Article published online: 2022-08-30

Imaging Artifacts on Synthesized Mammogram: What a Radiologist should Know!

Shrea Gulati[1] Ekta Dhamija[2] Roshni Anand[1]

[1] Department of Radiodiagnosis, All India Institute of Medical Sciences, Delhi, India
[2] Department of Radiodiagnosis, Dr. B. R. A. Institute Rotary Cancer Hospital, All India Institute of Medical Sciences, Delhi, India

Address for correspondence Ekta Dhamija, MD, Department of Radiodiagnosis, Dr. B. R. A. Institute Rotary Cancer Hospital, All India Institute of Medical Sciences, Room number 137, First floor, Delhi, 110029, India (e-mail: drektadhamija.aiims@gmail.com).

Indian J Radiol Imaging 2022;32:555–561.

Abstract

Synthesized mammogram is a new technique that involves reconstruction of a two-dimensional (2D) image from the tomosynthesis images rather than separate acquisition of a standard 2D mammogram. The advent of a synthesized mammogram (s2D) has helped in reducing radiation exposure. The technique of back projection used in reconstruction makes the appearance of these images different from a standard 2D mammogram. Because this is a relatively new technique, it is associated with a learning curve. Hence, it is important for the new radiologists and technicians to be aware of certain common artifacts encountered while using s2D images, which may hinder interpretation. In this pictorial review, we would like to highlight the common artifacts encountered while reading synthesized mammographic images.

Keywords
- artifacts
- C-view
- digital mammography
- synthesized mammogram
- tomosynthesis

Introduction

Digital breast tomosynthesis (DBT) has been a recent advancement in the field of breast imaging. It implies acquisition of multiple slices of breast tissue, which enables a mammogram to be read layer by layer, thus adding a third dimension of depth to the standard two-dimensional (2D) digital mammogram (DM). By virtue of this added feature, it is able to unmask the underlying pathology that may be obscured by the superimposed fibro-glandular parenchyma or in other scenarios, confirms the absence of a mass in an apparent density caused by overlapping normal breast tissue on a conventional mammogram (MG).[1]

The superimposition of structures can lead to difficulty in assessment of the margins of true masses. During the acquisition of DBT, the X-ray tube moves in an arc (15 to 60 degrees depending upon the sweep angle) over the breast simultaneously acquiring multiple low-dose projections.[2] While DBT enhances the efficacy and accuracy of DM, it adds to the radiation dose delivered to the breast tissue. The reconstruction of a single 2D image such as the standard MG with the use of these multiple slices has been approved by the Food and Drug Administration (FDA) in 2011.[3] Such images are referred to as synthesized (s2D) or composite images, depending on the vendors/equipment and these derived images are available to the radiologist as a substitute to the standard 2D image. Being derived from the DBT data, s2D images have the advantage of not requiring additional standard 2D images, reducing the radiation dose by 45%.[4] The latter has added inherent advantages of DBT in the form of better depth estimation and lesion localization, which helps to differentiate masses from the normal fibro-glandular breast tissue. However, due to the reconstruction process, these appear different from standard MG (►**Table 1**) and often have associated certain artifacts posing difficulty while interpretation. In this article, we aim to highlight these artifacts which radiologists as well as technicians should be familiar with.

published online
August 30, 2022

DOI https://doi.org/10.1055/s-0042-1754364.
ISSN 0971-3026.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Table 1 Broad differences between conventional mammographic image and s2D mammogram

Feature	Conventional mammogram	s2D mammogram
Breast density	Breast tissue appears denser	Breast tissue appears less dense
Skin outline	Skin outline is better appreciated	Not always well appreciated (burnt skin line)
Nipple outline	Nipple seen in profile, better evaluated	If nipple not visualized in profile- can limit evaluation

Table 2 Artifacts seen with synthesized mammograms

Artifacts due to reconstruction algorithm	
Terracing artifact Burned skin line artifact Dark regions near the skin folds Bright band under the skin line Bright band on top of the MLO view Falsely decreased density of the breast	
Artifacts due to the hyper-dense structures	**Artifacts that hamper interpretation**
Out-of-plane artifact Halo artifact Beam-hardening artifact	Non/partial visualization of the nipple Motion artifact Bright spots and false-positive calcifications False-negative calcifications

