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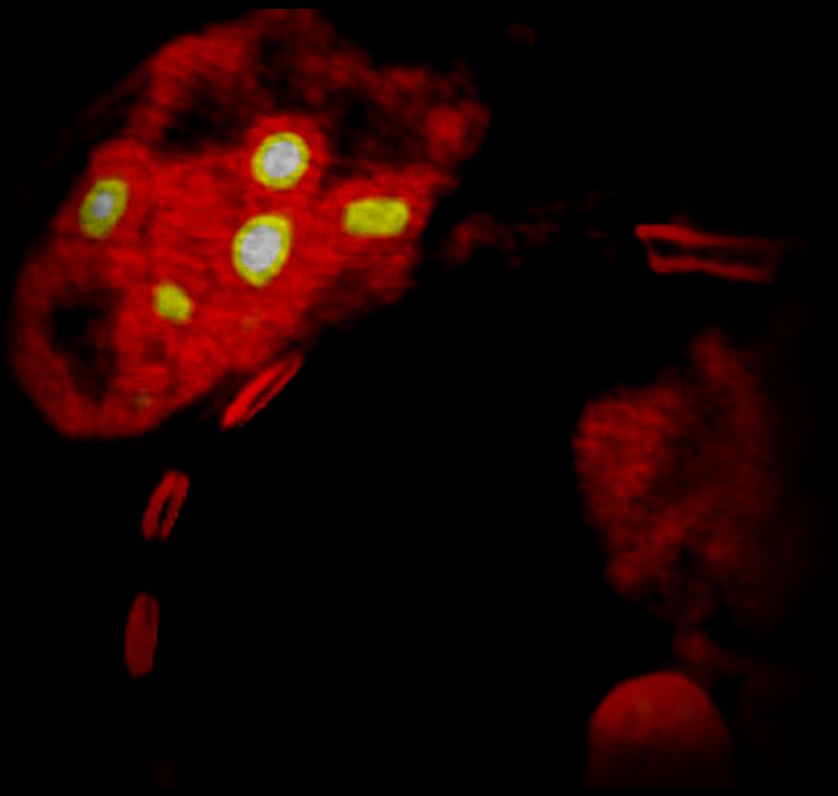

CME Comprehensive Review of Clinical Presentation, Multimodality Imaging, and Therapeutic Strategies for Inflammatory Breast Cancer

New Trends in Diagnosis and Management of Renal AML Subtypes: Part II

Breast Arterial Calcification: Why Radiologists Should Start Reporting This Silent Risk Factor for Heart Disease

Academic Radiologists Look for Help from AI to Meet Demands

Inflammatory Breast Cancer

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Rolling Along

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"How did you get to be here?"

This refrain from *Merrily We Roll Along*, one of my favorite Stephen Sondheim musicals, has been on my mind lately, as I step into the role of editor-in-chief of *Applied Radiology*. In the show, the story unfolds in reverse—starting in the present and tracing back through the experiences and relationships that shaped the main character's life and career. As I begin this new chapter, I find myself looking back with deep gratitude for the opportunities, mentors, and colleagues who have prepared me for this next role. My experiences—including serving on editorial boards, participating in peer review and grant review panels, founding a medical ethics journal during medical school, and reporting for my college newspaper—were all part of the road that led me here.

Looking back is as important as looking forward, both for individuals and for organizations. The field of radiology stands at the brink of unprecedented change, thanks to new technologies and the promise of artificial intelligence. As we look ahead with anticipation, we must remain guided by the principles that have always defined our path. Radiologists began as the "doctor's doctor," providing our colleagues with essential insights to guide patient care. In recent years, we have expanded our role to be more patient-centered, empowering patients to partner in their care. Today, as we enter the digital age, it is imperative that we remain connected to our human mission to be colleagues and caretakers.

Likewise, medical journalism is entering a brave new world. Today, journals like this one are electronic, on-demand, and competing with countless other sources of information. My challenge, as a new editor, will be to embrace these changes while preserving what has made this journal indispensable for more than 50 years: delivering timely, clinically relevant, evidence-based information that guides radiologists and supports quality care.

This is a season of change—for me personally, for our specialty, and for medical journalism. I am honored and thankful for the trust placed in me by Anderson Publishing to steward this journal into the future. I am also sincerely grateful for the leadership of my predecessor, Dr. Erin Simon Schwartz, who has led with vision and whose impact on this journal has been profound and transformative. My hope is to lead in a way that welcomes the road ahead without losing sight of the path that brought us here. As one song in *Merrily We Roll Along* reminds us: "Every road has a turning. That's the way we keep learning."

And so, the road turns. Let's roll along, together.

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Comprehensive Review of Clinical Presentation, Multimodality Imaging, and Therapeutic Strategies for Inflammatory Breast Cancer

Description

Prompt and accurate diagnosis of inflammatory breast cancer (IBC) remains a clinical and radiological challenge due to overlapping features with benign inflammatory conditions such as mastitis. Because of the poor prognosis of this rare, locally advanced breast cancer, timely diagnosis by biopsy and imaging escalation is critical. IBC has a unique imaging presentation compared with noninflammatory breast cancer. Optimizing imaging test utilization is essential for early and accurate diagnosis of primary breast lesions as well as distant metastases, evaluating treatment response, and possibly minimizing unnecessary diagnostic testing.

Learning Objectives

Upon completing this activity, the reader should/should be able to

1. Recognize the clinical and imaging features of IBC.
2. Determine the optimal combination of imaging modalities for IBC evaluation and treatment response evaluation by understanding the strengths and limitations of each modality.
3. Have current knowledge of the standard-of-care multimodal treatment approach for IBC.

Target Audience

- Radiologists
- Related imaging professionals

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Keywords: Inflammatory Breast Cancer, Rare Breast Cancer, Mammogram, Ultrasound, MRI, PET/CT, Breast Cancer Treatment, Skin Thickening

Introduction

Inflammatory breast cancer (IBC) is a rare, locally advanced invasive cancer that commonly presents with skin redness (erythema) and swelling (edema). Diagnosing IBC is difficult, and prompt identification is crucial when a patient presents with a reddened or inflamed breast. According to the National Cancer Institute's Surveillance, Epidemiology, and End Results data, the incidence of IBC was 2.76 cases per 100,000 from 1973 to 2015.[1] IBC has a higher mortality rate compared with noninflammatory advanced breast cancers,[1,2] with an overall relative 5-year survival rate of approximately 40.5%, which is even lower among Black patients.[1]

Specific clinical criteria for diagnosing IBC include rapid onset of erythema, edema, and/or peau d'orange with a duration of less than 6 months; inflammation occupying more than one-third of the breast; and pathological confirmation of invasive carcinoma.[3] The rapid onset distinguishes IBC from noninflammatory, locally advanced cancer.[4] In addition to clinical diagnosis, multimodality imaging tests improve IBC detection and confirmation, with the aim of improving overall survival. Breast MRI has been found to be most beneficial for identifying primary lesions and evaluating treatment response, while ^{18F}FDG PET/CT plays a significant role in detecting distant metastases at initial diagnosis for appropriate treatment selection. Here, we offer an overview of current approaches to diagnosis and treatment of IBC.

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Clinical Diagnosis

The clinical presentation of IBC arises from the diffuse and rapid obstruction of lymphatics in the breast by tumor emboli, leading to edema and hyperemia of the blood vessels in the skin.[5] The most commonly used definition of IBC is based on the American Joint Committee on Cancer (AJCC) Staging System, 8th edition. This system defines IBC, stage T4d, as a clinicopathological entity characterized by diffuse erythema and edema involving approximately a third or more of the skin of the breast.[6] The system requires a pathological diagnosis of invasive cancer in less than 6 months from initial symptom presentation[6]; however, while pathological identification of dermal lymphatic emboli is pathognomonic, it is not required for diagnosis. In addition, although skin erythema is a mandatory criterion for diagnosis under the staging system, it may not be present or may fluctuate or diminish over time.

The difficulty of diagnosing IBC was highlighted in an

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Figure 1. Bilateral mediolateral oblique digital mammogram at the diagnosis of the inflammatory breast cancer case demonstrates diffuse left breast enlargement, trabecular thickening (solid white arrows), and global skin thickening up to 9 mm (dashed yellow arrows). BI-RADS Category 5: highly suggestive of malignancy. Left axillary adenopathy is partially visible on mammogram (green arrow). Breast biopsy at the 12 o'clock position reveals triple-negative invasive ductal carcinoma and ductal carcinoma in situ. Biopsy of the left axillary node was positive for malignancy.

