JCSDA, Vol. 2, No. 1, 1–15
DOI: 10.69660/jcsda.02012501
ISSN 2959-6912

Profiling of Breast Cancer Prevalence and Its Diagnosis Using Varied Imaging Techniques in Tanzania

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Breast cancer is not only the most commonly occurring cancer among women, but also the most frequent cause of cancer-related deaths in women in developing countries. The mortality rate is marginally higher in developing countries than in developed countries with about 60% of the deaths occurring in developing countries. In Tanzania for example, breast cancer is the second leading cancer in terms of incidence and mortality among women after cervical cancer. Approximately half of all women diagnosed with breast cancer in Tanzania die of the disease. This is due to the limited number of medical facilities for cancer screening and diagnosis, the limited number of oncologists and pathologists,

and the diagnosis costs in the country. Due to the mentioned factors, it is approximated that, 80% of breast cancer cases in Tanzania are diagnosed at advanced stages (III or IV), when treatment is less effective and outcomes are poor. By 2030, new breast cancer cases are approximated to increase by 82% in Tanzania. The diagnosis/screening of breast cancer starts with breast imaging with ultrasound and mammograms. Suspected cases are then subjected to pathology for confirmatory tests. Although breast imaging plays a major role in both breast cancer screening and diagnosis, the service is largely not available in many developing countries. Our study found the absence of routine breast cancer screening in Tanzania, resulting in late-stage detection of many cases. This is mainly due to a lack of enough well-trained radiologists to read the images and the costs of the process. This study is aimed at exploring the role, importance and challenges of breast imaging in the screening and diagnosis of breast cancer in Tanzania, a developing country. It is worth noting that, breast imaging is an important step in screening for breast cancer. Our results found that, there is a significant number of malignancies under the recommended age of breast cancer screening of fifty years of age. Our study also found a very high Inter variability among radiologists. This study also discovered in our sample size that 66% of patients did not have their samples taken for confirmation by the pathologists. This might be due to the costs of the process or loss of follow-ups as many patients came far from the diagnosis Centre. Due to the higher intervariability among radiologists, this suggests the necessity of at least two radiologists reading the same case before the conclusion of the diagnosis. Also, due to the significant number of malignancies under the recommended age of 50 years, this study recommends the age to be reconsidered based on different settings. Due to the challenges observed in breast imaging, this study recommends the use of computer-aided diagnosis (CAD) with Artificial Intelligence to assist the limited number of radiologists available.

Keywords: Breast cancer, medical imaging, breast imaging, data analysis, Artificial intelligence, radiology.

1. Introduction

Breast cancer is currently the most common cancer globally, affecting mostly women compared to men. It forms in the cells of the breasts and arises either in the lining cells (epithelium) of the ducts or lobules in the glandular tissue of the breast [1][2]. According to WHO, 85% of breast cancer occurs in the lining cells of the ducts, whereas 15% occurs in the lobules in the glandular tissue of the breast [3].

There are many known risk factors leading to breast cancer, but the causes are not fully understood. The strongest risk factors for breast cancer are being female gender and to some extent, getting older. However, studies have shown that the number of young people diagnosed with breast cancer is increasing. Also, black women are reported to be at higher risk of dying from breast cancer compared to women from other ethnic groups[4].

The early diagnosis of breast cancer is associated with adequate prognosis. This early diagnosis is made possible by the standard way of screening, which involves the use of mammogram or ultrasound imaging to detect an anatomical derangement that will be confirmed by a pathologist.

A recent report by Globocan shows that 18.1 million new cases were recorded in 2018 and deaths of 9.6 million people in the same year [5]. The report also tells us that 70% of that death toll occurred in low- and middle-income countries [5]. Also, only 26% of low-and middle-income countries (LMICs) reported having pathology

services available in the public sector compared to 90% of high-income countries [6].