Principle of Image Formation

The image formation in s2D images is based on the principle of back projection. The slices obtained during DBT are back projected in a single plane to create a single image.[5] The design of the algorithm is such that voxels with the highest attenuation are taken from each slice to create the s2D image, which is similar to the maximum intensity projection (MIP) used in CT.[6] This data are then summed to create the s2D images. This accentuates high-contrast structures such as geographical linear areas, fibrous tissue, and micro calcifications on the s2D image.[5] s2D images increase the conspicuity of high-density masses to the eyes of the reader, especially in patients with dense breasts, where feature visibility might be obscured by superimposed tissue in FFDM.[7] The pitfall is that because these images are reconstructed from DBT, they inherently have certain artifacts (►**Table 2**). It is of prime importance that a radiologist be familiar with these artifacts to avoid misinterpretation. Being a new imaging tool, there is a learning curve that takes time for the radiologists' eyes to become familiar and gain confidence while using these images.

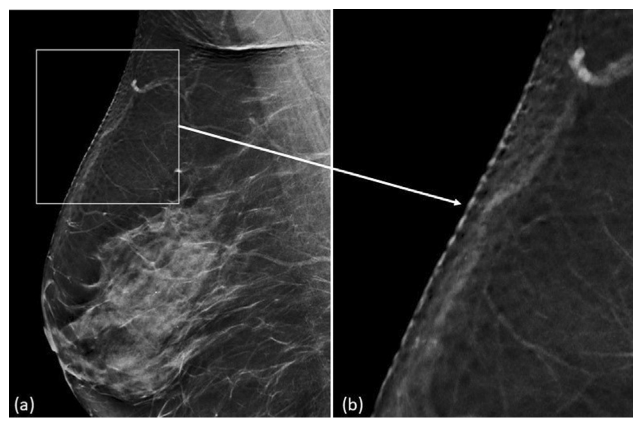

Fig. 1 Terracing artifact (**a**) s2D image showing stair-step pattern along the superior aspect of the breast. (**b**) Magnified view of the terracing artifact in the same patient.

Artifacts Due to the Reconstruction Algorithm

Terracing Artifact

The terracing artifact otherwise referred to as stair-step artifact, appears as multiple lines or striations perpendicular to the direction of the X-ray tube movement (►**Fig. 1**). As the tube rotates, the tissue that is initially out of the field of view (FOV) gradually comes into the FOV, resulting in terracing at the edge of the image. Hence, these are usually seen at the periphery of the image on the tomosynthesis and the s2D image. Currently, no algorithms are available to correct for this defect.[8]

Burned Skin Line Artifact

This artifact can be occasionally seen at the edge of the breast and appears as areas of irregularity or loss of the skin and superficial tissue resolution on the tomosynthesis and s2D images (►**Fig. 2**). It is usually seen in large or dense breasts where the high-dose X-rays travelling the skin and superficial tissue in the periphery undergo very little attenuation and this amount of radiation reaching the detector elements results in a burnt out effect, which results in inadequate characterization of skin calcifications.[9] Improving breast compression can help get rid of these artifacts.[8]

Dark Regions Near Skin Folds

Large skin folds are seen as dark regions or shadows near the line of transition (►**Fig. 3**) as a consequence of the image-processing filters used in the s2D software. These can result