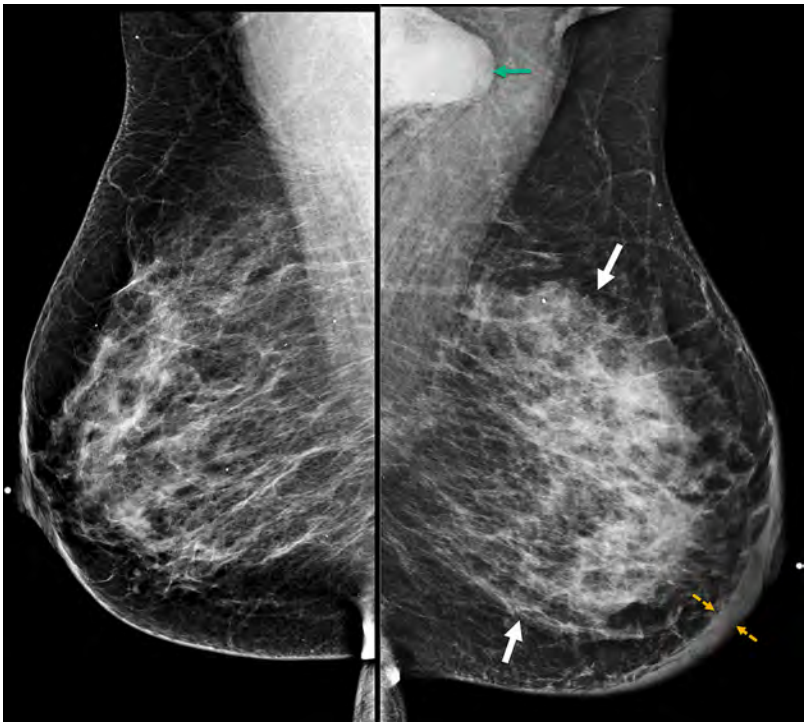
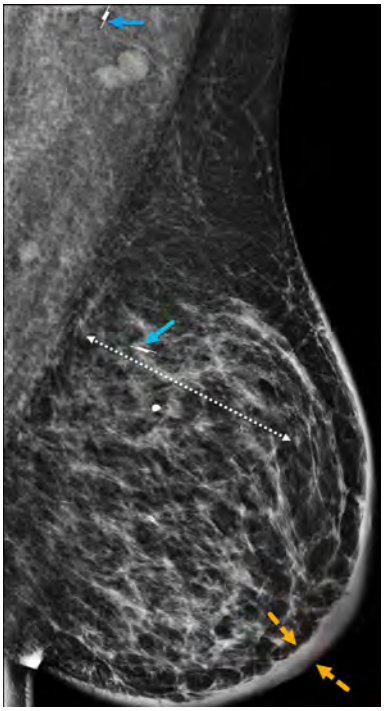


Figure 2. Mediolateral oblique left digital mammogram demonstrates diffuse skin thickening (solid yellow arrow) and suspicious, fine-linear pleomorphic calcifications (double-head dashed white arrow) spanning over 8.5 cm in the upper outer quadrant. BI-RADS Category 4C: suspicious for malignancy.



extensive external review of medical photographs and records of 270 patients with IBC across 6 sites in Egypt, Tunisia, and Morocco.[7] The clinical diagnosis was based on an expert panel consensus statement. Among the cases, 76% met the consensus criteria, but only 36% adhered to the AJCC 8th edition.[6,8] Nevertheless, 86% of the cases were confirmed as IBC through photographic review adherence to the consensus statement by independent, external experts.[7] An expert panel convened by the Susan G. Komen Foundation recently validated a more formal and quantitative definition of IBC that incorporates clinical, pathological, and imaging features that may improve diagnosis.[9]

The incidence of IBC among women with breast cancer is low, typically estimated at 2-3%.[1,10] However, according to the available references, IBC's incidence among women presenting with breast inflammation ranges from 5-50%.[11-13] Dabi et al proposed a diagnostic algorithm emphasizing the importance of identifying and treating IBC as an oncologic emergency. According to this algorithm, all nonlactating patients with inflammatory symptoms should undergo imaging. If malignancy is suspected but no focal mass abnormality is amenable to biopsy, a skin punch biopsy of the most involved skin should be obtained. A negative biopsy indicates the need for MRI with biopsy.[11] In lactating patients with strongly suspected acute mastitis, beginning with a "test and treat" strategy is a reasonable approach. If no improvement is observed within 2 weeks of antibiotic therapy, further imaging studies should be obtained.[11] At one tertiary surgical referral center, IBC accounted for 50% of cases presenting with inflammatory symptoms.[12] Thus, a high index of suspicion is warranted. Patients with presumed benign mastitis that does not resolve quickly with medical therapy should undergo imaging and image-guided biopsy.

Radiological Diagnosis of IBC

Mammography

Patients with suspected IBC are often initially referred for mammography despite the modality's limitation in detecting lesions in dense breast parenchyma. In many cases, no identifiable mass may be observed and/or the mammogram may be interpreted as normal.[13] The features most associated with IBC include diffuse breast enlargement,

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Figure 3. Figure 2MLO magnification view of Figure 2 better visualizes the pleomorphic calcifications (dashed white arrows).

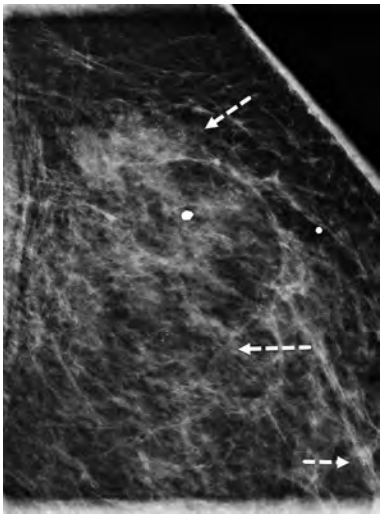
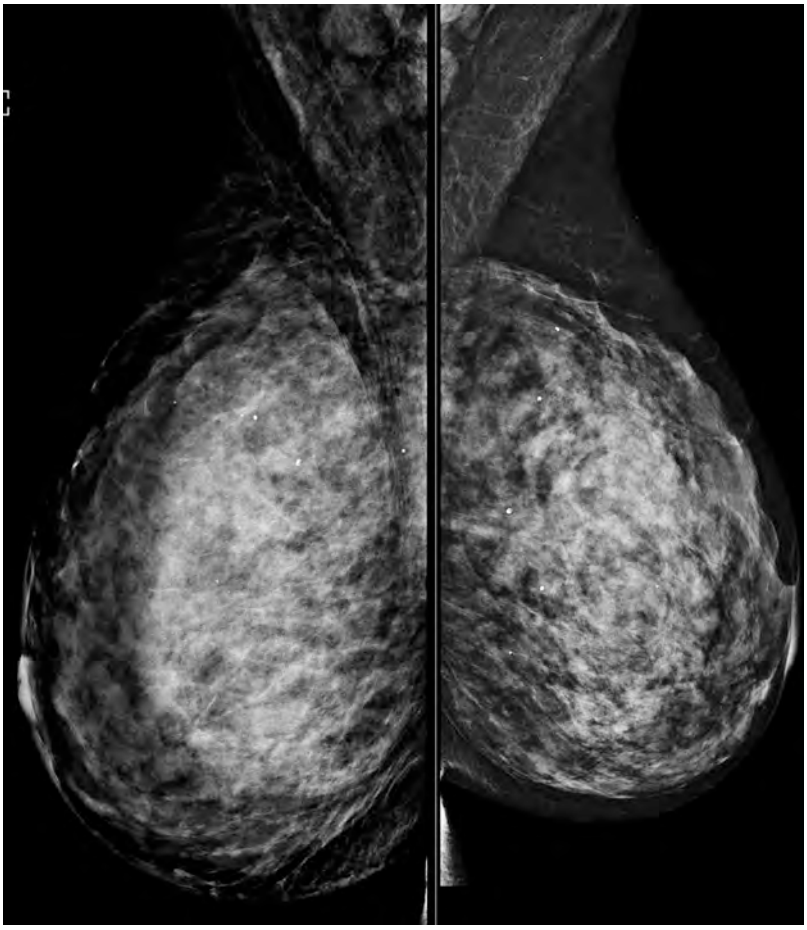


Figure 4. Mediolateral oblique view shows dense breast parenchyma, which obscures underlying masses. BI-RADS Category 0: incomplete, requires additional imaging evaluation.



trabecular thickening, global skin thickening, and ipsilateral axillary lymphadenopathy (Figure 1).[14-16] Skin and trabecular thickening, although nonspecific, are subtle early findings observed in 80% of IBC cases.[15-17] Less commonly seen mammographic findings include a visible irregular mass, architectural distortion, or calcifications (Figures 2, 3).[14,17]

The ability of mammography to detect a primary breast lesion in patients with IBC is limited; one retrospective study found that only 20% of cases demonstrated a detectable primary lesion on mammography.[15] 97% of subjects in the same study had nonfatty breasts, leading the authors to suggest that the dense breast parenchyma background likely contributed to the poor visibility of lesions (Figures 4, 5).[15] Another study observed that findings of skin thickening, axillary adenopathy, trabecular thickening, and nipple-areolar swelling were significantly more frequent in IBC than in non-IBC cases, while the presence of a mass was more commonly associated with non-IBC cases.[18] Compared with other imaging modalities, mammography is the least sensitive to multifocal and multicentric disease in patients with IBC.[15]

Ultrasound

Common sonographic features of IBC include one or more masses, skin thickening, tissue edema with lymphatic dilation, and regional lymphadenopathy.[15-20] However, these are nonspecific features that overlap with findings seen in benign conditions such as mastitis and in other malignancies such as locally advanced breast cancer (Figure 6). As a result, diagnosis with ultrasound alone can be challenging. If an index mass is identified, its common sonographic morphology includes hypoechoic mass with lobulated or irregular margins and posterior acoustic shadowing.[21-23] Ultrasound does not reliably detect microcalcifications, for which mammography remains the most sensitive modality for identification. Architectural distortion and diffuse posterior acoustic shadowing (Figure 7), often multifocal and multicentric in distribution, are observed in over 80% of cases.[15,16]

The inflammation seen in IBC is associated with increased vascularity of the breast lesions and surrounding parenchyma, which correlates with the erythema observed on physical examination. Diffuse skin thickening, a hallmark of IBC, can be quantified on ultrasound. Skin and breast edema are also commonly noted (Figure 7). The dermal emboli and dermal lymphatic involvement

Figure 5. Axial postcontrast MRI of the same case as that in Figure 4 demonstrates multiple suspicious, enhancing masses (white arrows) throughout the dense right breast. Early phase dynamic MRI reveals tumoral enhancement from the delayed enhancement of background dense breast tissue. BI-RADS Category 5: highly suggestive of malignancy.