According to WHO, breast cancer is the most frequent cancer among women, impacting 2.1 million women each year, and causes the greatest number of cancer-related deaths among women [7]. Breast cancer is the second most common cancer and the second leading cause of cancer mortality among women in Tanzania [8][9]. Approximately half of all women diagnosed with breast cancer in Tanzania die of the disease and approximately 80% of women diagnosed with breast cancer in Tanzania die at advanced stages (III or IV) [10], when treatment is less effective and outcomes are poor [9]. It is predicted that by 2030, new breast cancer cases will increase by 82% in the country [9]. It is worth noting that, Tanzania has very few well-trained radiologists and pathologists. This has resulted in a lack of systematic breast cancer screening programs. Efficient breast cancer screening systems are largely unavailable in many developing countries, leading to delayed diagnosis, which results in, by extension, a high mortality rate. The burden of breast cancer in the LMICs is escalated by different factors, including ignorance of the susceptible, limited technology, shortages of cancer healthcare-related personnel and the associated costs of the current ways for cancer diagnosis [11][12][13].

Breast Cancer Screening involves the organized checking of women's breasts for cancer before there are signs or symptoms of the disease [14]. According to WHO, the organized and effective screening program is one in which the participation rate (number of invitees screened) of the target population is over 70% [15]. Even though breast cancer screening cannot prevent the occurrence of breast cancer, it can help detect it early if there are any symptoms of breast cancer and when it is easier to treat. In Tanzania, different studies about breast cancer have been performed but currently, no systematically organized screening program performs breast cancer screening for the whole country except for some studies (the study carried out at Ocean Road Cancer Institute is the national cancer center) [14], the one carried in this study and other related studies. They highlight the status of breast cancer in certain localized places and sometimes are not fully focused on screening.

To alleviate the problem, the factors contributing to the burden need to be handled simultaneously. Also, systematic breast cancer screening programs can largely lower breast cancer morbidity and mortality.

This study aims to explore the role of breast imaging in the prevalence of breast cancer in Tanzania by highlighting the current situation of the screening and diagnosis process of breast cancer. Based on its findings, this study proposes potential ways to address the challenges facing the process of screening and diagnosis of breast cancer in the country.

2. Materials and Methods

Breast imaging modalities, mammography and ultrasound are the primary imaging modalities for the detection of breast cancer. Mammography may detect cancer one

and a half to four years before cancer becomes clinically evident. We explored the role of the two methods as described in the section "Materials". The performance of the two methods was also compared, as shown in Table 1. The role of human readers was compared in terms of variations among themselves when reading ultrasound images in Table 3 and when reading mammograms in Table 4. The imaging data used in this analysis was labeled by radiologists with reference to a ground truth of pathology results, as described in Figure 1.

2.1. *Material*

The data sets consist of images that were collected by using two different imaging technologies, which are ultrasound and mammogram. The ultrasound images were obtained using a GE Voluson Pro 8, while the mammography was obtained using a Genoray DMX600. All patient data attended the hospital for breast cancer-related cases were included in the study. Initially, a total of 1014 patients' data was extracted, which included duplicates. After the removal of duplicates, 987 patients ranging from 22 to 90 years of age were involved in the study as there were no participants outside that range. From the involved patients, a total of 3842 mammogram and 2021 ultrasound images were obtained. The study included all symptomatic women who came to the radiology department at Muhimbili Mloganzila National Hospital for breast cancer diagnostic imaging. However, those whose retrieval of images was not successful were excluded.

The labeling process for the obtained dataset was conducted by three radiologists. Two radiologists labeled the images independently, a third radiologist was involved only when the labeling of the first two radiologists differed. The images were labeled as either normal, benign, or malignant. Different labels were used for indicating the status of the patients: number 0 indicates normal, 1 for benign, 2 for malignant and 3 for inconclusive. The inconclusive classes were later classified into either 0,1 or 2 classes based on the pathology examination, and if the patient in class 3 did not perform a pathology examination, the patient was excluded from the study analysis. Most of the inconclusive cases were due to the quality of images, which affected the reading by radiologists. The methodology can be described as in Figure 1 below.

It shows that two imaging modalities were used for data in which radiologist one (Rad 1) and radiologist two (rad 2) labeled independently. A third radiologist was involved when the first two radiologists differed. The four classes labelling was used for analysis of the radiologists performance, but pathology results were referred as ground truth of Normal, Benign and Malignant.