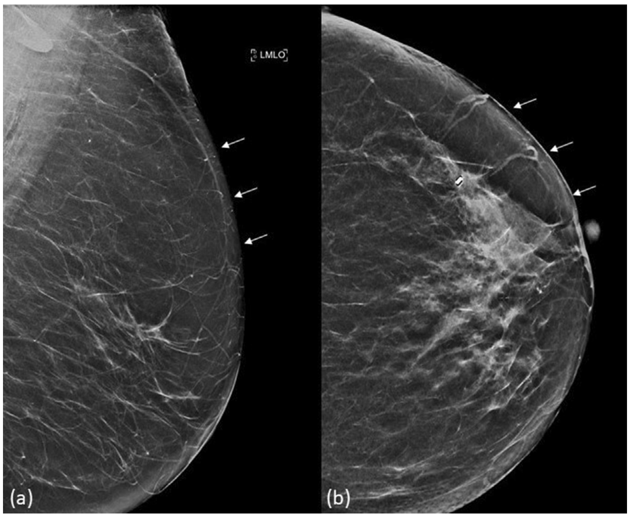

Fig. 2 Burned skin line artifact: (**a**) s2D image does not show the normal skin line along the upper half of the image (arrows). (**b**) In a different patient, the normal skin line (arrows) along the breast is well visualized.

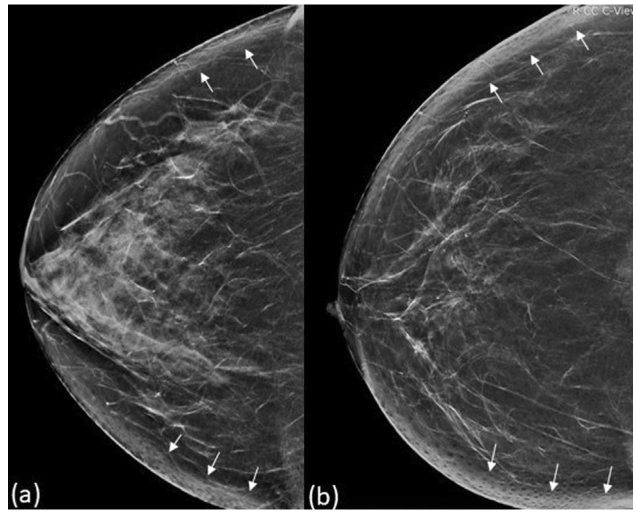

Fig. 4 Bright bands under the skin line (**a, b**): Bright bands seen under the skin line (arrows), usually do not impair interpretation of the mammogram.

in sudden changes in the pixel values on the image obscuring important findings. Proper positioning of the patient can help avoid these large skin folds.

Bright Band Under the Skin Line

The region of roll-off at the edge of the breast keeps changing its location in the tomosynthesis slices causing a bright band to be seen along the skin line in the s2D images (►**Fig. 4**).

Bright Band on Top of the MLO View

As the angle of projection changes during the tube rotation, the top-most part of the breast and pectoral tissue is not present in all slices causing a narrow horizontal bright band to appear at the topmost section of the MLO images (►**Fig. 5**).

Different Appearance of Breast Density

Due to the reconstruction algorithm used, the breast appears less dense on the s2D view as compared with the conventional mammogram image (►**Fig. 6**). This may result in alteration in the categorization of the ACR category to the breast.

Artifacts Due to the Hyper-Dense Structures

Out-of-Plane Artifact

These are also known as zipper artifacts and are seen around the high attenuation structures due to incomplete blurring on out of plane images, which leads to partial visualization in the other slices as well where the structures are not actually present. These are seen as multiple replications of high attenuation structures in all slices, except the one where they are in plane (►**Fig. 7**). The distortion of microcalcifications and shadowing of surgical clips caused by this artifact can hide underlying malignancy.[10] Few vendors have incorporated special post processing algorithms which analyze