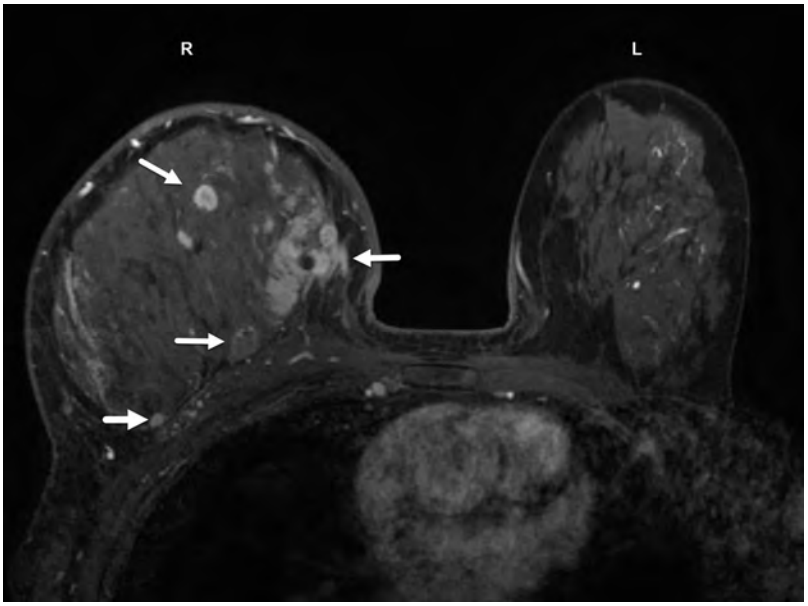
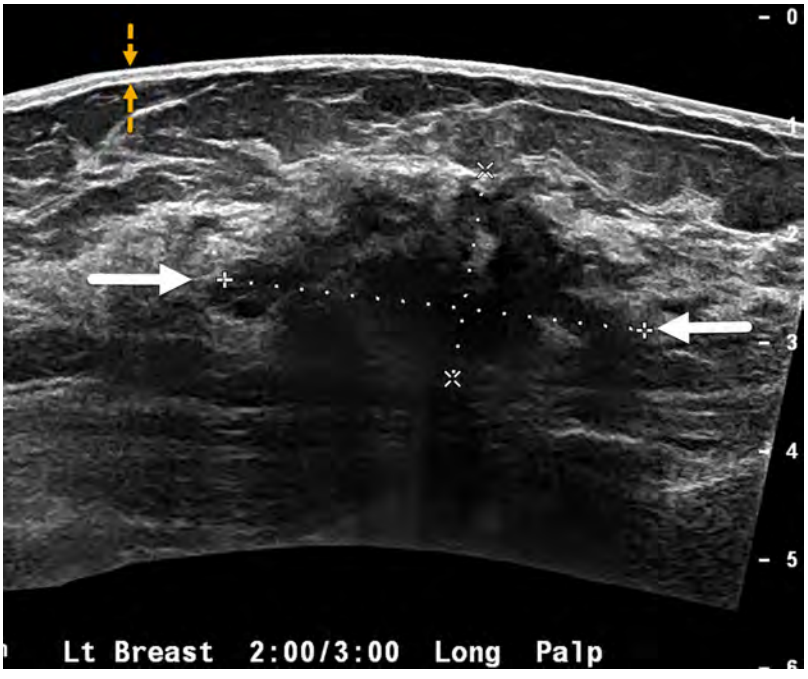


Figure 6. Sonogram of the left breast in a case of invasive ductal carcinoma shows a 4 cm mass with irregular margins and posterior acoustic shadowing (white arrows). BI-RADS Category 5: highly suggestive of malignancy. The skin is normal (yellow arrows), without thickening typically seen in inflammatory breast cancer.



characteristic of IBC may account for sonographic findings of diffuse hypoechoic and thickened skin with an indistinct dermal-subcutaneous fat interface.[20,24] Breast edema can extend into the chest wall and pleural spaces and may require multimodality imaging for complete evaluation.

MRI

MRI is superior to mammography and ultrasound in identifying index tumor masses (Figure 8), which are also referred to as primary breast parenchymal lesions (BPLs).[15,19] In a study at our center, MRI successfully identified all BPLs, while ultrasound identified 95%, and mammography 80%, of lesions in patients with a clinical diagnosis of IBC.[19] Owing to its high sensitivity, MRI is recommended early in the evaluation of patients with clinical suspicion for IBC, particularly when mammography and ultrasound fail to detect lesions. Additionally, MRI findings can guide biopsy procedures.

The multicentric distribution commonly associated with IBC, especially in dense enlarged and inflamed breasts (Figure 9), may best be appreciated on MRI. Edema of the subdermal breast, pre-pectoral region, and chest wall is more commonly seen in IBC than in other breast cancers and is most evident on T2 images (Figure 10).[19] The presence of pre-pectoral edema has been suggested as a prognostic factor in breast cancer.[25,26]

Diffuse skin thickening, observed in 90-100% of patients with IBC, may be present with or without skin enhancement or focal-enhancing skin lesions (Figure 11).[19] Skin thickening typically involves the entire breast and may extend across the midline or into the contralateral breast. Focal skin thickening adjacent to the BPL is more often associated with locally advanced or neglected carcinoma than with IBC.[27] Enhancing skin foci detected on MRI may represent tumor emboli or dermal lymphatic invasion, pathological hallmarks of IBC.

Nodal Staging

Bilateral nodal basins are visible on MRI despite artifact resulting from

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Figure 7. Wide FOV sonogram of the right breast in a case of newly diagnosed inflammatory breast cancer demonstrates ill-defined hypoechoic architectural distortion (solid white arrows) with diffuse posterior acoustic shadowing measuring 12 cm (dotted line). Unlike the case in Figure 6, diffuse tumoral infiltration of the entire right breast and skin thickening—but no discrete breast masses—were detected. The thickened skin contains tiny hypoechoic lesions (yellow dotted arrows) suggestive of dermal lymphatic involvement. BI-RADS Category 4C: high suspicion for malignancy.

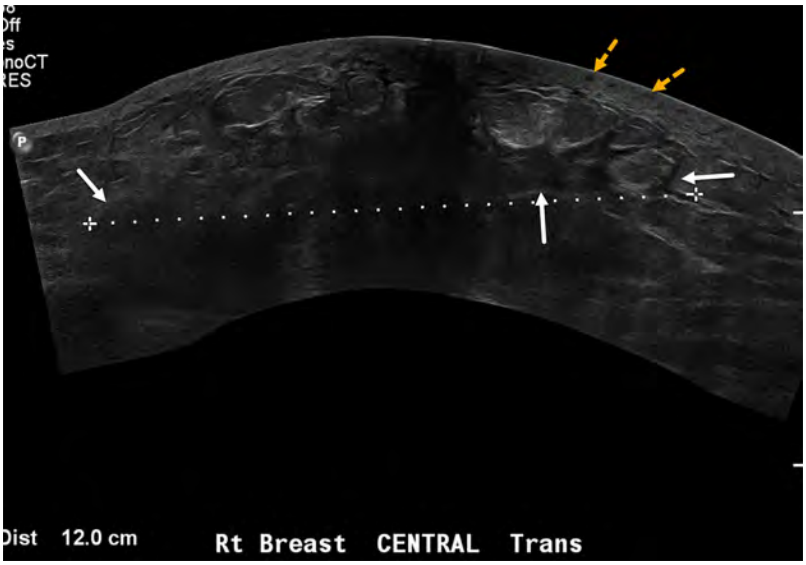
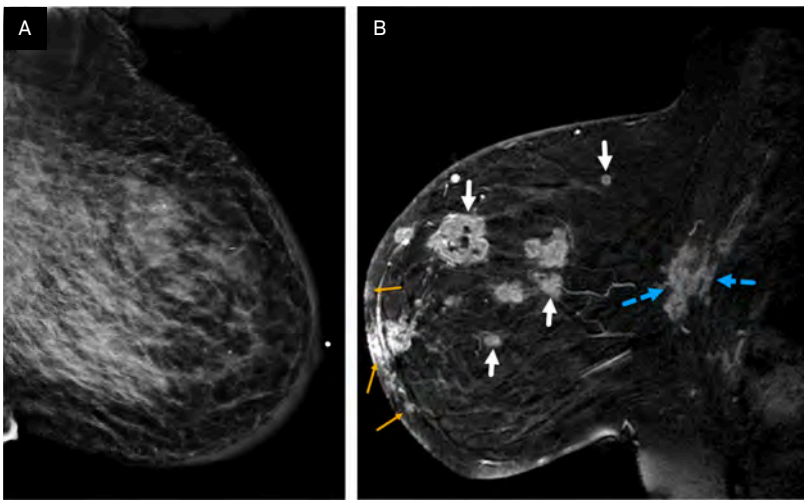


Figure 8. (A, B) Digital, mediolateral oblique mammogram in a senior patient with inflammatory breast cancer shows dense breast with no discrete mass. BI-RADS Category 0: needs additional imaging evaluation. Sagittal MR image of the same patient demonstrates multiple enhancing masses (solid white arrows) with irregular margins in multicentric distribution. Enhancing tumoral masses also extend into the anterior thickened skin (small yellow arrows) and infiltrate the chest wall (dotted blue arrows). BI-RADS Category 5: highly suggestive of malignancy.



cardiac motion and respiration. The axillary level I and II nodal regions, as well as the internal mammary nodal basins, are often well visualized (Figure 12), while the supraclavicular and medial infraclavicular or axillary level III regions are better evaluated with nodal ultrasound.

