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INVESTIGATING THE EFFICACY OF INTEGRATED DETECTOR AND PHOTON COUNTING APPROACHES FOR BREAST LESION DECOMPOSITION IN BREAST CANCER

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ABSTRACT
The World Health Organization (WHO) reports that breast cancer is the primary cancer diagnosis for women worldwide, accounting for 11.7% of new cancer cases. In Nigeria, 49% of women 36 and above are diagnosed with breast cancer, ranking Nigeria second in Africa. The National Cancer Control Programme (NCCP) seeks to improve patient survival through early diagnosis using various screening modalities, including Computed Tomography (CT). This study explores spectral decomposition techniques for lesion contrast enhancement in breast CT, building on previous research that highlights the benefits of CT over 2-D mammography. The work featured in this paper presents an idealized scenario of noiseless images devoid of scatter or photon noise to investigate the intrinsic characteristics of contrast in CT imaging. A 2-D breast phantom with a diameter of 100mm was built and employed in photon counting methodology to simulate breast lesions. Three distinct experiments were conducted across photon energies in bins of 20keV, 10keV, 5kev and examined spectrally. The decomposition lesion showed substantially greater contrast of about 70% within the energy spectrum of 1-60 keV in comparison to conventional integrating CT methodologies. Contrast values have been attained at lower energy bins, which agrees with the promising features of photon counting technology for early detection of lesions and correlate with the attenuation of glandular tissues. The photon counting technique has exhibited potential for the visualization of synthetic images in bins predicated on contrast analyses.

Keywords: Breast cancer, Photon counting, Integrated detector, Lesion decomposition, Diagnostic imaging

INTRODUCTION
Breast cancer is a substantial global health dilemma, profoundly affecting women's health and quality of life (Anggraeni et al., 2023). The World Health Organization (WHO) have predicted that over 35 million new cancer cases will be diagnosed globally by 2050, representing a 77% increase from 2022 (Anggraeni et al., 2023; Prevalence of Women Breast Cancer, 2023). The prevalence of breast cancer displays variations when assessing different geographical territories and nations, showing higher instances in affluent countries like the United States and certain European regions, unlike in less economically developed countries (Conti et al., 2022).
In Nigeria, the incidence of breast cancer has reached alarming levels, with approximately 49% of women aged 36 and above receiving a diagnosis of the disease, positioning Nigeria second in Africa regarding prevalence (Olasehinde et al., 2021). The early identification and precise diagnosis of breast cancer are essential for facilitating effective treatment. In recent times, studies have explored various imaging strategies and techniques aimed at increasing the accuracy of breast cancer diagnosis, especially stressing the enhancement of both sensitivity and specificity in identifying lesions. Recent innovations in imaging technologies, including integrated detector systems and photon counting techniques, have demonstrated potential in improving the quality of breast imaging, ultimately yielding better patient outcomes through timely intervention (Barber et al., 2015). These cutting-edge approaches not only seek to enhance image resolution but also aspire to furnish more comprehensive information regarding the characteristics of breast lesions, thereby assisting clinicians in making well-informed decisions pertaining to patient management and treatment strategies (Barber et al., 2015).
With the implementation of cutting-edge imaging methods, the National Cancer Control Programme (NCCP) in Nigeria seeks to prioritize the swift identification of cancerous ailments, thereby enhancing the overall well-being of patients (Ikubor and Tobi, 2022). Despite the global endorsement of 2-D mammography, this technique is inherently constrained by the superimposition of three-dimensional anatomical structures onto the two-dimensional images (Badal et al., 2018). Figure 1 illustrates the innovative breast screening techniques, including Dedicated Breast Computed tomography (DBrCT) and Photon Counting Breast Computed Tomography (PCBCT), are currently under investigation to yield clearer and more detailed imaging, thereby potentially improving detection rates while concurrently minimizing false positive results that arise from the aforementioned limitations.

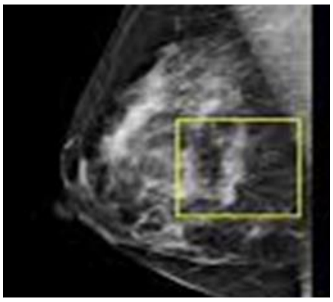

Figure 1: Superimposition of images from 2-D Examination (Badal et al., 2018)

The photon counting technique is presently undergoing research to assess its capability to deliver images with superior resolution while simultaneously reducing radiation exposure, which would enhance both patient safety and diagnostic precision. The photon counting method has garnered increased attention as the DBrCT fails to leverage polychromatic energy and predominantly relies on integrating detector technology, which may restrict its capacity to fully capitalize on the advantages offered by advanced imaging methodologies (Gomes, 2022). These advancements signify a notable progression in the realm of breast cancer screening, as they endeavour to address the shortcomings associated with conventional techniques and provide more precise evaluations of breast tissue.