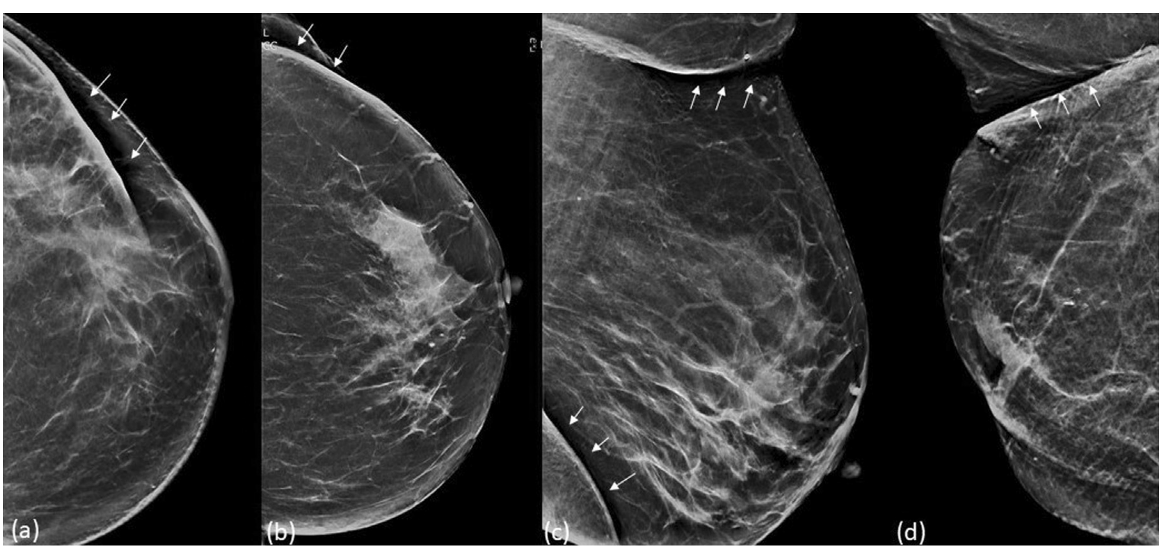

Fig. 3 Dark regions near skin folds (**a–d**): Skin folds appearing as dark areas impairing the evaluation of the underlying breast parenchyma.

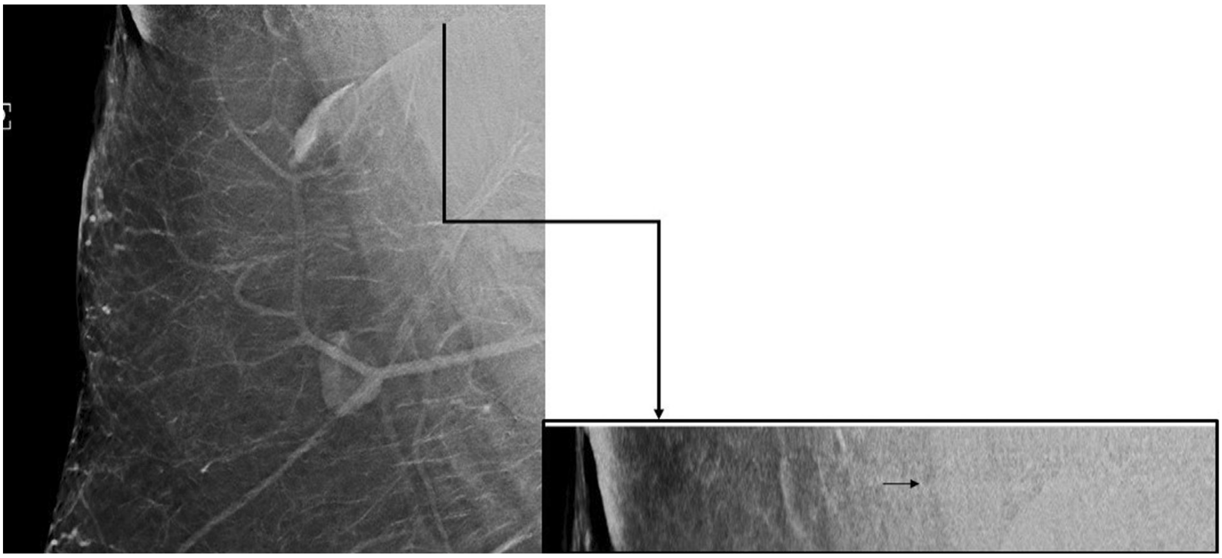

Fig. 5 Bright band on top of MLO image (arrow) and magnified view shown in the inset. These bright bands do not limit evaluation.