The images were stored in Picture Archiving and Communication Systems (PACS) server, and they were extracted by using *ClearCanvas DICOM Viewer*. For this case, *ClearCanvas* facilitates the management of the medical images, whereas *DICOM Viewer* communicates with PACS servers and views DICOM (Digital Imaging and Communications in Medicine) studies.

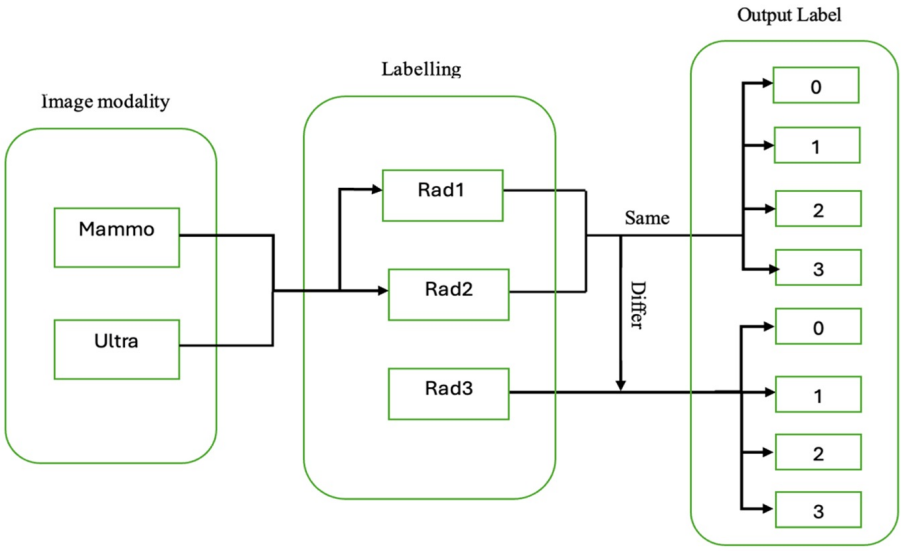

Fig. 1. Methodology showing that two imaging modalities were used for data in which radiologist one (Rad 1) and radiologist two (rad 2) labeled independently. (A third radiologist was involved when the first two radiologists differed).

2.2. *Methods*

2.2.1. *Study Design*

This was a retrospective study applying quantitative designs. Several patients attending the breast cancer clinic at Muhimbili Mloganzila National Hospital from October 2018 to February 2022 were identified and included in the study. This study explored the diagnosis process and qualities of the current diagnosis modalities available at the hospital, which represent the majority part of the country, as it is in many developing countries. The study was approved by the institutional ethical review board of Muhimbili University of Health and Allied Sciences (MUHAS). All the methods used in this study were performed following the guidelines and regulations of MUHAS.

2.2.2. *Study Settings*

This was a retrospective study that was conducted at Muhimbili Mloganzila National Hospital. Analysis of the data was conducted at the Emerging Technologies for Health Research and Development Laboratory (ETH), which is under the Muhimbili University of Health and Allied Sciences (MUHAS), unit of biomedical engineering. The lab is equipped with necessary computing facilities, including Graphics Processing Units (GPUs). This project was funded by the International Development Research Centre (IDRC) through Villgro Africa under the Artifi-

cial Intelligence for Development (AI4D) initiative, Google Ireland Limited and the Swedish International Development Cooperation Agency (SIDA) through the MUHAS small grant research program.

3. Results

Data analysis was conducted to assess the prevalence of breast cancer in Tanzania by looking into the burden of the disease geographically and the role of breast imaging in the diagnosis of the disease with reference to pathology results as a ground truth. The implementation was done by using the Python programming language.

3.1. *Prevalence Analysis*

The analysis performed in this study was focused on the representative sample collected at Mloganzila Hospital. The findings in this study may vary from the results obtained using data from other regions of the country. However, it is worth noting that Mloganzila Hospital is one of the few government hospitals in the country with breast cancer diagnosis clinics using mammograms. Hence, these results may be a good indicator of the prevalence of breast cancer in the country. Figure 2 shows the distribution of the patients involved in the study throughout the country.