In light of the recent surge in breast cancer incidence in Nigeria and the concerted efforts to ameliorate the circumstances of affected individuals, this research work seeks to investigate spectral decomposition techniques derived from computer simulations to critically compare the efficacy of Integrated Detector and Photon Counting methodologies for contrast visualization. As there hasn't been any study to compare these technologies for NCCP. The outcomes of this investigation are anticipated to yield significant insights regarding which imaging modality demonstrates superior effectiveness for the early diagnosis of breast cancer in an adult female breast.

An adult woman's mammary gland is an intricate assembly of glandular, adipose, and connective tissue types. Cloaking the breast region is a layer of dermis, which holds hair follicles, sweat glands, and sebaceous glands. Centrally positioned within the breast is the nipple-areolar complex (NAC) (Biswas et al., 2022), which comprises the nipple, areola, and the minute papules on the areola. The glandular component of the breast is constituted by 15-20 lobes, each harbouring a cluster of alveoli responsible for lactation. These lobes are interconnected through a system of ducts that coalesce to form larger ducts that discharge onto the nipple (Alekseev, 2021). The glandular tissue receives structural support from adipose tissue, which serves to provide cushioning and contour to the breast (Alekseev, 2021). On top of that, the breast houses lymphatic vessels and nodes that are essential in the filtering and removal of waste and toxins present in the breast tissue. The anatomical structure of the adult female breast is integral to reproductive and hormonal functions (Lawrence and Liu, 2022). A thorough grasp of the structure of breasts, illustrated in figure 2, holds great importance for accurately diagnosing and treating breast cancer.

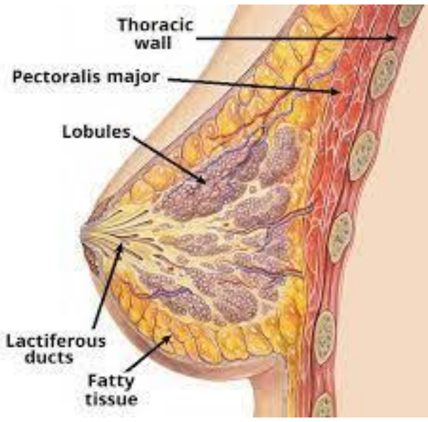

Figure 2: Anatomy of the Breast (Edwin et al., 2008)

Breast cancer represents a highly intricate and multifarious pathological condition that originates within the breast tissue, wherein normal cellular entities undergo a sequence of genetic aberrations and transformations, resulting in the emergence of malignant cells (Karrar et al., 2022). The pathological process generally initiates within the milk-secreting ducts or lobules of the breast, where cellular entities perpetually engage in growth, division, and programmed cell death as integral components of the standard cellular lifecycle (Mani, 2022). Nevertheless, when inaccuracies transpire during the DNA replication process, or when genetic mutations are instigated by environmental influences or hereditary factors, the normal cellular lifecycle may become perturbed, culminating in unchecked cellular proliferation and tumorigenesis. If these atypical cells remain active in their growth, they might give rise to a small, localized growth that could eventually invade neighbouring tissues and propagate to other body parts, involving lymph nodes, skeletal structures, and different organs, via a process called metastasis (Lloyd et al., 2017). The specific factors that bring about the onset of breast cancer as shown in figure 3, remain partially undefined; still, thorough research has mapped out several key variables, including mutations in the BRCA1 and BRCA2 genes (Siddig et al., 2021), hormonal abnormalities, and contact with ionizing radiation and particular chemical agents, which may promote the beginning and development of the illness. As the abnormal cells grow, they can also promote the creation of new vascular networks and involve adjacent tissues to foster their proliferation, eventually resulting in the emergence of a malignant tumour that can potentially cause considerable injury and damage to the breast and neighbouring tissues (Grigorievskaya et al., 2023).

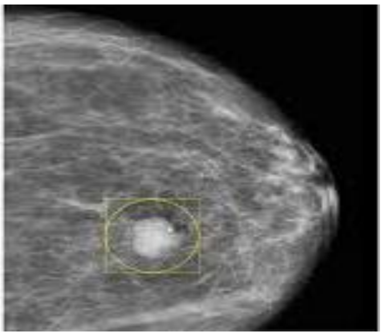

Figure 3: Clear image of breast cancer during screening (Lloyd et al., 2017).