^{18F}FDG PET/CT

PET/CT is recommended for patients with IBC at initial presentation, particularly when standard staging studies are inconclusive, and for identifying extra-axillary lymph node metastases (Figure 13) and occult distant disease.[28,29] Since at least one-third of these patients present with distant metastases, the modality is also valuable for guiding treatment selection and determining prognosis.[30] PET/CT has demonstrated a sensitivity of 96-100% for PBL in IBC.[31,32] However, false-positive findings are possible in such cases as mastitis, which may show FDG avidity similar to that of IBC.[32]

PET/CT is particularly valuable for evaluating regional lymph node metastases in patients with IBC. Studies by Alberini, Groheux, and Caracki et al have highlighted its utility in identifying nodal disease in the axilla, as well as in the subpectoral, internal mammary, and supraclavicular lymph nodes.[31-34] In addition, PET/CT may identify metastatic disease not evident on clinical examination and/or other imaging modalities.

In addition to regional lymph node assessment, PET/CT is useful in identifying distant nodal disease (eg, mediastinal or contralateral axillary adenopathy) and distant metastases. Studies by Groheux et al and Carkaci et al reported that distant metastases were detected by the modality in 46% and 49% of patients with IBC, respectively.[22,23] It was also superior to CT for distant lymph node, bone, and liver metastases, and it outperformed bone scans in identifying metastases in these tissues.[22] However, chest CT was more sensitive for lung and pleural metastases.[22] In certain subsets of patients with IBC, such as those with triple-negative breast cancer, visceral metastases, or young age at diagnosis, up to 30% of cases can present with brain

Figure 9. (A, B) Digital left craniocaudal mammogram demonstrates a mass in the lateral breast with irregular margins (solid white arrows) and mild medial skin thickening. BI-RADS Category 4C: high suspicion for malignancy. Axial postcontrast MRI of the same patient reveals additional tumoral lesions distributed multicentrically throughout the rest of the breast (small yellow arrows), along with the mass seen on mammogram (solid white arrow). Diffuse skin thickening is also observed of the left breast. BI-RADS Category 5: highly suggestive of malignancy. The multicentric disease is more conspicuous on the MRI than on the mammogram.

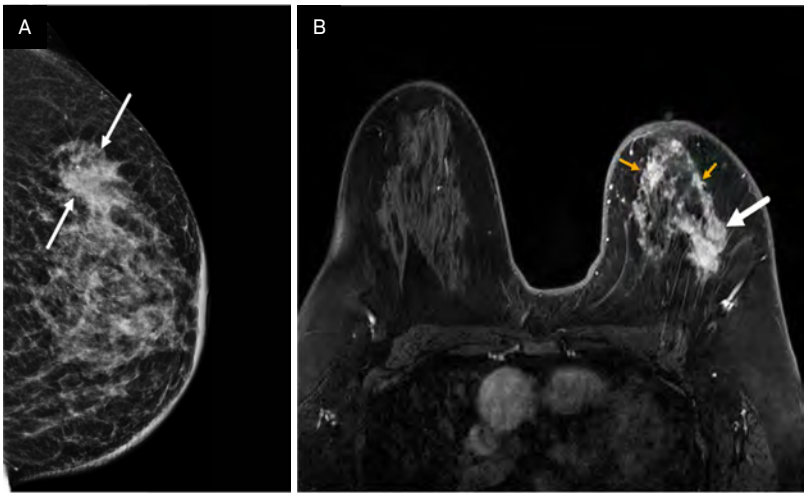
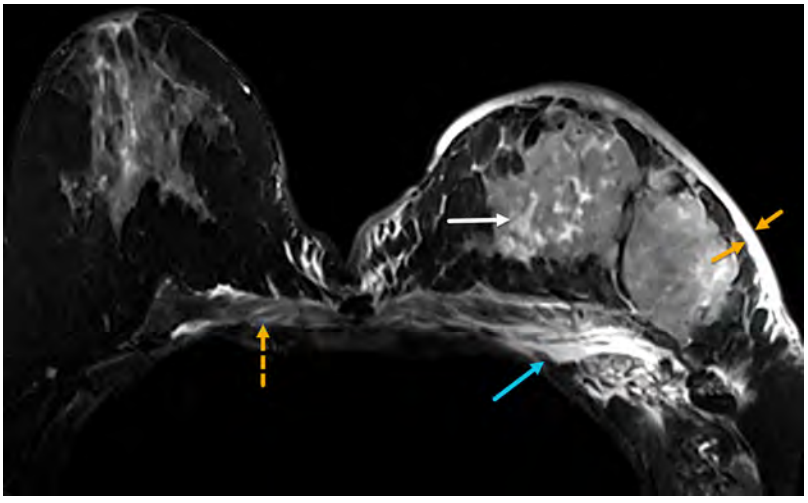


Figure 10. Noncontrast axial T2 MRI of both breasts in a patient with inflammatory breast cancer who presented with a 1-month history of rapid left breast swelling and redness that did not improve with antibiotic therapy. MRI demonstrates edema (bright T2 signals) in the thickened skin (yellow arrows), in the tumoral masses (white arrow), and in the chest wall and subpectoral region (blue arrow). Edema also crosses the midline into the contralateral chest wall (dotted yellow arrow). BI-RADS Category 5: highly suggestive of malignancy.



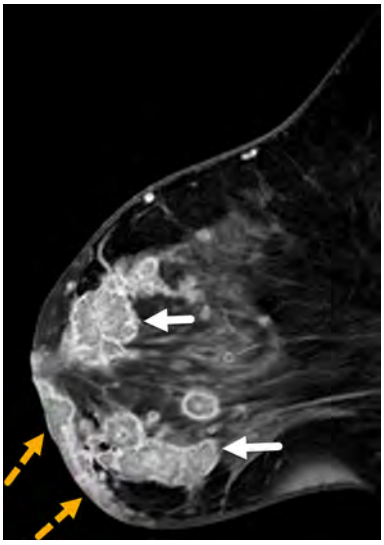
metastasis. Therefore, brain MRI is recommended for these patients.[34]

Treatment

Systemic Chemotherapy

IBC is highly aggressive, with poor survival rates. Before the introduction of systemic chemotherapy, fewer than 5% of patients treated with surgery and/or radiation therapy alone survived beyond 5 years, with a median survival under 15 months.[35,36] Local recurrence rates were high, at approximately 50%,

Figure 11. Sagittal postcontrast MRI of the left breast in a patient with inflammatory breast cancer who initially presented with mastitis-like symptoms not resolved with antibiotics. MRI demonstrates global skin thickening with multiple skin lesions in the dermis of the inferior breast (dotted yellow arrows). Conglomerate of suspicious breast masses are seen in all quadrants (solid white arrows). BI-RADS Category 5: highly suggestive of malignancy.



and many patients were candidates for surgery.[37] Over the past 2 decades, the consensus treatment for IBC has evolved to include systemic chemotherapy (with trastuzumab and endocrine therapy when indicated), followed by surgery and radiation therapy. Although IBC has been excluded from most prospective chemotherapy trials, retrospective trials have demonstrated the efficacy of systemic chemotherapy in IBC.

Anthracycline-based chemotherapy, introduced in the 1970s, significantly improved outcomes for IBC, achieving clinical response rates up to 72% and increasing 5- and 10-year survival rates compared with earlier treatments.[38-44] Combining anthracycline-based chemotherapy with taxanes has further enhanced these responses. Studies at the MD Anderson Cancer Center that added

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Figure 12. (A) Axial postcontrast MR image in a patient with inflammatory breast cancer (IBC) shows suspicious left axillary level I and III lymph nodes (solid yellow arrows). Biopsy confirmed metastatic adenopathy. Pma, pectoralis major muscle; Pmi, pectoralis minor muscle. (B) Axial postcontrast MRI in another patient with IBC shows suspicious right internal mammary node (yellow arrow) next to the internal thoracic vein (blue arrow). Biopsy of the internal mammary Internal thoracic artery (red arrow).

