experience of the practitioners were significantly related to the compression force applied. The age of the patient had no effect on the amount of breast compression force applied. 80% of the mammograms reviewed in this study were within the National Health Service Breast Screening Programme (NHSBSP) of the UK while 60% were not consistent with the more stringent Norwegian Breast Cancer Screening Program (NBCSP) guidelines. There was a weak correlation recorded between breast compression force and compressed breast thickness.

7 Limitation and recommendation for future study

As a baseline study, this study had small study size. A larger sample from all mammography centers in Ghana would be needed to establish whether breast compression force variability exists in Ghana, and the findings from that study will be used to inform the development of a national breast compression guidelines.

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