Lesion contrast is a crucial aspect of breast cancer detection, as it helps radiologists differentiate between benign and malignant lesions. Enhanced imaging techniques can improve the visibility of tumors, allowing for earlier diagnosis and treatment options that may significantly impact patient outcomes (Hashem et al., 2021). Clinical investigations have substantiated that screening mammography significantly diminishes mortality rates associated with breast cancer (Braitmaier et al., 2022). The efficacy of mammography is contingent upon its capacity to discern tumors in breast cancer, which is predicated on the differential absorption of X-rays by the affected tissue, in contrast to adipose and glandular tissues. Neoplastic tissues within the breast exhibit a radiographic brightness that is similar to that of glandular tissues, thereby complicating detection during imaging, particularly in cases of dense breast tissue (Chernaya et al., 2023).

Currently, the objective of screening mammography is to mitigate the occurrence of false positive results while addressing the constraints posed by superimposed tissues in certain imaging technologies. This objective can be realized by considering the magnitude of the signal differential between the tumor and its adjacent background, which constitutes the essence of contrast. In the case of breast imaging, achieving high contrast is imperative to facilitate the sensitivity of normal anatomical structures from pathological entities (Lee et al., 2022). Furthermore, enhanced contrast facilitates the identification of calcifications and lesions within the breast (Lee et al., 2022). A breast afflicted by cancer encompasses both the lesion and the surrounding tissues as shown in figure 4; thus, the contrast arises from the variances in X-ray attenuation characteristics between the lesion and the adjacent tissues. Additionally, the dimensions of the lesion serve as a contributory factor (Gao et al., 2023).

The investigation of the effectiveness of integrated detector and photon counting methodologies in the decomposition of breast lesions constitutes a crucial domain of research for the diagnosis of breast cancer. There is a direct influence on the precision and efficacy of breast cancer detection and subsequent treatment planning. Empirical evidence indicates that photon counting detectors (PCDs) demonstrate markedly enhanced performance attributes in comparison to conventional energy-integrating detectors (EIDs), with research findings illustrating that PCDs can significantly improve both image quality and diagnostic precision (Nakamura et al., 2022). This effect can be traced back to the essential advantages of PCDs, which feature their capacity to deliver excellent spatial resolution, heightened contrast-to-noise ratios, and lower radiation exposure, consequently enabling a more accurate and sensitive identification of breast cancer (Bulbul et al., 2020). The application of PCDs in the diagnostic process of breast cancer holds the potential to transform the discipline, empowering clinicians to identify and characterize breast lesions with heightened accuracy (Gong et al., 2023), hence contributing to the formulation of more effective treatment planning and management strategies.

Review of the existing literature shows a growing consensus among researchers regarding the transformative impact of PCDs on breast cancer diagnostics, highlighting not only their technical advantages but also the potential for improved patient outcomes through earlier detection and tailored therapies (Ahmed et al., 2023; Bulbul et al., 2020; Nakamura et al., 2022). Other scholarly authors have conducted extensive investigations regarding the integration of advanced photon counting technology into pre-existing imaging systems, which has resulted in a series of promising advancements that could potentially revolutionize the field of imaging (Sartoretti et al., 2023; Alkadhi and Runge, 2023). In a separate study, researchers performed a comparative analysis between photon-counting images and energy-integrated images specifically within the context of mammography, with a particular emphasis on evaluating their respective abilities to detect lesions of varying types. Both categories of imaging demonstrated a commendable visual detectability of gold discs within the CDMAM3.4 phantom, which serves to indicate that both methodologies possess the capability to identify lesions effectively (Shinohara et al., 2024). Worth mentioning is that the quality of images generated by these two distinct techniques showed important differences, which implies possible variations in accuracy and sensitivity as outlined in the work by (Shinohara et al., 2024). This research upholds a critical need for the development of larger detection devices tailored for clinical applications; as such advancements may further influence the overall effectiveness of each approach in the decomposition of breast lesions. This situation indicates a pressing need for additional research aimed at optimizing the image quality of photon-counting images to ensure that they can match or even surpass that of energy-integrated images, leading to improved diagnostic accuracy in clinical settings. An investigation conducted by (McCullagh, 2022) revealed that the CdTe-based photon counting detector (PCD) exhibited a level of accuracy and sensitivity that was superior when compared to the performance of the CMOS-based energy integrating detector (EID) specifically in the context of breast lesion detection. The findings from this study suggest that PCDs possess the capability to achieve image quality that is equivalent to or even better than that provided by traditional energy integrating detectors (EIDs), all while operating at a mean glandular dose (MGD) that is 30% lower, thereby indicating a significant potential for reducing radiation exposure to patients without compromising on the effectiveness of detection capabilities, as highlighted in the work of (McCullagh, 2022).

