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Review Article

Promoting Breast Cancer Screening Among Undeserved Women: An On-Site Dual Approach Involving Breast Health Education and AI-Assisted 3D Mobile Mammography

Victor Chigbundu Nwaiwu[1,2]*, Sreemoy Kanti Das[2] and Sherril Spencer[1]

[1]School of Health and Rehabilitation Sciences, Department of Radiography, Health Sciences University, United Kingdom

[2]Lincoln University College, Malaysia

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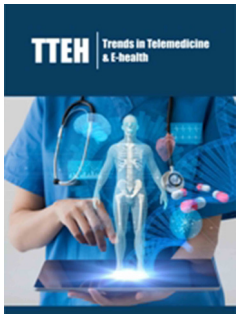

***Corresponding author:** Victor Chigbundu Nwaiwu, School of Health and Rehabilitation Sciences, Department of Radiography, Health Sciences University, United Kingdom.

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Abstract

Breast cancer is increasing globally; a major worry is the yearly continuous rise in the number of cases and deaths especially among underserved women aged 40 years and above in low-and middle-income countries. Statistical records on the mortality rate reveals that Melanesia and Africa rank highest, with Nigeria recording one of the highest age-standardized mortality rates globally and highest in Africa. Lack of early detection is a primary reason for this abysmal trend, which has been linked to several factors such as knowledge gaps, lack of infrastructure, inadequate personnel, low socioeconomic status and resource constricts. A close look at the pathophysiology of breast cancer clearly shows that early treatment prevents spread to other parts of the body, which is crucial for survival. To tackle such precarious situation in Nigeria, this educative and interesting piece, deeply rooted on up-to-date existing evidence, proposes an onsite approach involving breast health education and AI-assisted 3D mobile mammography that will definitely not miss out on breast cancer detection, even in its earliest stages. It is envisaged that more public awareness on breast cancer will be created, as well as knowledge gained on risk factors and breast self-examination following interactive teaching sessions; all interventions to follow established Health Belief Model (HBM). A mobile van is utilized to bring mammography screening services closer to many, utilizing Digital Breast Tomosynthesis (DBT) and Synthetic Mammography (SM) to obtain 3D slices, thus enhancing details and reducing the number of recalls for further imaging and biopsy. A deep learning-based Convolutional Neural Network (CNN) is applied to reduce the screening time, further improve detection rates, predict malignancy and reduce the number of requests for biopsies. Despite the extremely promising nature of this novel approach, cost appears to be a stumbling block. There is therefore need for increased funding from government, philanthropic donors, external bodies and NGOs, including multidisciplinary and international collaborations on breast cancer research to strengthen networks and promote evidence-based practice.

Keywords: Breast cancer screening; Undeserved women; Breast health education; Artificial intelligence; 3D mobile mammography

Introduction

Breast cancer remains the most diagnosed cancer in women globally [1]. Public health data have revealed that the burden of breast cancer in women worldwide measured by incidence, mortality and economic costs is tremendously high, with an estimate of more than 2.3 million women diagnosed with breast cancer every year and over 685,000 to eventually die from the disease [2]. Although the highest incidence rates (per 100,000) as at 2023 was found in Australia/New Zealand (95.5), Western Europe (90.7), North America (89.4), Central America (39.5), Middle and Eastern Africa (33) in decreasing order of magnitude; the highest mortality rate was reported in Melanesia (37.5), Africa and Polynesia (22.3) and

the Caribbean (18.9) [3]. In Nigeria, breast cancer is a well-known terrifying health issue of great concern, with about 1 death in every 25 reported cases and 12,000 deaths in 2018 alone (the highest breast cancer mortality rate of all nations) and these figures have since continued in an upward trajectory [4,5]. It is very common in women aged 40 and above, occurring only 4-6% among women less than 40 years of age [6]. According to [7], breast cancer is a major cause of morbidity and mortality among Nigerian women, with incidence rate ranging from 36.3-50.2/100,000 live birth. In fact, out of the biopsy specimens collected in Borno state, Nigeria, breast cancer accounted for 34.5%, with invasive ductal carcinoma the commonest (82.6%) histological type [8]. Previous research shows that the total number of confirmed cases has increased by an average of 1.5% per year over the past 10 years. This trend is disturbing, showing the public health threat posed by breast cancer.