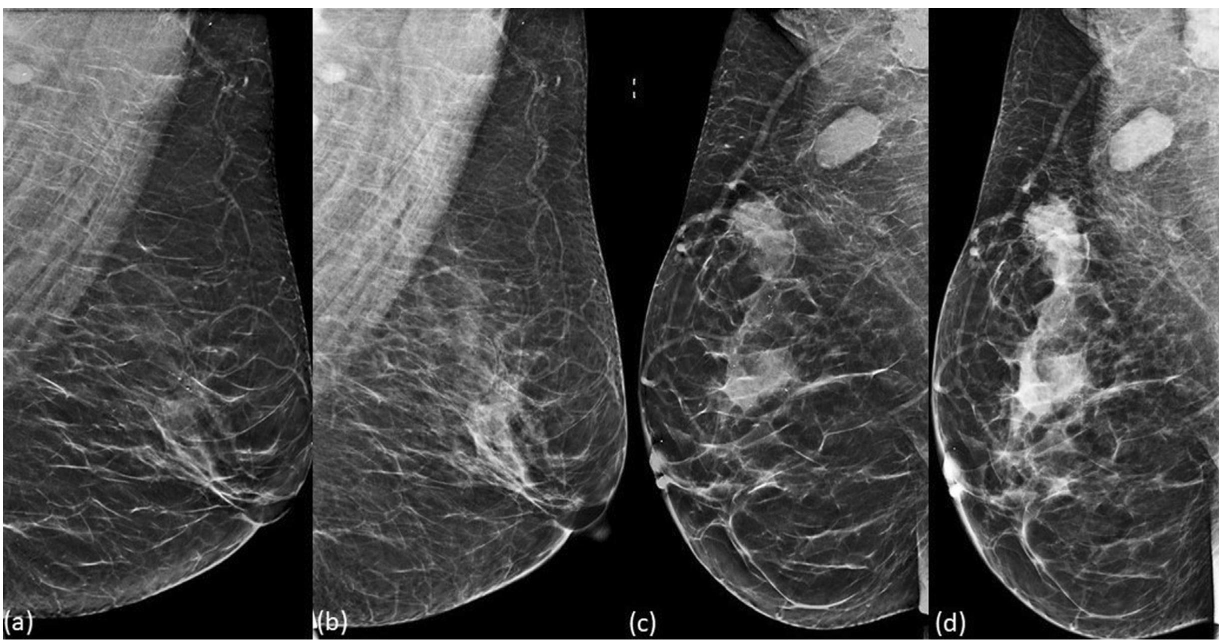

Fig. 6 Change in the ACR breast density category on synthesized mammogram (s2d, MG): The breast shows scattered fibroglandular parenchyma, Category B on conventional MG (**a**), whereas it can be categorized as category A on the s2D image (**b**). This might affect the interpretation in certain settings as seen in a female with irregular high-density masses and axillary lymph nodes on standard MG (**c**), which are seen as equal density lesions on s2D image (**d**). These can be missed or misinterpreted as glandular parenchyma in relatively denser breasts if not correlated with tomosynthesis slices.

the voxels for outliers and remove them before the creation of the s2D image.

Halo Artifact

The metallic artifact, commonly addressed as halo or photon starvation artifact, appears as an area of low or no signal surrounding an object of high attenuation.[8] These objects cause strong attenuation of the photons allowing only small numbers to reach the detector, appearing as an area of low signal surrounding the high-attenuating object (►**Fig. 8**). This artifact tends to be more pronounced in the direction of the X-ray tube sweep. Metal artifact removal algorithms are inherently present in some machines; however, these do not completely eliminate it.[8]

Beam Hardening Artifact

These are seen as areas of increased image brightness on the outer edge of the breast. These have similar appearance and mechanism as the beam hardening artifacts seen in computed tomography (CT).[8] It is due to the polychromatic nature of the X-ray spectrum in which low-energy photons are preferentially attenuated resulting in hardening/more

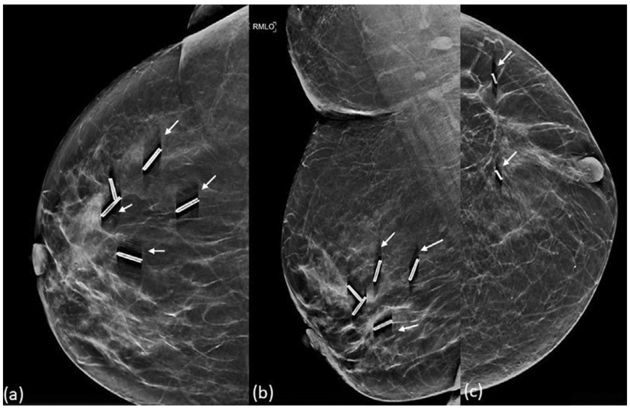

Fig. 7 Out-of-plane artifact (**a**–**c**): High-attenuation objects such as surgical clips appear as multiple replications parallel to the object, which causes obscuration of the breast in the region of the artifact (arrows).