The research work published by Schaeffer et al. (2024), specifically focused on the application of photon-counting detectors within the context of contrast-enhanced mammography (CEM), and it is important to note that this particular study does not offer a direct comparison with integrated detector approaches. Nonetheless, it indeed emphasizes various perks linked to photon-counting detectors, like their skill in enabling the simultaneous capture of different energy bins and their promise for reducing electronic noise, both of which can substantially elevate sensitivity and accuracy in breast lesion identification.

A different investigation by Schaeffer et al. (2022) focused on a comparative study of photon-counting detectors (PCDs) that employed both CdTe and GaAs materials in the context of contrast-enhanced spectral mammography, thus showcasing the various benefits that PCDs provide over dual-energy systems that feature energy integrating detectors. According to the findings published in this study, PCDs are capable of acquiring multi-bin data from a single exposure, which enhances the accuracy of iodine quantification. Furthermore, the study shows that the GaAs material may offer enhanced performance characteristics due to its lower energy characteristic X-rays which help to mitigate charge sharing and spectral degradation, thereby potentially This increases sensitivity for the decomposition of breast lesions in the critical field of breast cancer imaging. However, the research presented in this study adopts a distinct methodology as it concentrates on the visualisation of lesion contrast to evaluate the efficacy of traditional integrating detector systems in comparison to the techniques employed by Photon-counting detector (PCD) systems, through the implementation of spectral imaging methodologies. The examination is conducted across a spectrum of specific photon energy windows, aimed at augmenting the visualization of lesion contrast. To comprehend the discrepancies in image quality and diagnostic accuracy that are inherent between these two detection methodologies, the study utilizes computer simulations to analyse Computed Tomography (CT) images in a spectral context, with the aim of discerning the most effective approach that would enhance the early detection of breast cancer.

MATERIALS AND METHODS

This section focuses on the use of simulation software and a phantom model that mimic breast tissue, the section further clarifies the simulation work undertaken in Breast Computed Tomography (CT) and the approach through which the data presented in section III has been realized. The investigations are aimed at the visualization of lesion contrast to evaluate the effectiveness of traditional integrating detector systems in comparison to the techniques employed by Photon-counting detector (PCD) systems.

Phantom Design

The phantom utilized in this study was built using in house software with an approximate diameter of 100mm. Two lesions were incorporated, each measuring 5mm, which represent a complete 100 percent of glandular tissue, along with a calcification cluster characterized by an average calcification diameter of 0.1mm. The breast phantom is explicitly designed to model various tissues, including adipose, glandular, blood vessels, Cooper's ligaments, and air as shown in figure 4. Computer Aided Software (CAS) developed by (Elangovan et al 2017) was used, where the insertion cite for calcification clutter and lesion inserted manually.

The attenuation properties of each tissue exhibit variability with respect to energy levels as the energy transitions within the polychromatic beam. The two-dimensional computational phantom illustrated in (Figure 4) was constructed for the purpose of developing, optimizing, and evaluating a spectral imaging system intended to accurately reproduce breast characteristics for this investigation. This concept has been advanced to supplant physical phantoms, which have historically been cost-prohibitive. A code was developed for this simulation work to experiment with the phantom in order to ascertain contrast at varying photon energies. This process employs Computer Aided Software (CAS) for reconstruction to facilitate the assessment of contrast across different photon energy windows.