Improved diagnostic imaging techniques has resulted in detection at increasingly early stages, sometimes in the primary stage where many women can be successfully treated [9], the outcome of treatment greatly depends on the timing of detection [10]. According to the World Health Organization, early diagnosis improves breast cancer outcomes by providing care at the earliest possible stage, preventing metastasis, ensuring that lives are saved and the personal, societal and economic cost of care reduced [11]. The gold standard to achieve this in women aged 40 years and above is mammography screening, with 30-50% breast cancer preventable [12]. However, in low-and middle-income countries such as Nigeria, lack of awareness and proper knowledge exist, together with limited infrastructure, personnels and resources for routine screening mammography. This is even worse in the villages and communities, with extensive research proving that women from rural areas of the state face the burden of higher rates of breast cancer incidence and mortality and are less likely to undergo mammography at recommended time intervals [13]. These have been the key reason for presentation of breast cancer cases in the Nigerian population at more advanced stages, compared to people of the European descent. Recently, a very high triple-negative breast cancer occurrence rate of 76.9% has been reported in Borno state, North-East Nigeria [14]. In such settings, breast cancers are usually diagnosed at very late stages, with very slim chances of survival [2]. Early detection aimed at improving breast cancer outcome remains the cornerstone of breast cancer control, with mammography the only effective breast cancer screening method [10].

The earlier studies of [14], supports this assertion, showing that rural women are faced with this burden, owing to their low socioeconomic status, high illiteracy, indulgent in modifiable risk factors and poor knowledge of breast cancer. In addition, results from the studies of [15] shows that approximately 32% of women in Nigeria are not aware of breast cancer screening, with only 14.5% having heard of mammography. It is interesting to see that very recent discoveries have demonstrated the application of Artificial Intelligence (AI) techniques in mammography screening to be associated with improved accuracy levels, prognosis and therapeutic response prediction, although ethical considerations must be in place [16]. Additionally, "some breast tumors" can be detected by women themselves through regular repetitive monthly palpation. Thus, having the knowledge, skills and confidence to detect breast changes and present promptly to a healthcare professional is vital for early detection and key to better outcomes [1]. Knowledge here entails an accurate understanding of breast cancer, its symptoms, risk factors, prevention, screening methods, treatment options and centres [4]. The findings of [15] established that wrong beliefs about breast cancer prevention is responsible for the negative perception of the curability of breast cancer detected early, with "fear" a factor that discourages women from seeking early intervention. On the other hand, those with a positive attitude towards screening are hampered by limited resources. Hence, an effective health promotion intervention, geared towards driving positive behaviour pertaining to timely breast mammogram, avoidance of risk factors and breast self-examination is pivotal to early detection and improved survival.

Discussion

Design

A combination of both quasi-experimental and observational (case) design should be adopted. The entire intervention would last for about fourteen weeks, beginning with a period of intensive learning on breast health education that will encompass knowledge of breast cancer, risk factors, prevention, breast self-examination and regular taking of mammograms. This packaged lesson would be delivered by a certified health educator for about an hour every day and will feature presentations, questions and answers, forum discussions, interactive video moments on the five-step method of breast self-examination (visual inspection, palpation while lying down, palpation while standing or in the shower, nipple check and armpit examination), counselling session and practical. A brief explanation of the five-step method of breast self-examination is given as follows:

A. Visual inspection: Standing in front of a mirror and inspecting the breasts for any changes in size, shape, symmetry or skin texture. Also, look for dimpling, puckering or redness on the skin and observe the nipples for any changes in their appearance, such as inversion or discharge.

B. Palpation while lying down: Applying a mix of light and firm pressure while lying on the back, with the opposite hand (three middle fingers) on the entire breast area and under the armpits; feeling for lumps, thick spots or any breast changes in a circular and up-and-down manner.

C. Palpation while standing or in a shower: Applying a mixture of light, medium and firm pressure using the three middle fingers with the opposite hand in an erect position, checking for breast changes, adopting a circular pattern, as well as up-and-down to cover the entire breast including under the areola and nipples.

D. Nipple check: Gently squeezing the nipples while both in a lying and standing position to check for discharge.

E. Armpit examination: Carefully examining both armpits, feeling for lump or any other changes in the underarm area of both breasts (Figure 1).