	Both Ultra and Mammo	**Mammo Only**	**Ultra Only**	**Total**
Malignant Cases	53	100	1	154 (15.602%)
Benign Cases	67	86	5	158 (16.008%)
Normal	11	12	0	23 (2.330%)
No histology results	158	450	44	652 (66.058%)
Total	289	648	50	987(100%)

Table 1. Ultra = Ultrasound and Mammo = Mammogram. The confirmation of the malignant, benign, and normal cases was based on the pathology results.

Table 1 shows that 15.602% of all the patients in this study were malignant based on who did both imaging (53 patients), mammo only (100 patients), and ultrasound alone (1 patient). Studies show that doing both imaging is more accurate in detecting breast cancer than doing one. In our case, we found that only 29% of the participant performed both mammo and ultrasound, with the majority (66%) did only Mammo and Only 5% of the participants did ultrasound. Although a mammogram is better at detecting abnormalities deeper within the breast tissue, which can tell why it was frequently used, ultrasound might be a potential alternative, especially in resource-limited settings, which is the case in many LMICs like Tanzania. There are fewer than ten mammogram machines in government hospitals compared to ultrasounds available up to district-level hospitals. In addition,

women younger than 40 years of age are not recommended for mammograms [16], which contributed to more cases of going through mammograms seen in Table I. Ultrasound is recommended mostly for younger women with dense breasts, pregnant women and in evaluating suspicious lumps found on a mammogram[17]. The high number of patients who did not conduct the pathology process (66%), might be due to the high cost associated with the process.
Note that patients who had status indicating Right breast: Benign and Left breast: Malignant or the other way around were counted in the malignant cases in this analysis. The patients without histology results did not have their samples taken for pathological tests. Most of these cases were normal on the image-based screening, hence not subjected to pathology examination. But it is also possible that some patients had different statuses as some of the image-based suspected cases did not proceed into pathology examination, most likely due to the associated costs of the procedure or did not go back to the hospital due to the travel distance from their initial locations. The small number of patients with normal status in the tables throughout this paper indicates image-based suspected cases who were sent to the pathologists and confirmed to be normal.

	Age Groups							
	20-29	30-39	40-49	50-59	60-69	70-90	Unspecified	Total
Malignant Cases	2 (1.3%)	24 (15.6%)	52 (33.7%)	32 (20.8%)	27 (17.5%)	12 (7.8%)	5 (3.2%)	154 (100%)
Benign Cases	4 (2.5%)	22 (13.9%)	52 (32.9%)	47 (29.7%)	26 (16.5%)	4 (2.5%)	3 (1.9%)	158 (100%)
Other cases	13 (1.3%)	115 (11.6%)	323 (32.7%)	262 (26.5%)	172 (17.4%)	48 (4.8%)	54 (5.5%)	987 (100%)

Table 2. Distribution of malignant and benign cases based on their ages. The numbers in the third row for "other cases" include Normal cases and cases that did not have histology results. The Malignant and Benign cases are only those confirmed by pathology examination.

The distribution of the malignant cases is normally distributed across the age groups. The group ranging between 40 and 49 years of age is mostly affected because the highest number of malignant cases fall in this group. Most of the recommendations for breast cancer screening suggest starting at the age of 50. There was no participant under the age of 20 years. Table II shows a significant number of women who are malignant under the age of screening recommendation. Figure 2 shows distribution based on the percentage of benign and malignant in their respective age groups. The graph shows that malignant cases are found in almost all age groups with different intensities.
Figure 3 is the Tanzania map showing the distribution of the patients who were involved in this study throughout the country. Although the study was conducted at Muhimbili Mloganzila National Hospital, the hospital is a campus of Muhimbili