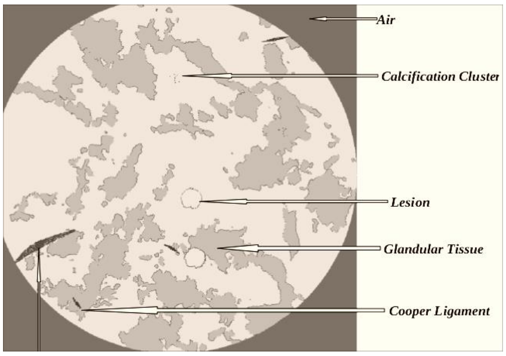

Figure 4: 2-D Breast Phantom

Filtered Back Projection and Siddon Algorithm

Filtered Back Projection was employed due to its inherent simplicity and computational efficacy; it remains a conventional reconstruction technique that continues to be utilized in clinical settings (Ye et al., 2018). The execution involved filtering the data followed by the back projection of the processed data. In the context of two-dimensional image acquisition, each projection row has a specific significance as it embodies the cumulative counts along a linear trajectory through the subject undergoing imaging. The back projection process entails reiterating the total count accumulation at every point along the same trajectory but in the opposite direction relative to its origin. This procedure was reiterated for all pixels and angles involved. However, these operations are accompanied by certain artefacts and image blurring, which can be attributed to the limited quantity of projections. Mitigating this limitation necessitates filtering the projection prior to executing the back projection along the same trajectories. The ramp filter was employed to mitigate image blurring by eliminating low-frequency components that would otherwise manifest in the image, functioning as a high-pass filter. This methodology effectively eradicates artefacts resulting from the rudimentary back projection technique and consequently sharpens regions of the image that alter the signal due to blurring, primarily at the edges of the images. Nonetheless, the high-pass filter does amplify statistical noise, yet the research presented in this manuscript remains unaffected by photon or statistical noise. The Siddon algorithm was utilized for the precise calculation of the radiological path traversing through voxels as it delineates the rays. It is employed for X-ray tracing within the volumetric confines of objects and for quantifying the attenuation through a composite of various materials and intensities. The cumulative attenuation of the tissues is assessed along the X-ray projection that traverses the tissues, as illustrated in figure 5. Where each voxel $v_1, v_2, v_3 \ldots v_n$ has different values of attenuation $\mu_1, \mu_2, \mu_3, \ldots \mu_n$

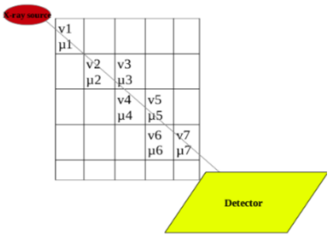

Figure 5: A representation of different tissues with different attenuation in a phantom

The Simulation Process

The methodology employed for the simulation pertinent to this work has been elucidated through the principal elements of the simulation framework shown in Figure 6. A comprehensive array of simulation instruments was utilized to replicate a photon counting breast computed tomography (CT) system. Furthermore, a polychromatic energy spectrum was generated utilizing in-house-software capabilities, predicated upon the energy spectrum for these experimental analyses. The geometric specifications reviewed are 840mm and 740mm, which relate directly to the source-to-detector distance (SDD) and the source-to-sample distance (SOD), respectively. Additionally, the anode filtration employed consisted of Rhodium and Aluminium (Rh/Al). This simulation was conducted to emulate a CT procedure, during which a ray tracing algorithm was employed for the purpose of tracing the photons as shown in figure 5. A phantom, as previously articulated in Section 2, was subsequently utilized in conjunction with the Siddon algorithm and the fan beam acquisition methodology to produce sinograms. The reconstructed images were derived from the sinograms generated. In the reconstruction phase, an angular beam spacing of 0.5 degrees, a fan sensor spacing of 1 cm, and line fan sensor geometry were incorporated into the process.

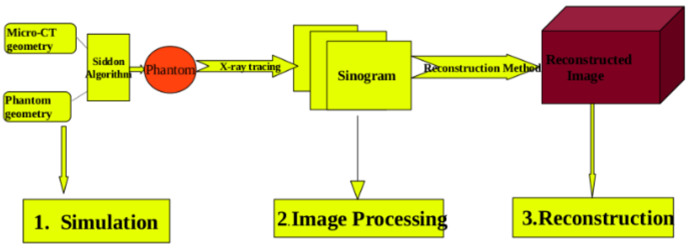

Figure 6: A representation of key components used within the simulation framework

Photon Energy Investigations

In the quest to assess how well photon counting technology improves lesion contrast, various photon energies from 0 to 120 keV were first examined using 20 keV windows in the initial experiment, which is essentially the integrating detector system. The experiment shifted to 10 keV windows in the following experiment, and finally employing 5 keV windows in the last experiment. The broadest window width was employed in the initial experiment, while the final assessment aimed to investigate any fine structures or additional effects that may have been uncovered. A region of interest (ROI), comprised of 4 x 4 pixels, was designated within the lesion and denoted as (ROI). In a similar manner, 4 x 4 ROIs were utilized for the background across four distinct positions, with the average value computed and referred to as (ROIbg). The contrast was subsequently calculated utilizing equation (1) with an error margin of ±0.2

$$\text{Lesion contrast} = ROI_{bg} - \frac{ROI_l}{ROI_{bg}} \qquad 1$$

Image Reconstruction Process

The fundamental principle of image reconstruction involves evaluating the spatial distribution of certain parameters within an object based on its projections (Cierniak, 2010). These projections represent a collection of quantified boundary integral values of the parameters in question. The parameters in this context refer specifically to the linear attenuation coefficient associated with X-ray transmission. The Filtered Back Projection (FBP) approach is applied for this investigation. To enhance the image quality produced by FBP, ramp filters are utilized; however, these filters are adjusted according to specific parameters that must be appropriate for the respective acquisition process.