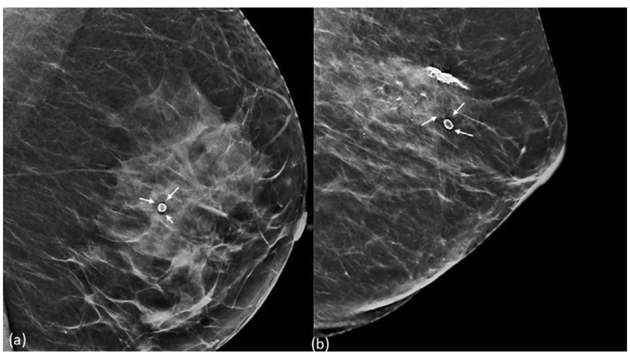

Fig. 8 Halo artifact (**a**, **b**): Coarse calcification with surrounding halo (arrows) limiting the evaluation of surrounding breast parenchyma.

penetrative beam. The inhomogeneous spatial distribution of the amount of attenuation renders the brightness of the image non-uniform.

Artifacts Which May Hinder the Interpretation

In addition to the out-of-plane, beam hardening and skin fold artifacts, there are other artifacts which may pose difficulty while reading the mammograms.

Non/Partial Visualization of the Nipple

As compared with the standard 2D mammogram image, the nipple-areolar complex may be partially or completely non-visualized on the s2D images causing its incomplete evaluation (►**Fig. 9a**). It might be based on the same mechanism as burnt skin artifact.

Motion Artifact

Blurring resulting from motion artifacts are not readily identified on s2D images. DBT inherently has the property of blurring, which reduces noise from overlapping breast tissue.[9] Motion artifacts are best detected by identification of changes in the breast contour through a cine of projection images.[8] The presence of motion artifacts in DBT may further hamper the detection of microcalcifications. Motion causes degradation of the quality of the image. Inadequate compression of the breast, patient movement, long exposure times, and poor positioning of the breast can lead to motion artifacts.[9] Currently, no algorithms are available to correct for motion.[8] However, motion artifacts are unlikely to be significant enough to cause image degradation. Adequate breast compression and patient counseling is the most important measure to reduce motion artifacts.

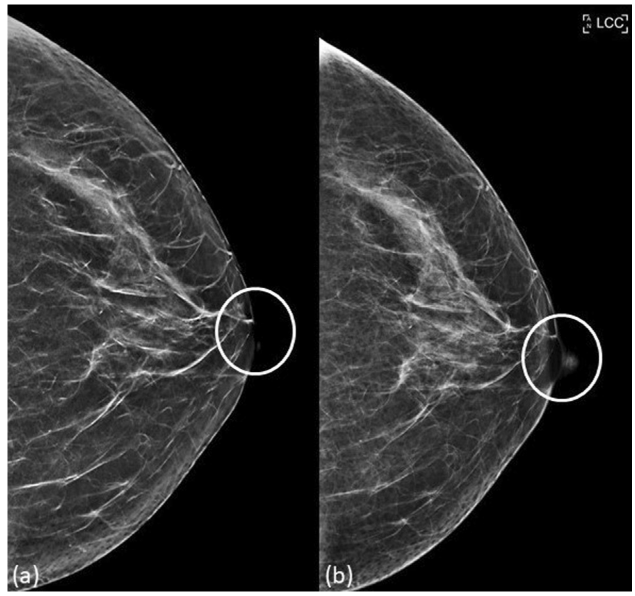

Fig. 9 Non-visualization of the nipple on s2D vs. standard mammogram: (**a**) s2D image showing non-visualization of the nipple-areola complex (circle). (**b**) Corresponding standard 2D mammogram showing the nipple areolar complex well.