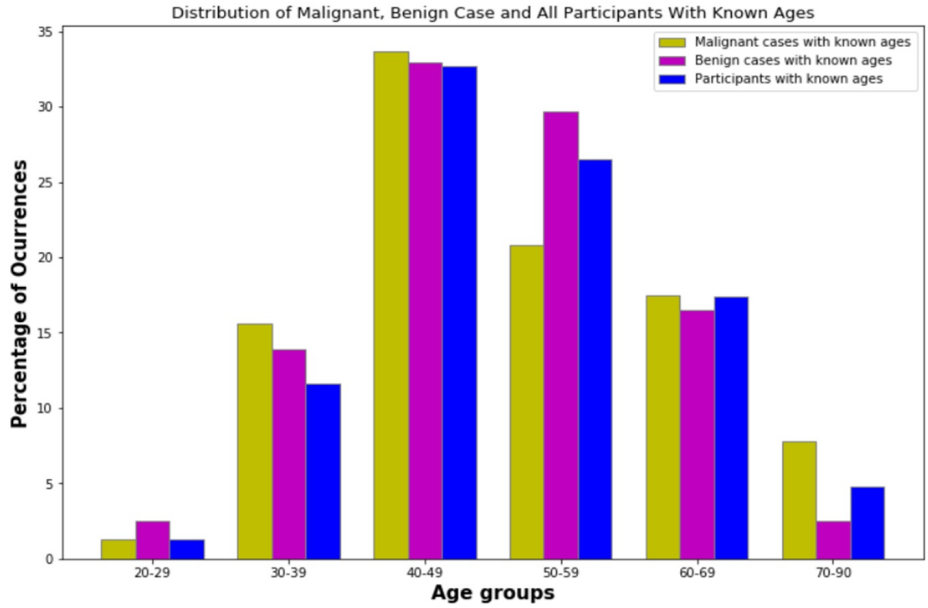

Fig. 2. The distribution of Malignant and Benign cases as well as the distribution of all participants with known ages

National Hospital, which is a national referral hospital and hence receives patients from all over the country.

The data recorded at the hospital also includes the origin of the patients. The distribution of patients from all over the country may show the need for breast cancer screening and diagnosis and the overwhelming limited number of radiologists at the Muhimbili Mloganzila. There are only five (**??**) government hospitals around the country with cancer diagnosis capabilities, resulting in the absence of screening programs.

3.2. *Inter variability between the Radiologists*

Although breast imaging can play a major role in the early detection of breast cancer for early intervention, accurate reading of the obtained images is of high significance. Many studies have reported a very high intervariability among radiologists in reading mammograms for the detection of breast cancer [18][19]. Table III and Table IV present results comparing the labeling for breast cancer that were done by three radiologists for ultrasound and mammogram images, respectively. The pathology results were used as the gold standard (ground truth). Only patients who had results from the pathologists indicating the tumor status had their results compared to the radiologist labels. Any patient missing any of the information was excluded from this analysis.

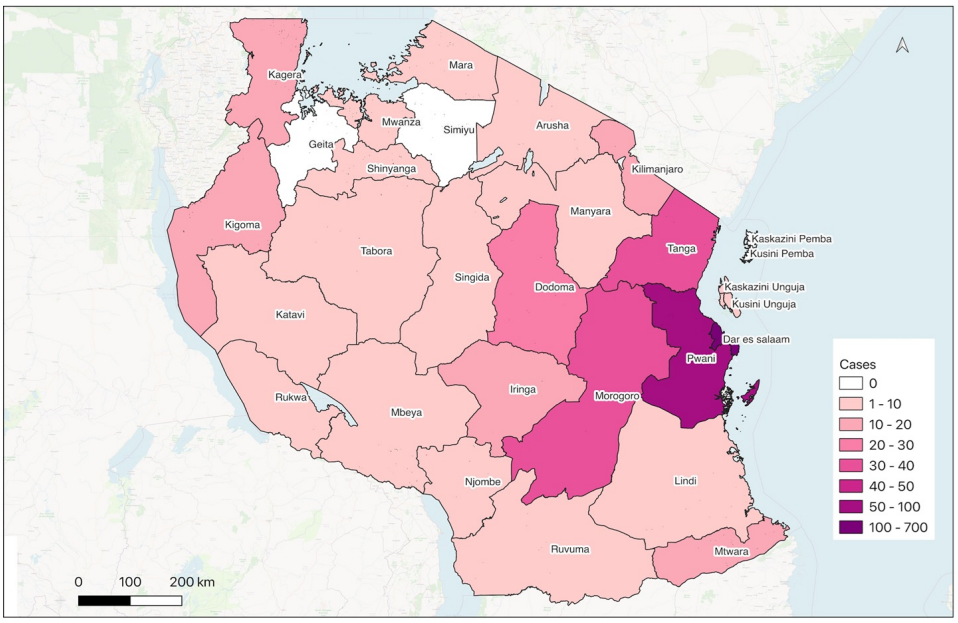

Fig. 3. The distribution of the Participants involved in the study throughout the country