RESULTS AND DISCUSSION

The outcomes of lesion decomposition for each experimental trial across varying energy windows, alongside the conventional methodology employed in computed tomography (CT), have been tabulated and subjected to graphical analysis. The findings derived from these experimental investigations are presented herein, with a particular focus on the process of lesion decomposition. The results pertaining to the experimental methodology are subsequently presented, accompanied by data generated from simulation studies. The attenuation coefficients attributed to this specific tissue classifications exhibit variability at each energy point, as they fluctuate along the energy spectrum shown in figure 7.

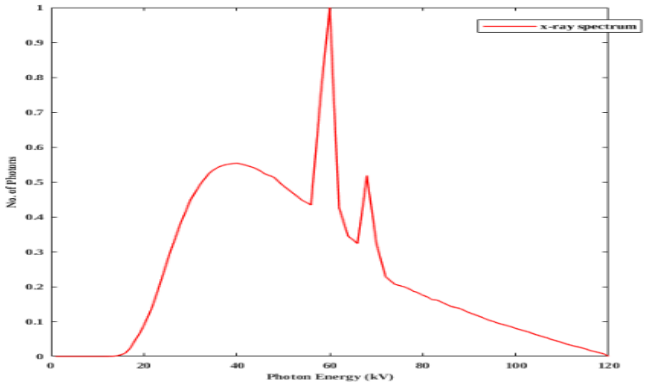

Figure 7: X-ray spectrum across photon Energies

Figures 8 to 11 illustrate the various contrasts identified within these specific energy windows, with Figure 7(a) presenting sinograms derived from polychromatic projections. While 7(b) illustrates the reconstruction from polychromatic projections, which is also referred to as the integrating detector system. Other experimental findings from analysing contrast across a range of energy windows are presented with selected reconstructed images. Conversely, Figure 9 displays images obtained at a window width of 20 keV. Figure 10 distinguishes the reconstruction at a reduced window width of 10 keV, whereas Figure 11 showcases images acquired at an even narrower window width of 5 keV. Tables 1, 2, and 3 enumerate the findings related to the lesion contrast for the images evaluated across different window widths.

(a) (b)

Figure 8: (a) Sinogram from the phantom using polychromatic projections and (b) Reconstructions from ploy-chromatic projections (1-120) keV

(a) (b)

Figure 9: Reconstruction with window width of 20keV at (a) (1- 20) keV and (b) (101-120) keV

(a) (b)

Figure10: Reconstruction with window width of 10keV at (a) (1-10) keV and (b) (111-120)keV

(a) (b)

Figure 11: Reconstruction with window width of 5keV at (a) (1- 10) keV and (b) (116-120) keV

Table 1: Lesion contrast (%) corresponding to Energy bins at bin width of 20keV

Energy Bin(keV)	Lesion Contrast (%)
1-20	22
21-40	15.6
41-60	7.8
61-80	4.4
81-100	2.5
101-120	1.6
1-120	6.83

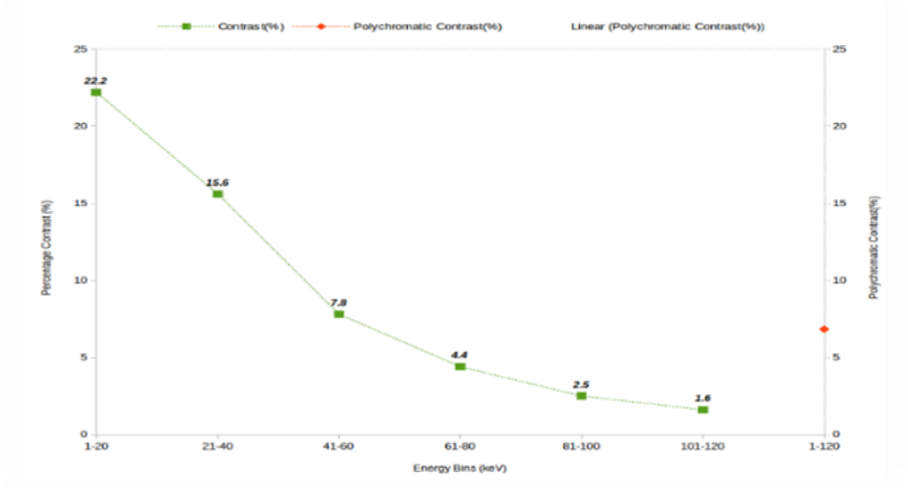

Figure 12: combined graph of lesion contrast versus Energy at bins of 20keV and polychromatic energy