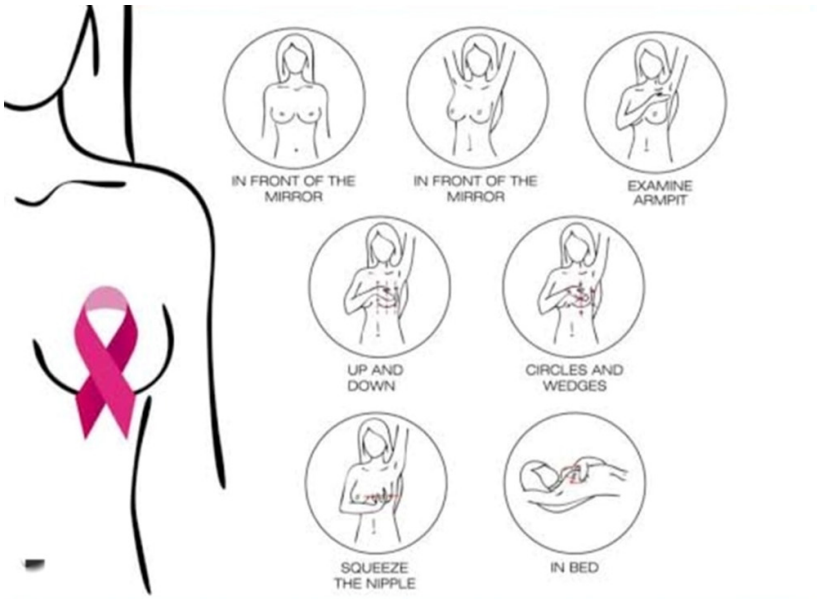

Figure 1: Brief explanation of the 5 steps of breast self-examination.

A mammography van (mobile mammography) should be on spot to take mammograms of interested women for 90% discount of the original price.

Proposed chosen site for the intervention

Borno state in Nigeria, recording a triple-negative breast cancer burden, is proposed and it is anticipated that this intervention will gradually spread out to other territories of the federation. The premises of the Borno state museum situated within Maigduguri (the state's capital), a place with famous history and cultural heritage, is intended. This site seems to be accorded preference based on the safety and nearness to majority of the Local Government Areas (LGAs), thus allowing for effective participation.

Participants

The inclusion criterion for this intervention involves a focus on all women within the LGAs of Borno state aged 40 years and above, irrespective of their cancer history. Younger women less than 40 years, due to their denser breast tissue (relatively high amounts of connective/glandular tissue and low amount of fatty tissue which results in less sensitivity to mammography), are excluded.

The breast tissue

It is primarily composed of lobes, lobules, ducts, surrounding fat and connective (fibrous) tissue (Figure 2). Breast cancer commonly originates in the cells lining the lobules and ducts (structures responsible for milk production and transport respectively), although some rare forms start in the fibrous and fatty tissue. These cells could invade nearby issue or spread through the body via the lymphatic system (axillary nodes) and blood, a process called metastasis, reducing the chances of survival [17].

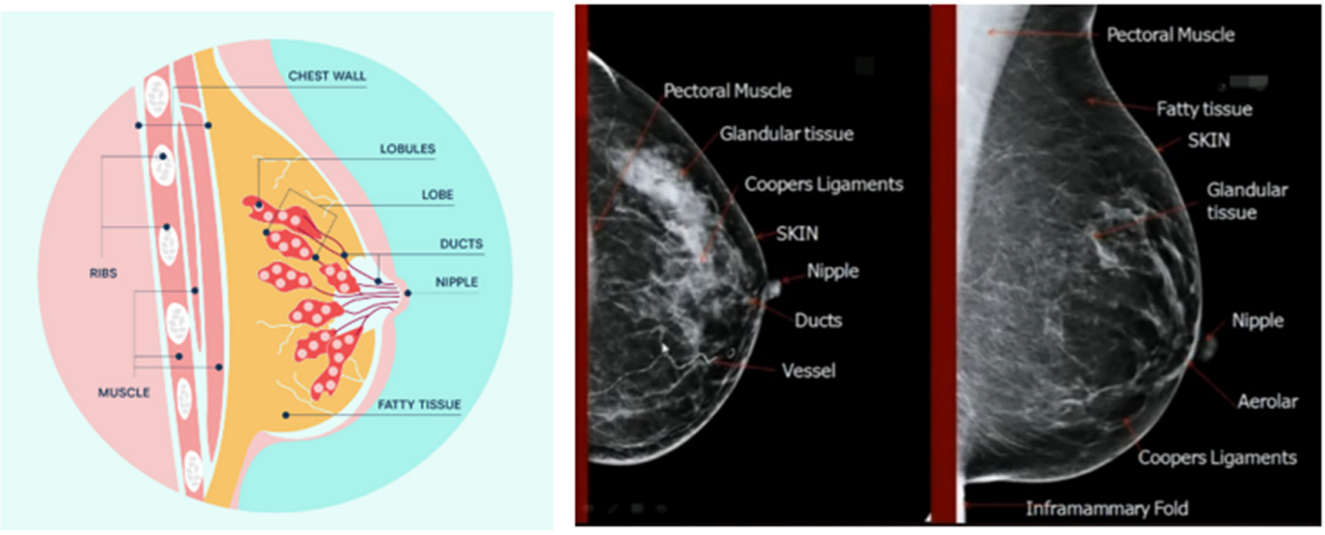

Figure 2: Breast anatomy.