We compared the analysis results of the images in which the three radiologists labeled correctly and vice versa against the pathology results. Also, we checked when only two radiologists out of three labeled correctly and vice-versa against pathology results. We also present the situation where all three radiologists differed from each other in their labels compared to the pathology results.

	Pathology Results					
	Normal (??)		**Benign** (??)		**Malignant** (??)	
Rad. agreement	True Labeling	False Labeling	True Labeling	False Labeling	True Labeling	False Labeling
3 out of 3	20/29	9/29	99/218	119/218	58/164	106/164
2 out of 3	20/24	4/24	79/149	70/149	16/101	85/101
1 out of 3	0/1	1/1	3/8	5/8	1/9	8/9

Table 3. Summary of the results indicating the true and false labeling of the ultrasound images compared to the pathologist results.

In Table 3, radiologists were correct at an average of around 50% when 2 or 3 of them were involved against the pathologist results. They were more correct in labeling Normal cases with 68.96%, followed by 45.41% in labeling Benign, with a very low percentage of 35.37% in detecting malignant cases. The normal classes presented in this Table are those which went through pathology examination. We

couldn't calculate the percentage for when one radiologist was involved due to Nan values. In Table IV, a higher percentage was achieved on average when three radiologists were involved in detecting both cases, with a significant drop when 2 or 1 radiologist was involved. In Table IV, the three radiologists achieved a higher percentage of 76.29% in detecting malignant cases.
Looking at Tables 3 and 4, the three statuses (normal, benign, malignant) in each case show true as well as false labeling by the radiologists. In each row, both true and false labels have a common denominator. The common denominator under each case that corresponds to the radiologist's agreement is the number of pathology results in that case. In each case, the numerators are the predictions done by radiologists. The variation among radiologists is a common factor in many countries [20][21][22], this is why it is strongly recommended that radiology images be read by more than one reader[23][24], and this is why this study recommends the use of computer aided technologies like AI especially in resource limited settings.

	Pathology Results					
	Normal (37)		**Benign** (252)		**Malignant** (205)	
Rad. agreement	True Labeling	False Labeling	True Labeling	False Labeling	True Labeling	False Labeling
3 out of 3	4/10	6/10	30/70	40/70	74/97	23/97
2 out of 3	9/19	10/19	36/109	73/109	4/66	62/66
1 out of 3	2/8	6/8	25/73	48/73	3/42	39/42

Table 4. Summary of the results indicating the true and false labeling of the Mammogram images compared to the pathologist results

4. Discussion

The burden of breast cancer among women in lower-income countries is contributed by late/missed diagnosis of the disease. The results show that 15% of those who were tested were pathologically confirmed to be malignant. This is a significant percentage of malignancies, and it cannot be overlooked. It is possible that more cases were malignant because 66% of patients did not have their samples taken for confirmation by the pathologists. Difficulties in accessing and high costs of pathology examination are common in many LMICs, while the burden of breast cancer is predicted to increase [25][26]. To address these challenges, other studies have suggested the use of local trainers and virtual mentorship to increase the availability of services in local areas instead of just relying on well-established referral hospitals, as has been seen in this study[27].
The WHO recommends Mammography screening based on age group and resource setting [13]. It recommends organized and population-based mammography screening programs for women aged 50 - 69 years. Despite the recommended age for breast cancer screening, in this study, about 50% of malignant cases occurred among

women below the WHO recommended age. The results show that 33.7% of the malignant cases are from women with age 40 to 49. Although the WHO recommends mammogram-based screening of breast cancer, the high infrastructure costs limit the practice in LMICs[28]. This paper reports the high incidence rate of breast cancer, absence of screening programs, largely absence of mammograms as it can be seen in Table I. To lower the burden, this study recommends the use of ultrasound imaging due to its cost effectiveness [29]and the use of computer aided diagnosis like AI to address the problem of user dependency variations of ultrasound[30].