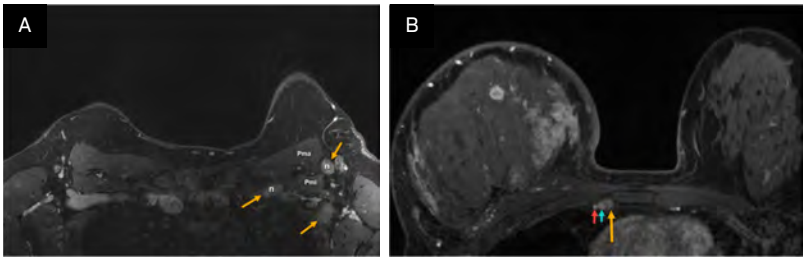
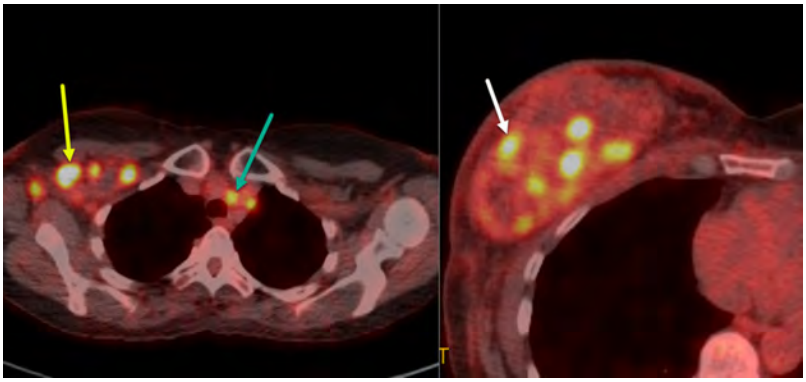


Figure 13. Two axial images of the $^{18\text{-}F}$FDG-PET/CT exam in a patient with inflammatory breast cancer reveal right axillary level I, II, and III hypermetabolic nodes (yellow arrow) and contralateral superior mediastinal nodes (green arrow). The patient has multiple hypermetabolic right breast tumoral masses (white arrow) within the enlarged inflamed right breast.



paclitaxel to standard regimens increased pathological complete response (pCR) rates.[39-43] Achieving pCR, particularly in the axillary lymph nodes, remains the most significant prognostic factor for long-term survival.[44]

Approximately 17-30% of IBC cases are triple-negative; that is, the tumor lacks estrogen and progesterone receptors and HER2 overexpression.[45,46] For these patients, adding pembrolizumab to neoadjuvant anthracycline- and taxane-based systemic chemotherapy has demonstrated improved pCR rates.[47] This combination is now widely used for triple-negative IBC.

HER2-positive IBC accounts for 36-60% of cases and benefits significantly fr om trastuzumab-based regimens.[48,49] The NOAH trial demonstrated that adding trastuzumab to standard chemotherapy significantly increased the pCR rate in patients with HER2-positive IBC.[50] Other studies corroborate these findings, suggesting that trastuzumab is essential to treatment in these cases.[51,52]

No standard IBC-specific treatments currently exist for patients with advanced or metastatic disease. This highlights the importance of clinical trials, including those focusing on exploratory or novel targeted therapies for patients with advanced or metastatic IBC.

Surgery

Total mastectomy with axillary lymph node dissection (modified radical mastectomy) is recommended for patients with IBC. The optimal timing for surgery is 3-6 weeks after the completion of neoadjuvant systemic therapy. The primary goal is to excise all macroscopic diseases and obtain pathologically clear margins. Excising grossly abnormal skin is also recommended; in patients where primary closure is not possible, advanced wound coverage techniques, such as skin grafting or myocutaneous flap closure with assistance from plastic surgery, may be indicated. Because breast skin excision is necessary for patients with IBC, immediate reconstruction is contraindicated. An MD Anderson Cancer Center study evaluating long-term outcomes in patients who completed trimodal therapy (neoadjuvant systemic therapy, modified radical mastectomy, and radiation) showed durable survival and a local recurrence rate of 6.9%, which is comparable to that of non-IBC patients.[52] Metastatic spread to the regional nodes is noted at presentation in most patients; axillary dissection is recommended in these cases. De-escalation measures such as breast conservation and limited axillary surgeries, which have not been well studied in patients with IBC, may be associated with increased rates of local recurrence.[53] As such, total mastectomy with axillary dissection remains the recommended approach to these cases.

Radiation Therapy

All patients should be offered radiation therapy regardless of treatment response. Radiation targets the chest wall and undissected draining lymphatics, with an extra dose (boost) to the chest wall and any undissected clinical stage N3 disease (infraclavicular, supraclavicular, or internal mammary lymph nodes). Dose fractionation details can be

found online.[54] While historical locoregional control rates are low, at approximately 80% over 5 years, recent data show significant improvement with a risk-stratified approach.[54] It is important to note that patients with IBC were excluded in recently presented clinical trials of de-escalation treatment, including hypofractionation and observation after pCR. Therefore, these approaches should be avoided in these patients.

Conclusion

IBC is a rare and aggressive form of advanced breast cancer characterized by rapid progression and distinct skin findings. Accurate, timely diagnosis is essential as skin findings overlap with benign pathologies such as infection and mastitis. Standard-of-care confirmatory imaging tests consist of mammography, breast and nodal ultrasound, and MRI. PET/CT is instrumental in detecting distant metastases and disease staging. Standard-of-care treatment involves a multimodal approach with chemotherapy, mastectomy with axillary lymph node dissection, and radiation therapy. Despite advances in imaging technology and emerging chemotherapies, IBC survival rates remain poor, underscoring the importance of continued research and encouraging participation in clinical trials.

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New Trends in the Diagnosis and Management of Renal AML Subtypes: Part II

Anthony F. Chen, MD; John P. McGahan, MD, FACR

Introduction

Up to 20% of all renal masses are benign, with the majority of these benign renal masses being angiomyolipomas (AMLs). The majority of AMLs contain macroscopic fat, which is their key imaging feature. Accurate diagnosis of these classic AMLs may help prevent unnecessary surgery or percutaneous ablation. These classic AMLs and their imaging features are discussed in more detail in Part I of this 2-part series.[1]

Most AMLs have a variable composition of smooth muscle, blood vessels, and fat, and this variability results in multiple subtypes. A minority of AMLs lack macroscopic fat, making differentiation from other renal masses, such as renal cell carcinomas (RCCs), much more challenging. This subset of AMLs has been described by various names and classified both by imaging and pathology, including fat-poor AML (fpAML), lipid-poor AML, AML with minimal fat, minimal-fat AML, and fat-invisible AML.[2] In this review, we refer to this common, non-classic subtype as fpAMLs.

Because they lack the classic feature of macroscopic fat, fpAMLs have garnered significant attention in imaging literature. Most fpAMLs occur in female patients, and, while they tend to occur in patients at a younger age than RCCs, the age ranges can overlap.

There is no universally accepted classification system for fpAMLs.[2-4] This may be due to their rarity compared to classic AMLs.

On CT, fpAMLs are classified as either hyperattenuating or isoattenuating. Other subtypes include rare variants such as AMLs with epithelial cysts, which are benign and contain a cystic component, and epithelioid variants, which may be malignant. Additionally, renal AMLs occur in association with tuberous sclerosis (TS) and, rarely, pulmonary lymphangioleiomyomatosis (LAM).[2-4]

Hyperattenuating fpAMLs

Most fpAMLs are hyperattenuating on CT (Hounsfield units >45) owing to the absence of macroscopic fat. This increased density distinguishes fpAMLs from many RCCs (Figure 1, Table 1). Without macroscopic fat, the muscular portion of the AML becomes the dominant component of the mass, leading to higher attenuation values. The attenuation of the mass can be compared with that of the adjacent renal cortex using the tumor-to-cortex ratio (TCR). In one study by Jeong, the TCR on unenhanced CT was 1.37 for fpAML and 0.83 for clear cell RCC (ccRCC).[5] This higher density is helpful in distinguishing fpAML from most RCCs, particularly ccRCC, though the TCR for fpAML and chromophobe RCC is similar. Hyperattenuating fpAMLs rarely contain cysts or calcifications. In a series by Ma, calcifications were observed in 12.9% of RCCs compared with only 4.5% of fpAMLs, but this difference was not statistically significant. In contrast, cystic degeneration on CT was seen in 61.3% of ccRCCs compared with only 9.1% of fpAMLs, a difference that contributed to a radiomics-based CT model in distinguishing between these 2 masses.[6]

On MRI, a hyperattenuating AML appears hypointense on T2-weighted images (Figure 2, Table 1), whereas ccRCCs are typically hyperintense, aiding their differentiation. However, papillary RCC (pRCC) can also appear hypointense on T2, potentially mimicking fpAML. As with density comparisons on CT, the T2 signal intensity (SI) of these masses on MRI can be quantified using the TCR, which compares the SI of the mass to that of the spleen or adjacent renal cortex. In a study by Jeong et al, the mean TCR for fpAML was 0.75, significantly lower than the 1.21 reported for ccRCC.[5] Setting the TCR threshold at 0.86 achieved a sensitivity of 93% and a specificity of 82% for distinguishing fpAML from ccRCC.