Mobile mammography

A digital 3D mammography unit with deep learning-based AI CAD (Computer Aided Detection) system should be acquired in the mammography van (Figure 3). Series of comprehensive quality control tests is expected to be performed by a medical physicist, in conjunction with radiographers (mammographers) and radiologist prior to its use (as well as periodically as the case may be) to guarantee safety [18,19]. It is important to note that the procedure for a 3D is similar to a conventional 2D mammogram (obtaining routine craniocaudal, CC and mediolateral oblique, MLO views) with the major difference in the way images are captured. Here, the x-ray tube moves in an arc (15^0-60^0) over the compressed breast to capture images from different angles, which further undergoes computer processing to create 3D slices [reconstruction into 1mm-thick 2D Full Field Digital Mammography (FFDM) images for review, thickness of compressed breast to determine the total number of reconstructed images], allowing radiologist to see through tissue layers. This process is referred to as 'Digital Breast Tomosynthesis' (DBT) and results in an increase in the radiation dose as well as acquisition time. Interestingly, Synthetic Mammography (SM) (Figure 4), a 2D reconstruction directly from the tomosynthesis slice set has compensated for these limitations, eliminating the need for a separate FFDM [20-22].

Figure 3: Mammography van with an inbuilt AI-assisted DBT unit.

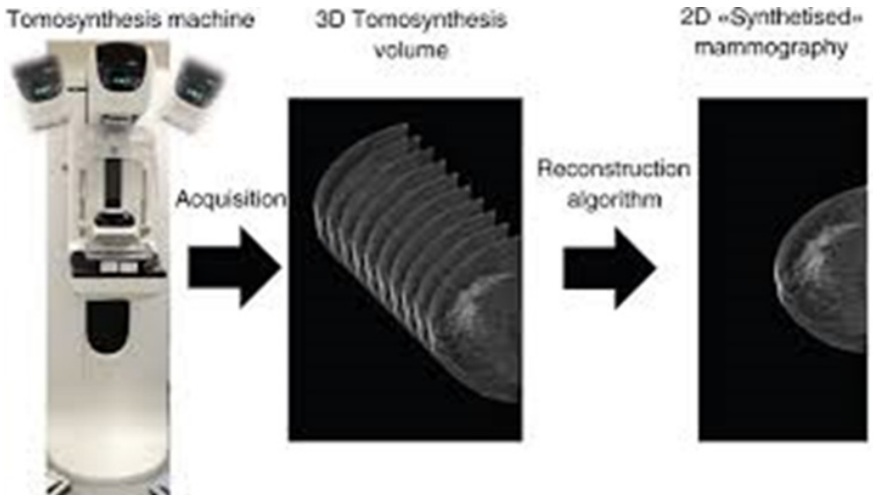

Figure 4: Synthetic mammography process.

This mechanism has successfully proven to lower radiation exposure by almost 50% when compared to FFDM+DBT and SM dose now only 19% higher in comparison to 2D Mammography alone. Also, did significantly reduce imaging screening time and is being designed to replace FFDM+DBT [23] (Figure 5). DBT minimizes tissue overlapping and enhances the detection of subtle changes, thereby reducing recalls. However, despite its improved diagnostic performance and about 30% reduction in overall recall rate, takes approximately double the time for reading 2D conventional images [24,25]. Therefore, its application in breast screening programs implies introduction of methods to reduce its reading time, an aspect that AI, highlighted below has compensated for with promising results (Figure 6).

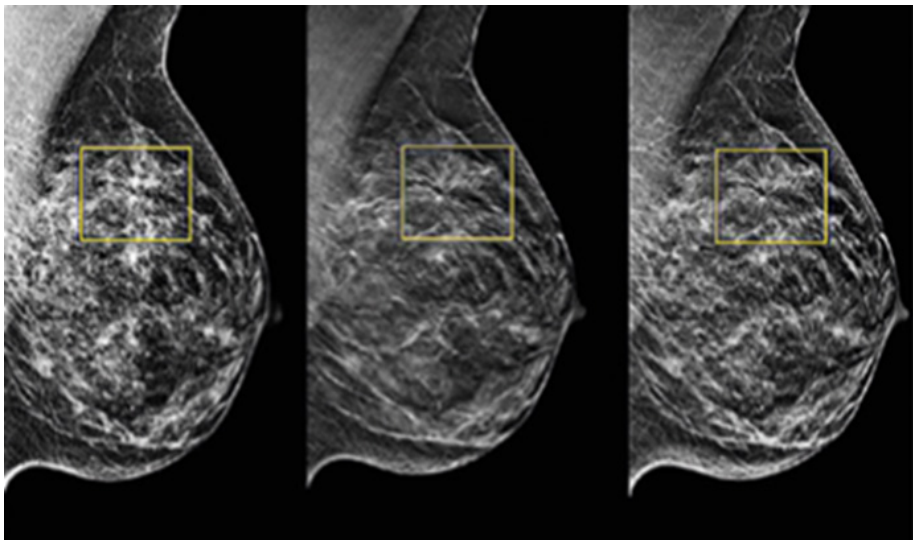

Figure 5: Image comparison from left to right-FFDM, FFDM+DBT, SM.