Table 2: Lesion contrast (%) corresponding to Energy bins at bin width of 10keV

Energy Bin(keV)	Lesion Contrast (%)
1-10	21
11-20	16.5
21-30	14.5
-	-
-	-
91-100	1.6
101-110	1.4
111-120	1.2
1-120	6.83

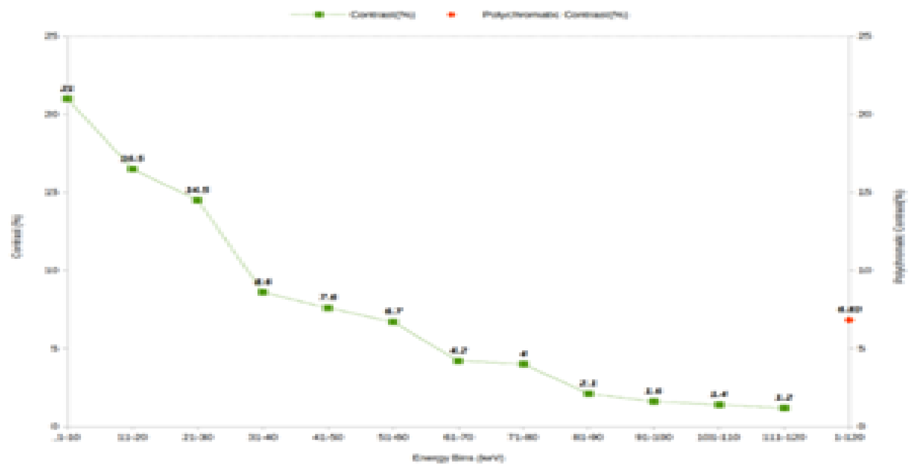

Figure 13: combined graph of lesion contrast versus Energy at bins of 10keV and polychromatic Energy

Table 3: Lesion contrast (%) corresponding to Energy bins at bin width of 5keV

Energy Bin(keV)	Lesion Contrast (%)
1-5	20
6-10	18.3
11-15	-
16	-
106-110	1.2
111-115	1.2
116-120	0.9
1-120	6.83

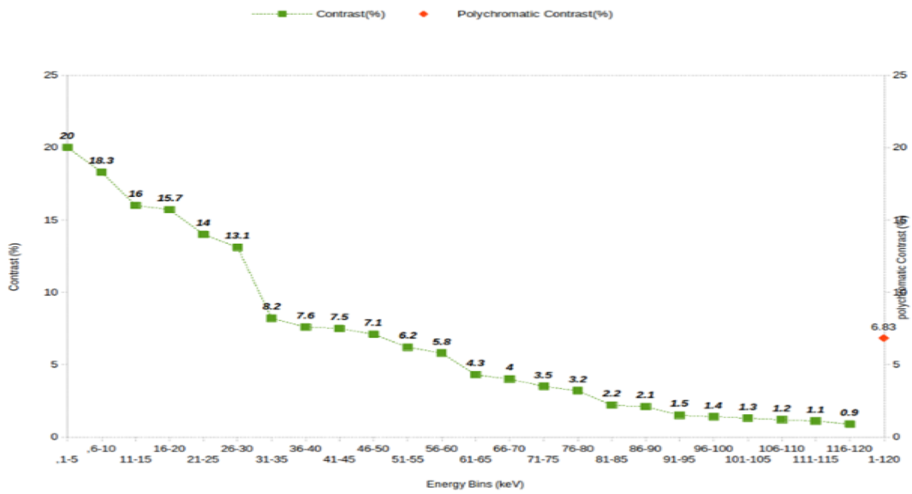

Figure 14: Combined graph of lesion contrast versus Photon Energy at bins of 5keV and Polychromatic energy

Discussion

Investigations conducted regarding lesion contrast utilizing the integrating detector methodology were predicated upon the software spectrum that delineates the spectrum within a conventional computed tomography (CT) system. The phantom, as illustrated in Figure 3, was emulated employing the Siddon algorithm across a polychromatic energy range of (1-120) keV, in accordance with the imaging geometry explained in Section 2. The results garnered from these experiments indicate a percentage contrast of 6.83 percent for lesion decomposition within the conventional integrating detector system. Given that the capability to execute spectral decomposition constitutes a significant potential advantage of the photon counting methodology in contrast to traditional CT, additional investigations were undertaken employing the photon counting technique, wherein photons embodying a spectrum of energies are consolidated into a series of discrete energy windows or bins. This process aims to procure data across various energy windows and to ascertain individual windows alongside their corresponding contrast and spectral energy values. In the initial experiment, seven arbitrary energy bins of 20 keV each were selected to scrutinize the decomposition at each energy bin and to analyse contrasts within each bin.