Bright Spots and False-Positive Calcifications

On DBT images, normal tissue structures such as ligaments and vessels may falsely appear to be calcified (►**Figs. 10** and **11**).[11] The s2D images may display an increase in the number of microcalcifications, which may not be visible on the corresponding conventional 2D images.[12] These may

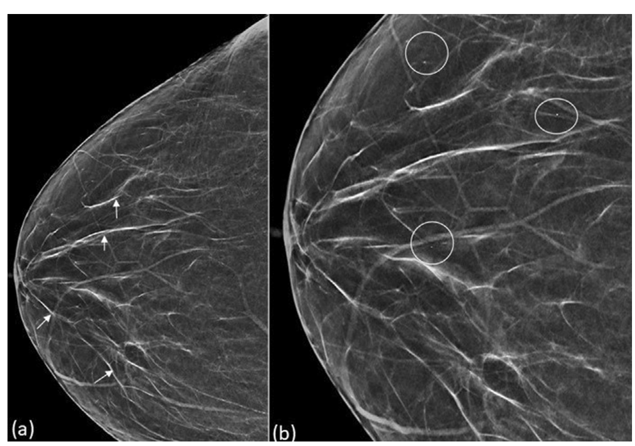

Fig. 10 False-positive calcifications: (**a**) s2D image shows high-density linear structures (arrows), which represent accentuated fibroparenchymal tissue, which may falsely be mistaken for calcifications suspicious for malignancy (**b**) s2D image shows foci of falsely elevated density may be mistaken for calcification (circles).

Fig. 11 False-positive calcifications: (**a**) s2D image showing areas of punctate calcification (arrows), which are not seen on the corresponding conventional mammogram image (**b**).

represent bright spots due to causes other than calcification. This is because the algorithms used in s2D inherently have the tendency to cause the enhancement of real calcifications to assist radiologists to spot them easily. This also causes pseudo enhancement of bright spots other than calcifications. It is recommended that calcification clusters that appear ambiguous on s2D image must be confirmed with the tomosynthesis slices. If a bright spot suspected to be calcification is not seen on the corresponding tomosynthesis slices, it is unlikely to be calcification.[12]

False-Negative Calcifications

TThe inherent tendency of blurring in tomosynthesis slices may cause amorphous microcalcifications to become invisible.[12] It is suggested that because these microcalcifications have an exceedingly small signal, even a small degree of motion causes their blurring. Because the s2D derives its information from the tomosynthesis slices, the blurring of the microcalcifications on the tomosynthesis slices leads to their non-visualization on s2D images as well (►**Fig. 12**) as compared with the full-field digital mammography images (FFDM). Another explanation offered is that very small calcification disappears during the binning process performed by certain mammographic software.[8] Because the microcalcifications occupy an exceedingly small number of detector elements, they may be averaged out by the processing software's and replaced by a pixel more representative of the mean value. Standard 2D mammography has superior resolution than s2D in viewing subtle calcifications.[13] For micro calcifications, it is recommended to use slab views, which collect the entire cluster into one slab rather than having the microcalcifications spread over multiple slices.

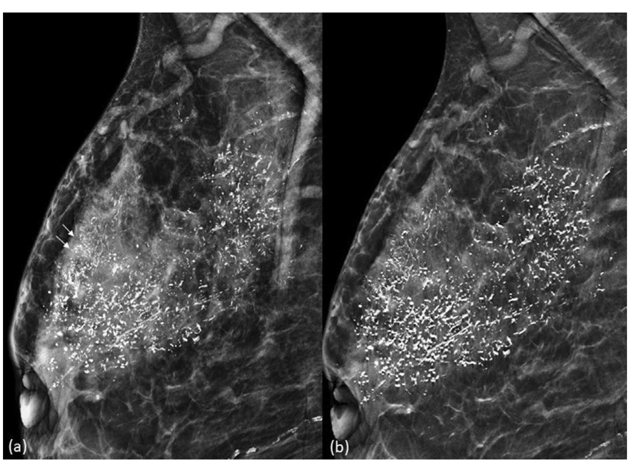

Fig. 12 False-negative calcifications: Pleomorphic calcifications seen in regional distribution are evident on both (**a**) conventional mammogram and (**b**) synthesized (s2D) mammogram. However, the low-density calcifications seem to get suppressed on the s2D image, more conspicuous along the superior and anterior aspect. Although the overall BIRADS was same in this patient; this artifact raises the concern for characterization of grouped calcification when seen as the only finding.