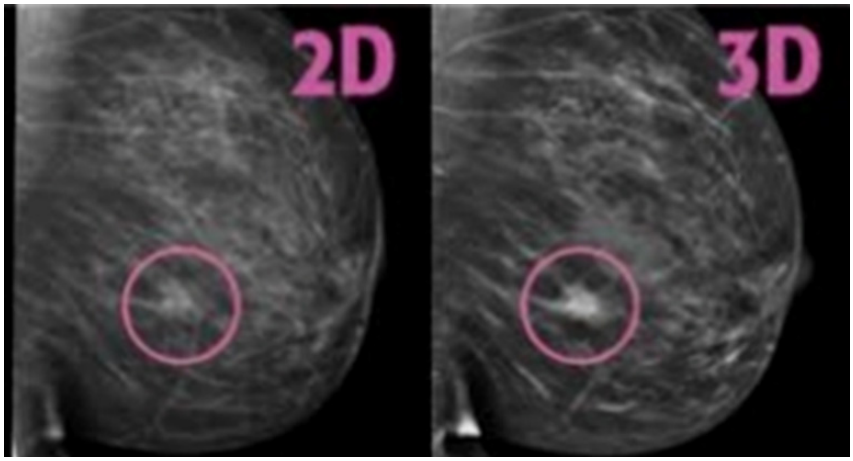

Figure 6: 2D in comparison to a 3D view of the left breast, showing a mass clearly visualized in the 3D due to less of tissue overlap.

AI software

The AI software will be built on Deep learning (DL) techniques, as oppose the conventional CAD algorithms (CADe/CADx-traditional machine learning methods) used in 2D conventional mammography that reported increased number of false positive marks per image (its successful use was limited to a specific lesion). This shift has led to an increase in sensitivity for breast masses (ROI from 83.2% to 89.3% for suspicious lesions and 85.2% to 93.0% for malignant lesions) [26]. DL algorithms particularly CNNs has been useful for image segmentation and classification tasks in FFDM and DBT, extracting patterns and features from inputs (imaging and non-image data) to arrive at accurate outcomes. The usual pixel method of DL (comprising training, validation and test datasets) requires annotated training sets outlining malignant lesions in the images. This could presently be challenging with respect to the study population due to inadequate datasets, although several strategies can be put in place to achieve this. Hence a pre-trained deep learning convolutional neural network in which the parameters of the final layer of the network are fine-tuned for breast cancer detection (a process known as transfer learning), will be employed.

This method leverages on information from large unrelated data sets (of over one million images) in the training of CNN oriented at analyzing mammograms and has been very successful in situations that obtaining adequate training datasets proves difficult. This is because images used in the training set should always be quality and a representative of the population to produce accurate results [27]. Furthermore, studies have shown that AI has the ability to overcome the time limitation of DBT highlighted above by a reduction in the reading time (up to 53%), while further improving diagnostic yield (2% to 27%) [28]. Again, certain AI tools such as ibrisk (intelligent-augmented breast cancer risk calculator) possess the potential to accurately predict how likely an abnormal tissue flagged by a radiologist is benign or malignant (Figure 7a & 7b). This exciting future avoids unnecessary biopsies thereby cutting down time and cost especially in a low resource setting, with about 80% of performed biopsies turning out negative [29,30].