Chemical shift imaging may assist in distinguishing fpAMLs from pRCCs.[5] Most fpAMLs demonstrate no signal loss on out-of-phase chemical shift images,

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Figure 1. Fat-poor angiomyolipoma (fpAML) with angular interface. CT scan (A) showing the right kidney [K] with a simple cyst [C] and a fpAML [A]. The Hounsfield unit of the fpAML was 50 and identical to the HU of the adjacent muscle [M]. US showed this fpAML (B) to have mixed echogenicity, with an angular interface (arrows) and some overflow of the renal cortex (curved arrow, K = kidney). US of peripheral AMLs (C), which, like fpAMLs, often have the "overflowing beer" sign (arrows) with the renal cortex. The presence of either an angular interface or "overflowing beer" sign is helpful in distinguishing fpAMLs from renal cell carcinomas.

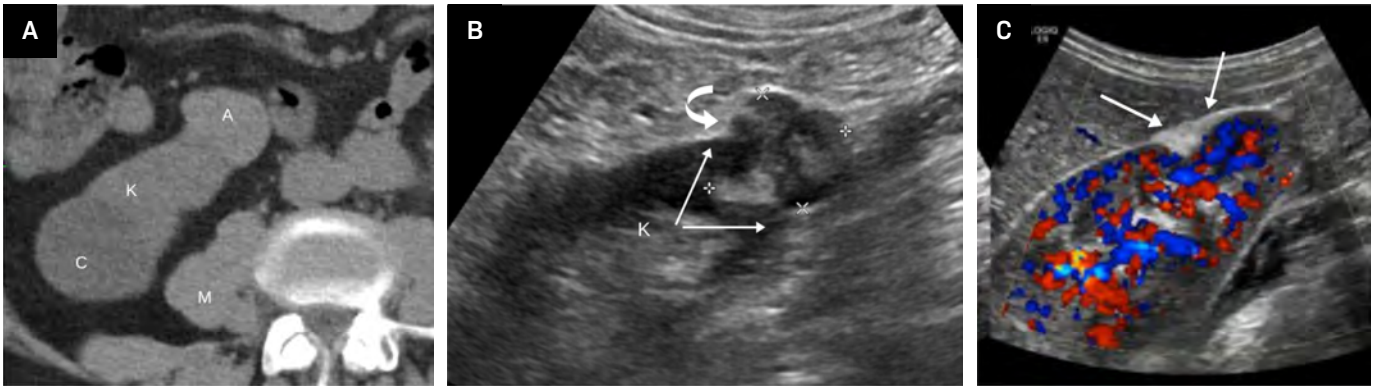

Table 1. CT and MRI Features of Hyperattenuating Fat-Poor Angiomyolipomas

CT	MRI
Hounsfield unit >45 with no fat attenuation	T2-weighted—homogeneously hypointense
Variable, frequently homogeneous, early enhancement	Fat sat—no signal loss
No fat attenuation	Chemical shift—usually no signal loss
No calcifications or cysts	No cysts

although occasional small foci of signal drop may be present due to microscopic fat (Figure 2). By comparison, ccRCCs possibly show diffuse signal loss on opposed-phase imaging due to the presence of intracytoplasmic lipid.[3,4]

On contrast-enhanced imaging, fpAMLs are usually homogeneously avidly and rapidly enhancing, whereas pRCCs demonstrate delayed contrast enhancement.[7] Arterial-to-delayed enhancement ratios on MRI have been proposed to differentiate fpAMLs from RCC subtypes. Using dynamic contrast-enhanced spoiled gradient-echo images, arterial, venous, and 3-minute-delayed phases can be obtained. A 5 mm or larger region of interest is placed in the most arterial enhancing portion of the mass as the SI. The ratio is calculated as follows: (ST arterial – SI pre)/(SI delayed – SI pre). An arterial-to-delayed enhancement ratio >1.5 for T2-hypointense lesions can aid differentiation between the fpAMLs and all subtypes of AMLs.[8]

Park et al examined US features of renal masses with low T2 SI on MRI and found that 45% of fpAMLs were hyperechoic, whereas none of the low T2 RCCs demonstrated hyperechogenicity.[9] Thus, approximately half of fpAMLs exhibit the hyperechogenic appearance seen in classic AMLs.

As we discussed more extensively in Part I, morphological features help distinguish classic AML from RCC on US, and they can similarly aid in differentiation of fpAML.[1] Kim et al found that on contrast-enhanced CT of renal masses <4 cm, an angular interface had a sensitivity of 55% and specificity of 81.9% for fpAMLs, while the "overflowing beer" (also referred to as the "drooping") sign carries a sensitivity of 61% and specificity of 97.[10] Strother et al demonstrated that both signs were strongly associated with fpAML, with odds ratios of 12.6 and 11.2, respectively (Figure 1).[11] Thus, when an angular interface or overflowing beer sign is present, the lesion is more likely an AML than RCC.

Isoattenuating fpAMLs

There are other subtypes of AMLs, including isoattenuating AMLs, AMLs with epithelial cysts, and epithelioid AMLs (Table 2). Isoattenuating fpAMLs are rarer than hyperattenuating AMLs and have Hounsfield units between –10 and 45. Like the hyperattenuating fpAML, these types lack macroscopic fat, cysts, or calcifications. On MRI, isoattenuating fpAMLs are typically T2 hypointense and do not exhibit signal drop-out using fat saturation techniques, though signal drop-out is occasionally seen on out-of-phase chemical shift imaging. Due to overlapping features with RCC, differentiation can be challenging, and biopsy is often required.[5] However, in select cases with more characteristic features, imaging surveillance may suffice.

Renal Mass Management

Although the American Urological Association guidelines do not recommend biopsy of renal masses before

Figure 2. Hyperattenuating fat-poor angiomyolipoma (fpAML) in an adult female. US of the right kidney showing an echogenic mass (arrow) (A). Non-contrast CT shows the mass to be hyperattenuating, with Hounsfield units >45 (arrow) (B). Axial single-shot fast spin echo (SSFSE) T2-weighted MRI shows the mass to be of low signal intensity (arrow) (C). Contrast-enhanced LAVA FLEX (FAT SAT) MRI shows early contrast enhancement of the mass (arrow) (D). Chemical shift imaging with in-phase LAVA FLEX coronal MRI showing the mass (arrow) (E). Chemical shift imaging with out-of-phase LAVA FLEX coronal MRI shows no signal drop-out within the mass (arrow) indicative of no microscopic fat (F).