Conclusion

Artifacts in DBT and s2D images can obscure important diagnostic findings. The radiologist must be well versed with the presentation, underlying principle of appearance of these artifacts, and measures to ameliorate them. The use of regular quality control checks may help reduce artifacts. With rapid technological advances occurring, newer algorithms and post processing techniques for remediation of these artifacts are being considered.

Authors' Contributions
Shrea Gulati and Roshni Anand: writing the manuscript; Ekta Dhamija: concept design and critical editing of the manuscript.

Conflict of Interest
None declared.

Acknowledgments
We would like to acknowledge the efforts of our mammography technicians Ms. Pooja Khurana and Ms. Srishti for their contribution and support.

References

1 Rangarajan K, Hari S, Thulkar S, Sharma S, Srivastava A, Parshad R. Characterization of lesions in dense breasts: does tomosynthesis help? Indian J Radiol Imaging 2016;26(02):210–215
2 Dhamija E, Gulati M, Deo SVS, Gogia A, Hari S. Digital breast tomosynthesis: an overview. Indian J Surg Oncol 2021;12(02): 315–329
3 Health C for D and R. Digital Accreditation*FDA*. Published online November 3, 2018. Accessed February 14, 2022. Available at: https://www.fda.gov/radiation-emitting-products/facility-certification-and-inspection-mqsa/digital-accreditation
4 Skaane P, Bandos AI, Eben EB, et al. Two-view digital breast tomosynthesis screening with synthetically reconstructed projection images: comparison with digital breast tomosynthesis with full-field digital mammographic images. Radiology 2014; 271(03):655–663

5 Zuckerman SP, Maidment ADA, Weinstein SP, McDonald ES, Conant EF. Imaging with synthesized 2D mammography: differences, advantages, and pitfalls compared with digital mammography. Am J Roentgenol 2017;209(01):222–229
6 Mumin NA, Rahmat K, Fadzli F, et al. Diagnostic efficacy of synthesized 2D digital breast tomosynthesis in multi-ethnic Malaysian population. Sci Rep 2019;9(01):1459
7 Durand MA. Synthesized mammography: clinical evidence, appearance, and implementation. Diagnostics (Basel) 2018;8(02):22
8 Geiser WR, Einstein SA, Yang WT. Artifacts in digital breast tomosynthesis. Am J Roentgenol 2018;211(04):926–932
9 Tirada N, Li G, Dreizin D, et al. Digital breast tomosynthesis: physics, artifacts, and quality control considerations. Radiographics 2019;39(02):413–426
10 Abdurahman S, Jerebko A, Mertelmeier T, Lasser T, Navab N. Out-of-plane artifact reduction in tomosynthesis based on regression modeling and outlier detection. In: Maidment ADA, Bakic PR, Gavenonis S, eds. Breast Imaging. IWDM 2012. Lecture Notes in Computer Science. Berlin, Heidelberg: Springer;2012:729–736
11 Lai YC, Ray KM, Mainprize JG, Kelil T, Joe BN. Digital breast tomosynthesis: technique and common srtifacts. J Breast Imaging 2020;2(06):615–628
12 Herschorn SD. An implementation guide to C–ViewTM software that minimizes dose and recalls while maximizing physician confidence. Available at: https://www.hologic.com/sites/default/files/2017/Products/Image%20Analytics/PDFs/WP-00121%20_Rev001_CViewImplementation_FINAL.pdf
13 Freer PE, Winkler N. Synthesized digital mammography imaging. Radiol Clin North Am 2017;55(03):503–512