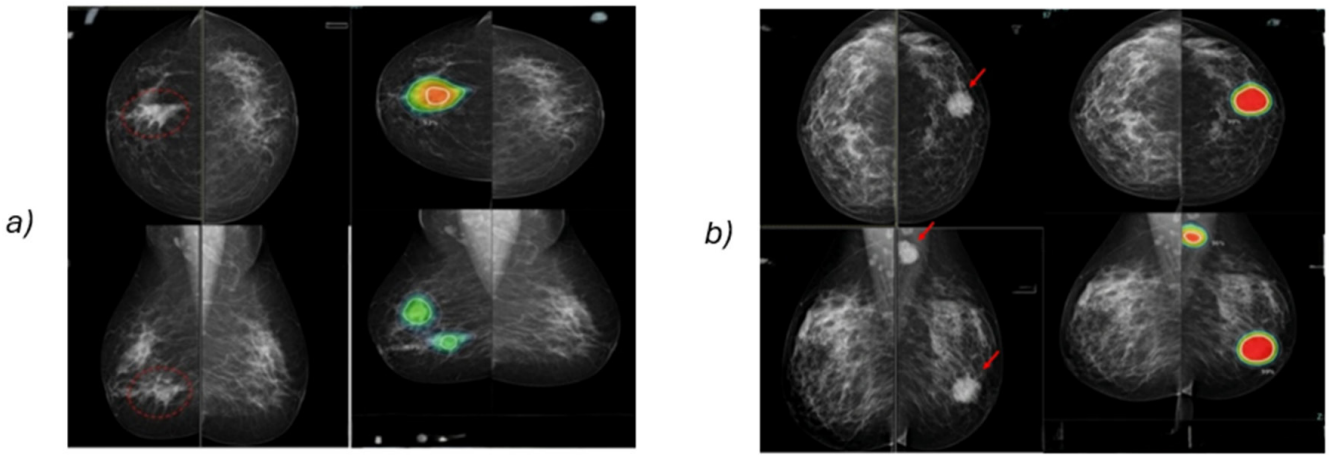

Figure 7a & 7b: AI use for mammography screening, highlighting focal asymmetry with distortion at the right breast and irregular dense mass lesion on the left breast (accompanying 93% and 99% risk of malignancy respectively).

Method

Upon arrival at the site, participants would be expected to provide answers to a baseline questionnaire after obtaining informed consent. Information obtained here is key to ascertaining eligibility and confirming their telephone numbers in cases of follow-up. More importantly, it will help in accessing the level of knowledge on breast cancer, risk factors, breast self-examination and mammography prior to the intervention through well-structured simple questions. Women who applied deodorant under the arm or breast will be asked to wash it off as this could mimic calcium deposits on the image. After the intervention, participants would be required to fill their same set of questionnaires given before the intervention, without having a prior knowledge of this. Health workers would be on standby to help in filling of the questionnaire for women (especially the elderly ones), who can neither read nor write. Furthermore, qualitative data would be collected based on perceived uptake of mammography screening, interviews and open-ended survey questions.

Training radiographers (mammographers)

A three-day training session is expected to be organized for mammographers (not less than 3 years of experience), who will be saddled with the responsibility of taking mammograms of very high diagnostic value. An issue to consider is if it's a genuine occupational requirement to have only female mammographers in breast screening, as there have been contrasting views on this [31]. While it is very much likely that the study population will prefer female radiographers, it is important to promote a culture of inclusivity and diversity in patient-centered care, which necessitates a balanced screening workforce (male and female radiographers), putting LGBTQ women into consideration.

Radiologist

An intensive two-day training course will be organized for a radiologist (not less than 3 years of experience) on how to use AI when reading mammograms. This follows recent prospective cohort research in 2025, conducted by [32], pointing at the enhanced diagnostic performance of radiologist in interpreting screening mammograms with and without AI assistance in the ratio 140:123 respectively.

Availability of an engineer

Provision would be made for a standby engineer to handle unforeseen technical challenges that may arise from the mammography-machine or automobile-related or AI software-related issues throughout the fourteen weeks duration of the program.

Training of research assistants

Research assistants would be trained to collect valid and reliable data as well as outcome testing.

Involvement of voluntary community health workers

Five weeks prior to the program start date, voluntary health workers (not less than 3 years of experience) in the various primary health care centres distributed across the LGAs in the state would assist in extensive campaigns, beginning at their respective primary care health centres, water collection points, women's association meetings and markets (especially on market days) where over 90% of women come out to buy and sell. In addition, via large posters and open communication. To women who visit the health centre for other personal health needs before the supposed start date, the health workers will be required to hold a sensitization session, informing them of the scheduled period of this program and encouraging them to participate. When the program eventually starts, they will again be helpful in facilitating meetings. More specifically, health workers conversant with the native language would be required to act as interpreters to transmit key health messages during the intervention process. Incentives have been shown to be an important motivating factor for health workers in this regard and should be made available if possible.

Goal

The primary aim of this will be to reduce breast cancer mortality among underserved women, exploring breast health education and AI-assisted 3D mobile mammography strategies.

Objectives

Objectives include raising breast cancer awareness, sufficient knowledge on risk factors, effective breast self-examination and promoting regular mammography screening.

Theoretical framework

The development of this intervention will follow the Health Belief Model (HBM) (Figure 8).