The high prevalence of breast cancer in low-income countries is most likely attributed to different factors. Poor technological advancement may cause many people to be diagnosed late or miss the opportunity. This can be supported by the absence of screening programs in many developing countries. For example, in Tanzania, the screening program is conducted only once a year, in October, during breast cancer awareness month with the support of the Medical Women Association (MEWATA).

The analysis has shown that patients involved in the study mostly come from the Dar es Salaam region and the nearby regions. This situation can be justified by the fact that Mloganzila Hospital was the only government hospital in the country with a breast cancer diagnosis clinic using mammograms. That is the possible reason that drives patients to travel and access the service. It is also possible that the high concentration of patients in Dar es Salaam might be influenced by economic status. The distribution map has indicated that few patients came from regions from the periphery. These patients traveled long distances to access mammogram diagnosis services. There are only a few who can afford it, but there are many out there who need similar services. This suggests that the diagnosis needs to be performed in a different part of the country. In addition, although there are already a few numbers of radiologists, further training to use affordable and available imaging methods like ultrasound might reduce the current burden of breast cancer in the country.

Also, there is a limited number of radiologists. It is possible the regions that do not have any data in this study do not have radiologists to interpret the images. This fact does not imply that these regions do not have breast cancer cases. The results suggest that there is a need for screening programs available in many regions that start at an early age. According to the data analysis presented in this paper, women below 50 years of age are also at high risk of getting breast cancer. The results suggest that there is a need to recommend a new lower age threshold for beginning breast cancer screening to reduce the burden of breast cancer that is likely to happen in old age.

5. Conclusion

This study highlights the critical role of breast imaging in the screening and diagnosis of breast cancer in Tanzania, emphasizing the existing challenges and potential solutions. The findings reveal that breast cancer is often diagnosed at advanced

stages due to the limited availability of screening programs, inadequate numbers of trained radiologists, and the high cost of pathology confirmation. The data also indicate significant inter-reader variability among radiologists, underscoring the need for multiple readings to improve diagnostic accuracy.

A key observation from this study is that a substantial percentage of malignant cases occur in women younger than the WHO-recommended screening age of 50 years. This suggests the necessity of reconsidering the recommended screening age, particularly in settings where the early onset of the disease is prevalent. Additionally, the geographic distribution of patients in this study illustrates the lack of widespread access to mammography and pathology services, necessitating the decentralization of breast cancer diagnosis services to ensure broader reach and early detection.

To address these challenges, this study recommends the integration of Computer-Aided Diagnosis (CAD) using Artificial Intelligence (AI) to support radiologists in image interpretation. This could significantly reduce the burden on the limited number of radiologists and improve diagnostic consistency. Furthermore, the expansion of systematic breast cancer screening programs across different regions of the country could play a crucial role in reducing late-stage diagnoses and improving patient outcomes.

In conclusion, This study recommends the implementation of a comprehensive breast cancer screening program in Tanzania that integrates both mammography and ultrasound to improve early detection, particularly in younger women and those with dense breast tissue. Given the high inter-reader variability among radiologists, a double-reading system should be adopted, and the use of Computer-Aided Diagnosis (CAD) with Artificial Intelligence (AI) should be explored to enhance diagnostic accuracy and reduce workload. Additionally, breast cancer screening services should be decentralized to improve accessibility in remote regions, reducing the need for long-distance travel. The government and healthcare stakeholders should prioritize training more radiologists and pathologists, while also subsidizing pathology services to ensure that all suspected cases receive confirmatory diagnosis. Finally, considering the significant proportion of malignant cases found in women under 50, it is crucial to reassess the recommended screening age and adapt guidelines to reflect the specific epidemiological trends observed in Tanzania.

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