The results presented in Figure 12 demonstrate a corresponding exponential decline in contrast across the energy bins, where contrast diminishes concomitantly with an increase in photon energy. This phenomenon is ascribed to the variance in the linear attenuation coefficients of adipose and glandular tissues. The results illustrate alterations in contrasts and affirm that the decomposition of lesions within bins yielded substantial contrast, adhering to a pseudo-exponential relationship between contrast and energy bins, with 22 percent in bin (1-20) keV and 5 percent in bin (61-80) keV, in comparison to the polychromatic decomposition where the lesion contrast was 7 percent, as exhibited in Table 1. This percentage is approximated closely to the 8 percent contrast of lesion decomposition corresponding to the energy bin (61-80) keV. Nevertheless, the decomposition for photon counting energies for bin (81-100) keV and (101-120) keV yielded 2.5 percent and 1.6 percent, respectively, which were comparatively lower than the polychromatic decomposition of 6 percent. This observation suggests that polychromatic contrasts may surpass those in the higher energy spectrum; however, it further underscores the advantage of concentrating imaging efforts on the medium to lower energy ranges.

In order to conduct further examinations pertaining to the photon counting methodology, an additional twelve arbitrary energy intervals of 10 keV each have been scrutinized; this investigation aimed to ascertain whether alternative selections of energy bins could enhance the lesion contrast. The findings, as presented and analysed in Figure 13, illustrate the variation in contrast and reveal a comparable exponential decline in lesion contrast analogous to that observed in the 20 keV bin width experiment, with a contrast of 21 percent recorded at the minimal energy bin of (1-10) keV and a 1.2 percent at the maximal energy bin of (111-120) keV, as shown in Table 2. Likewise, the polychromatic contrast of 7 percent was again less than the initial four energy bins, with 8 percent being the nearest contrast corresponding to (41-50) keV. The polychromatic contrast is significantly superior to the contrasts identified within the energy bins ranging from 51 keV to 120 keV.

Subsequent experiments were conducted by reducing the energy width to 5 keV each, resulting in a total of twenty-four energy bins, with the objective of re-examining lesion decomposition at much finer bin widths. The investigation of lesion decomposition within each bin reveals an exponential correlation between contrast and energy bin, with 20 percent representing the peak contrast at the bin (1-5) keV and 0.9 percent at the bin (116-120) keV, as illustrated in Figure 14. Following the same trend, the lesion decomposition assessed using the conventional approach to computed tomography (CT) was lower than that of the first four energy bins, with the closest lesion contrast occurring at the bin (31-35) keV. Nevertheless, the polychromatic contrast exceeded the contrasts observed from 31 keV down to 120 keV, as indicated in Table 3. All three experiments took place in an idealised noiseless simulation, this is to eliminate noise, and study the impact of different decompositions at different energy bins for contrast thresholds on image quality and material decomposition. Findings from the this research portrays promise for visualisation of contrast in photon counting detector approach, with a focus on dose reduction going by the enhanced contrast at the lower energy bins and can be applied clinically.

CONCLUSION

Investigations conducted across three distinct experimental setups for lesion decomposition have evaluated the efficacy of the photon counting methodology in comparison to the traditional computed tomography (CT) approach. In all experiments associated with the photon counting technique for lesion decomposition, as seen in Section 2, significantly greater contrast levels were observed within the energy range of 1-60 keV when compared with the conventional CT methodology. Notably elevated contrast values were attained within lower energy bins (photon counting approach), which are indicative of the attenuation characteristics of glandular tissues. Consequently, the photon counting technique has demonstrated considerable potential for the enhancement of synthetic image visualization based on contrast, as seen in this work. In summary, contrast levels are maximized at reduced energy levels. This phenomenon occurs in the region where photoelectric absorption predominates and where absorption in breast tissue is most pronounced. Nevertheless, to successfully construct an image, it is essential to achieve the highest differential absorption to foster contrast; this, however, must be balanced against the necessity for maximal transmission to mitigate patient radiation exposure and to reduce the influence of dose-limiting noise. For further studies, the study suggests clinical experiments with patients' data towards achieving NCCP's goals in Nigeria.

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