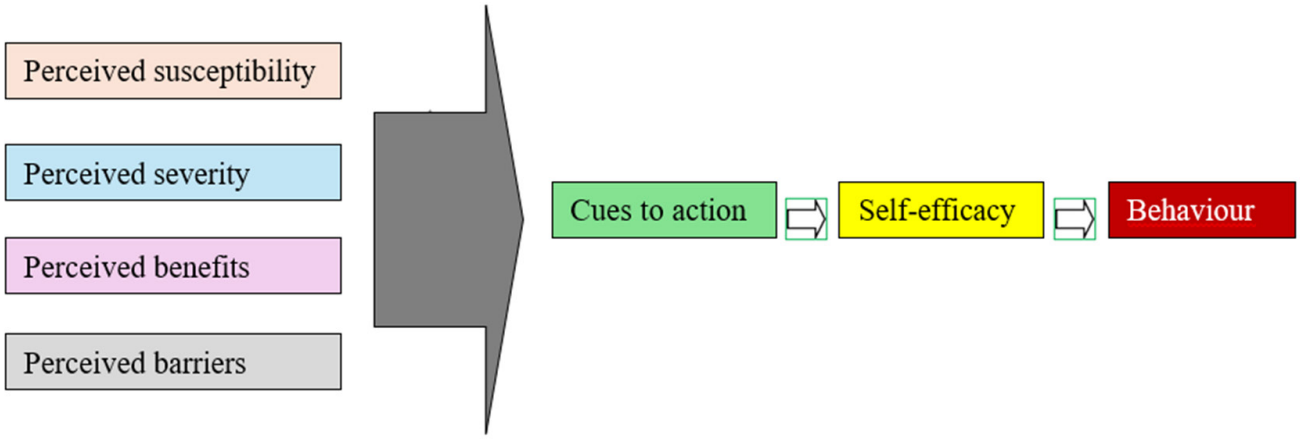

Figure 8: Health belief model.

a) Perceived susceptibility: Is the belief of an individual that habitual engagement in a particular behavior can lead to acquiring a disease. While delivering presentations, the health educator will expatiate on the modifiable and non-modifiable risk factors to breast cancer such as hereditary, age, race/ethnicity, physical inactivity, smoking, excessive alcohol intake, early menarche, late menopause, use of oral contraceptive and hormone replacement therapy, overweight and obesity. It is expected that participants would start engaging in health protective behaviors such as involvement in exercises, consuming a healthy diet and avoiding health risk behaviors like smoking and alcohol consumption.

b) Perceived severity: Denotes the belief of an individual of the extent of harm that can result from a disease due to habitual engagement in a behavior. The health educator will further educate the women on the potential negative effect/dangers of breast cancer such as breast hardness and redness, breast lump, severe pains, unintentional weight loss, metastasis, associated high cost of treatment and finally death. After this, participants are likely to have gotten sufficient knowledge and be convinced on the need to avoid risk factors to breast cancer.

c) Perceived benefits: This is seen as the belief of an individual about the advantages of suggested methods for reducing the disease. The health educator will demonstrate the five steps of breast self-examination via video clips, a practical session and re-iterate the need for women to undergo mammography screening, as early detection is critical to survival. This is expected to be well received by all participants.

d) Perceived barriers: Refers to the belief of an individual about the actual or imagined cost associated with engaging in a new behavior. The health educator is required to correct misperceptions some people have about going for mammography screening such as fear, or that breast cancer instantly kills. A counselling session will help tackle this. In addition, reassurance of participants on the need to have a mammogram considering the availability of a mammography machine for screening, which saves transport as well as the 90% offered price discount. The participants are likely to view this as an opportunity, one not to miss out on.

e) Cues to action: Is the sudden force influencing an individual to feel the need to take actions. At this stage, the whole message is well digested and assimilated by the participants and an abrupt force to want to engage immediately in mammography and observe breast self-examination and avoidance of breast risk factors at home.

f) Self-efficacy: Is the confidence in one's ability to change the behavior. Participants are very hopeful in themselves achieving everything required. This leads to new behavior.

It is important to consider a wide range of factors that can influence breast screening behavior. Cultural factors are one of such. In Borno state, females are not offered same educational opportunities as compared to males. It is a belief of the people that women should stay at home and be responsible for taking care of the family. This results in high female illiteracy rate. Also, religious values such as gender-bias issues, where women are reluctant to be attended to by male health professionals, is peculiar to this region

[33,34]. Social factors such as lack of education and awareness coupled with low income can impede mammography screening uptake. These women are unaware of breast self-examination because of their low level of education, thus are likely to be poor and not have money for taking regular mammograms [34]. Finally, psychological factors like fear due to misconception of breast cancer, shyness to share health problems, embarrassment and previous negative experiences can prevent Nigerian women from going for mammography screening [35].