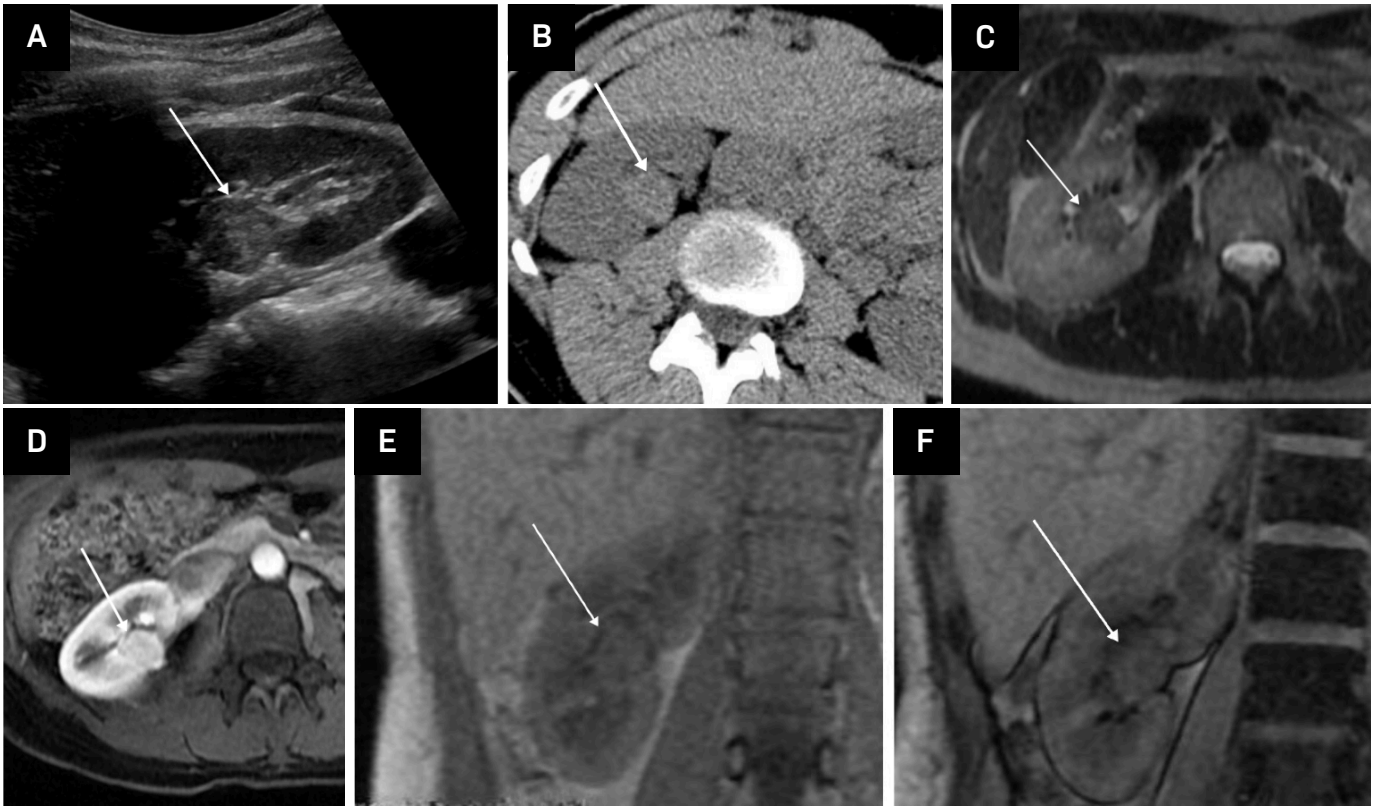

Table 2. Other Subtypes of Angiomyolipomas and Their Imaging Features

	CT	MRI
Isoattenuating fat-poor angiomyolipomas	Hounsfield unit –10 to 45 with no macroscopic fat variable contrast enhancement pattern	T2-weighted—homogeneously hypointense Chemical shift—signal loss Variable enhancement pattern
Angiomyolipomas with epithelial cysts	Hyperattenuating with variable cysts	T2-weighted—hypointense solid component Fat sat—variable signal loss Variable cysts
Epithelioid angiomyolipoma	Hyperattenuating with Hounsfield unit >45 May have cysts Heterogeneous contrast enhancement	T2-weighted—hypointense May have cysts Heterogeneous contrast enhancement

resection, approximately 20% of renal masses smaller than 4 cm, most commonly oncocytomas or AMLs, are benign and may be unnecessarily treated. Noninvasive imaging plays a critical role in preventing overtreatment; however, accurate diagnosis of oncocytomas by CT or MRI is not possible. Classic AMLs are readily diagnosed using CT or MRI based on the presence of macroscopic fat. While fpAMLs are more difficult to diagnose in one meta-analysis, fpAMLs were diagnosed with a sensitivity of 83% and a specificity of 93% with MRI.[12]

Still, it is important to try to noninvasively diagnose these fpAMLs. Active surveillance has been advocated for renal masses <2 cm or when there are significant comorbidities or limited life expectancy. Imaging is also helpful in the management of masses that are highly suggestive of fpAMLs. As noted in one review, "radiologists influence management of solid renal mass and the decision to perform active surveillance by diagnosing masses that may be benign (eg, fat-poor AML)."[13] In doing so, patients may avoid unnecessary surgery or other invasive interventions.

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Figure 3. Angiomyolipomas (AMLs) on US. Adolescent with tuberous sclerosis and multiple echogenic AMLs (arrows) within the right kidney (A). Similar masses were seen in the left kidney (B).

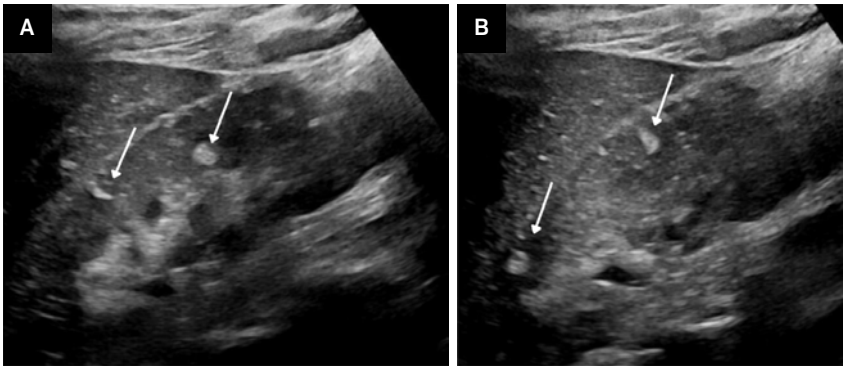


Figure 4. Angiomyolipomas (AMLs) on CT. Adult with tuberous sclerosis and multiple AMLs, most of which are classic with macroscopic fat (arrow) in the right kidney, but hyperattenuating fat-poor AML (curved arrow) in the left kidney.

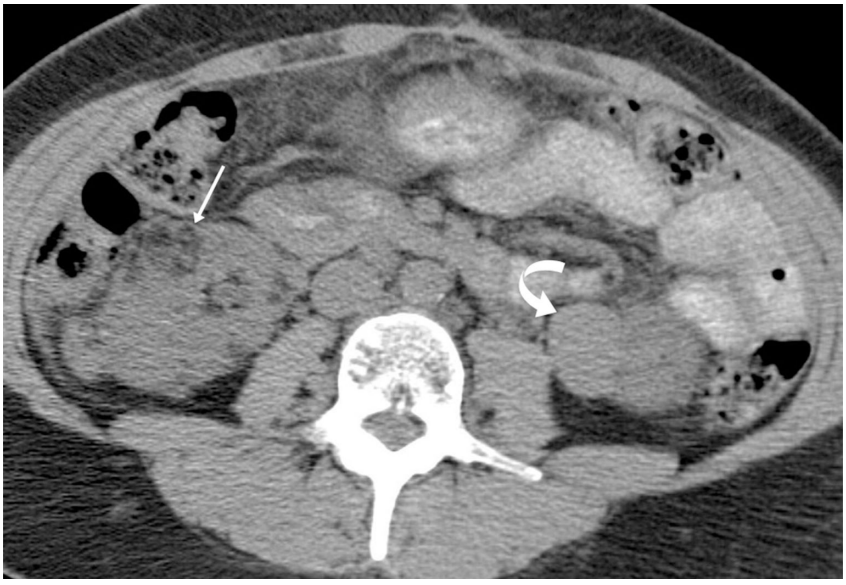
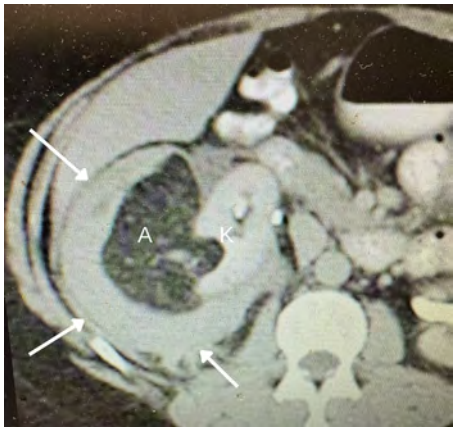


Figure 5. Hemorrhage in large angiomyolipoma (AML). Adult with sudden onset of right flank pain. Coronal reformation contrast-enhanced CT showing left upper pole AML with angular interface (arrow). There is a large hematoma (H) that extends into the pelvis (B = bladder).



AML with TS

TS is a genetic disorder characterized by the presence of noncancerous tumors in multiple organs. Renal AML, usually the classic, fat-containing type, occurs in up to 75% of patients with TS. These tumors, which may occur at any age, are often multiple and bilateral (Figure 3) and tend to enlarge with age (Figure 4). Nonclassic subtypes, including fpAML, AML with epithelial cysts, and epithelioid AML, occur more frequently in TS than sporadic AML.[4,5] Close follow-up may be indicated. AMLs in TS tend to be larger and hemorrhage more frequently, necessitating treatment, often with catheter-based interventions for larger tumors (>4 cm) or those that have hemorrhaged.

AML with LAM

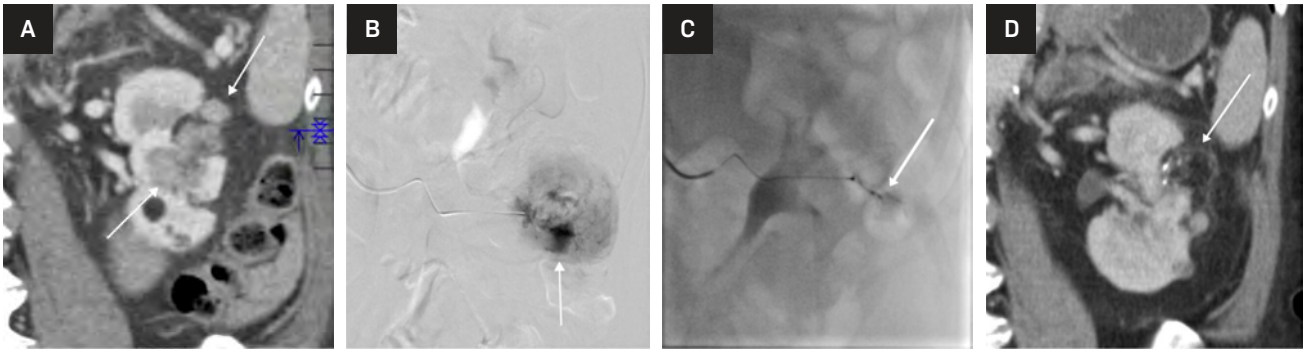
LAM is a rare, multisystem disorder, usually affecting females, that primarily presents with lung disease. The presence of pneumothoraces and chylous effusions can lead to respiratory failure. Though overwhelmingly pulmonary, LAM is a multisystem disorder that can result in meningiomas, chylous ascites, cystic masses, and renal AMLs. Renal AML occurs in fewer than 50% of patients with LAM, tends to be smaller than in TS, and hemorrhages less frequently.