Implication

The implementation of this on-site dual approach to breast screening behavior is expected to result in positive health outcomes among underserved women in Borno state. In a systematic review carried out by [10], it was observed in one of the earlier studies that self-examination of the breast among rural women increased from 0 to 93% after extensive health education on breast cancer and breast self-examination, delivered by trained health workers. This agrees with the later findings of [36] on the high statistical correlation between breast education and breast self-examination, with 90.7% of the participants practicing breast self-examination after extensive lectures, pamphlets and audio-visual aids on breast examination, compared to an initial 0% pre-test. Routine breast self-examination is valuable in noticing early breast changes such as breast lump, which when used in combination with mammography, is very effective in early breast cancer detection and an increased likelihood of survival. Elsewhere, such awareness emanating from numerous interactive educational sessions prompted 18% of the total population to participate in mammography screening, due to the availability of mammography machines in the health facility, with a high recall rate of 31.6% [37]. Furthermore, a practical component of breast education that involves intensive training on breast palpation using the breast model and mammography displayed visually in an x-ray film, yielded an uptake of breast self-examination 0.8 times and mammography 0.7 times.

Increased motivation among participants in each unit was noted, with a further clinical breast examination increase rate of 1.3 and 1.5 times for that of mammography [38]. Tracing memory lane down the studies of [39], a well-structured health education material, reduced-price mammograms and a mobile van had a strong impact on mammography use, with 45% of women in the experimental group obtaining mammograms compared with 12% of women at control sites. Such mammogram-seeking behavior has resulted in regular mammography screening, thereby contributing immensely to a 46% reduction in breast cancer mortality [40]. In joint research carried out by [16], it further reveals that the percentage awareness of risk factors such as age, family history, alcohol consumption, age at menarche and obesity substantially increased with each successive year for the studies conducted over a 4-year period. This affirms a prominent rise in cancer literacy as regards possible risk factors in this group. An expert review discovered that sufficient understanding of the risk factors and practicing health protective behaviors such as physical activity resulted in 20-40% breast cancer reduction. An additional 14% reduction in breast cancer is possible if alcohol use is eliminated or drastically reduced [41]. Communicating health promotion messages to inform and influence individual's decision that affects health requires several measures and techniques, which is highly dependent on the intended audience.

Taking a closer look at this proposed health promotion intervention, it is seen that the target population (undeserved women) is characterized by low educational levels, low health literacy and low income. As a result, any chosen communication route is one that allows for majority of the audience to be reached. Hence a poster, written in plain language to present health information in a visually appealing, logically organized and comprehensible format with clear headings and bullets is vital. A design that uses an active voice and one that increases comprehension such as use of pictures or graphics to illustrate important points is advised [42]. These posters should be mounted on key areas such as entry to primary health clinics/hospitals, community town halls, markets, entry point to banks and along important roadside/bus stops. Social marketing as a technique to promote mammography screening behavior is yet another strategy, with the four-core marketing mix-product, price, place and promotion to be taken into consideration. Developing an effective press release, directed to news media such as newspapers, TV and radio in particular is a way to achieving this. Such press release should have a strong headline such as "The increasing death rate of breast cancer among women in Borno state-the need for greater awareness on risk factors and breast self-examination, with routine mammography strongly advised", with a body that is brief and straight to the point. Furthermore, audio-visual materials such as cassettes, compact music discs and DVDs should be made available and sold in the markets and primary health centres at a giveaway price.

In summary, the study offers detailed insights into complex behaviours and social interactions, designed to have wide applicability across both resource constrict and knowledge gap settings and making this novel approach a vital weapon to bring about the necessary positive changes globally. The layout is foreseen to provide valuable understanding for developing hypotheses which can be further tested through rigorous research methods. Nevertheless, it is imperative to identify some potential difficulties associated with the implementation of this health promotion intervention. The primary barrier is the cost associated with a mobile mammography program [23,43]. This includes the high cost of maintenance of the mammography unit, mechanical problems with the vehicle, educational services and operational expenses. Secondly, bad weather may have an adverse effect on the machine. Having a dedicated team with an efficient workflow could be challenging. Low literacy level and language issues may also pose an obstacle to preventive services and effective communication of health messages. It is therefore imperative to recognize these limitations and to map out ways to effectively address them to produce the best results.

Conclusion

The incidence of breast cancer is increasing all over the world, connected with poor health outcomes due to late detection. This is

invariably a direct consequence of lack of breast cancer awareness, poor knowledge of risk factors and breast self-examination and lack of regular mammography screening. This intervention seeks to introduce a specialized on-site breast health education and AI-assisted 3D mobile mammography to enhance breast cancer knowledge and promote regular mammography screening among undeserved women in Nigeria, with the HBM theory forming the theoretical framework. It is expected that successful implementation of this intervention, including effective communication of this health message via posters, press release and audio-visual materials will substantially decrease breast cancer mortality and boost survival chances. However, financial barrier remains a major obstacle.

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