AML with Epithelial Cysts and Epithelioid AML

The solid components of AMLs with epithelial cysts are hyperattenuating on CT, T2 hypointense on MRI, and associated with cysts, which may be multilocular. These are benign and typically managed with biopsy confirmation followed by observation.[3]

Epithelioid AML is rare and may be malignant. It is hyperattenuating on CT (HU >45), often shows heterogeneous contrast enhancement,

Figure 6. Embolization of large angiomyolipoma (AML). Coronal reformation contrast-enhanced CT showing AML with a large solid component (arrows) (A). Selective catheter angiography showing pooling of contrast (arrow) within the AML (B). Post-embolization catheter angiography showing near-complete occlusion of the vascular component of the AML (arrow) (C). Follow-up coronal reformation contrast-enhanced CT showing regression of the solid component of the AML, with some of the fatty component still visible (arrow) (D).



and may have cystic components, hemorrhage, vascular invasion, necrosis, and/or metastases. Internal hemorrhage and necrosis are more common with epithelioid AML. On MRI, the solid components are T2 hypointense but more variable on fat saturation or chemical shift imaging.[3] Owing to this, biopsy is often required to distinguish them from RCC.

Radiological Interventions

AMLs contain vascular tissues and may develop aneurysms, which can lead to hemorrhage, particularly as tumors enlarge (Figure 5). Treatment approaches include percutaneous interventions (Figure 6). Current treatment recommendations are predominately based on lesion size and patient symptoms.[14] For the asymptomatic AML <4 cm diameter, serial imaging surveillance is typically sufficient.[15] The presence of tumors larger than 4 cm, which carry higher risks of hemorrhage, and aneurysms >5 mm, meet the criteria for prophylactic intervention. Symptoms of hemorrhage may include acute abdominal pain (Figure 5).[16] AMLs may enlarge during pregnancy owing to hormonal effects, with an associated increased hemorrhage risk.[17]

Arterial embolization and lesion ablation are common radiological interventions for AMLs. Embolization is preferred for larger tumors as it more effectively and directly addresses their vascular components. Arterial embolization may be used for prophylactic treatment of tumors >4 or >6 cm or those with aneurysms, and it is the treatment of choice when there is associated hemorrhage. Embolization is minimally invasive, with minimal blood loss and short hospital stay compared with surgical intervention.[16]

Radiofrequency ablation, including microwave and cryoablation, is a new treatment for AMLs <4 cm.[14,16] Ablation is performed under CT guidance using a percutaneous approach. Surgery remains an option in these cases but is more invasive and has been shown to have a higher rate of complications. Thus, surgery is usually reserved for larger lesions, but is associated with a higher rate of complications, including hemorrhage and urine leak,[16] compared with embolization.

Summary

Most AMLs are sporadic, occur in females, are highly echogenic, and contain macroscopic fat detectable on CT and MRI. However, several subtypes exist, which the radiologist should be aware of, including the hyperattenuating and isoattenuating forms of fpAML, AMLs with epithelial cysts, and epithelioid AMLs. All of these have some imaging features that may allow them to be distinguished from RCC.

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Academic Radiologists Look for Help from AI to Meet Demands

Joseph Jalkiewicz, BA

As the supply of clinical radiologists shrinks in the face of growing demand for medical imaging, academic radiologists face growing pressure to fill service gaps—often at the cost of research and education. Like their clinical counterparts, they're looking for AI to help offload routine tasks and reclaim time for innovation and training the next generation.

"In the US, there are around 250 academic radiology departments. Everybody's in the same squeeze," says Paul Kinahan, Vice Chair for Research and Professor of Radiology at the University of Washington School of Medicine. "Probably a couple of dozen are our peers in terms of grant funding and innovating with research. But that number could shrink to 10 or 12 in the next few years."

"The thing that we're realizing is that AI can help the academic radiology side as well as the clinical side," Dr Kinahan adds. "It's not a complete answer by itself, but it can help."

Imaging Demand vs Radiologist Supply

Over 300 million diagnostic imaging procedures are performed in the United States each year, resulting in a medical imaging market that, according to one estimate, is projected to grow from $140.2 billion in 2024 to $239.74 billion by 2032.[1]

With respect to specific modalities, 84.5 million CT scans were performed in the United States in 2021, a 15.8% increase from the prior year. PET scans are projected to grow by about 23% over the next decade, while US is anticipated to increase 16% over the coming decade.[2]

Population growth is a major driver of future imaging utilization, potentially accounting for 73-88% of increases across all modalities. Indeed, owing to the prevalence of age-related health issues, older Americans are expected to contribute 12-27% of utilization increases.[3]

Meanwhile, more than 80% of health systems are reporting staffing shortages in radiology, shortages that show no sign of easing. The Association of American Medical Colleges' 7th annual analysis of physician supply and demand noted that the shortage of "radiologists and other specialists" could exceed 35,000 by 2034, owing to retirement and various causes of attrition, including burnout. Of some 21,000 radiologists in the United States, more than half are nearing retirement.[4]

Impacts on Medical Imaging Research

That may seem like a long time off, but clinician scientists like Katy Lowry, MD, an associate professor of radiology at the UW School of Medicine and a radiologist at the Fred Hutchinson Cancer Center in Seattle, are already seeing and experiencing the early signs and symptoms.

"Radiology volumes are high, and radiologists feel it, and there's definitely a tension and a stress of trying to keep up with the clinical work to a point but also having the time to do academic pursuits," says Dr Lowry.

Dr Lowry's research focuses primarily on breast cancer screening and outcomes. A 2022 study led by Dr Lowry highlighted the potential benefits of expanding eligibility for MRI breast cancer screening for people with genetic variants beyond *BRCA1* and *BRCA2*, such as *ATM*, *CHEK2*, and *PALB2*. Her team's study findings led to changes in screening policy that expanded MRI screening to younger patients with these variants.

"This kind of research requires large buckets of time. This is not something you squeeze in an hour here, an hour there, and one day a week, which may be typical for academic radiology," says Dr Kinahan. "That's just enough to keep up with your email and administrative duties, not the consistent effort over years that moves the field ahead."

And while he and Dr Lowry agree that patient care should always be the top priority, room should also be left for research that leads to innovation.

"At the end of the day, the first priority is making sure we have enough radiologists to do the clinical work because we have a commitment to our patients, who always come first," Dr Lowry says. "But you also really need substantial time to think, to meet with your collaborators and have long conversations about the design of your study, the interpretation of your study, and what you're going to do with the findings. Having time to write, having

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time to get the grant in the first place, is extremely time-consuming."

Impacts on Teaching

Teaching is also taking a hit from the disconnect between radiologist supply and imaging demand, says Gelareh Sadigh, MD, associate professor of radiology, director of Health Services and Comparative Outcome Research, and vice chair for faculty development at the University of California, Irvine.

Dr Sadigh studies social determinants of health factors that affect patient access to health care, including medical imaging. The most significant impact of growing imaging caseloads on her, Dr Sadigh says, relates to teaching medical students and residents.

"Yes, my main mission is clinical, but I also have an educational mission for the next generation of radiologists," she says, explaining that greater demand for image interpretation leaves her less time to review each case in detail with her trainees.

"In general, if [a finding] is positive, I want to talk about it at least 15 to 20 minutes with the trainee, and not only about that case, but the mimics of that case. But if I have a ton of imaging exams to be read on my list, then I don't have time to talk about all these different things with these residents or medical students that sit with me."

Dr Sadigh adds, "They should be able to learn from the experience."

AI to the Rescue

Artificial intelligence, by virtue of its ability to automate many tasks handled by humans, has the potential to free academic radiologists from many mundane activities that hinder their goal to innovate and educate, says Dushyant Sahani, radiology chair at the University of Washington School of Medicine.

"I feel that AI has a tremendous promise, but it's not a panacea, and I think the real huge opportunity with AI is on the operation side or the workflow side of radiology," says Dr Sahani. "We have to work smarter and invest in the right infrastructure and technology."

Initiatives are underway at UW and other academic radiology departments to work with AI companies to strategically implement such tools to improve efficiencies, notes Dr Sahani. He cites a particularly strong role for AI in helping to determine the appropriateness of an exam for a given condition, communicating with patients and other physicians, and customizing scans to particular circumstances.

Dr Sadigh agrees, citing examples such as worklist prioritization; automating protocols, lesion measurements, and recommendations; as well as extracting data from electronic medical records and even making patient scheduling predictions (e.g., who's likely to be late or to cancel at the last minute) to help determine when to overbook the schedule.

"I'm just giving you some examples of how this can open up not only my time, but our technologists' time, our scheduler's time, the whole department," she says. "It can definitely help me in terms of now using that time to teach my residents, using that time to talk to referring providers, and participate in the multidisciplinary meetings. It basically opens up these pockets of time during the day as opposed to being swamped by these imaging volumes."

Keep Pedaling

Radiology's future hinges not only on integrating cutting-edge technologies but on effectively balancing clinical demands with academic priorities. In describing the relationship between clinical and academic radiology, Dr Kinahan cites an analogy he attributes to a former faculty member.

"It's like a tricycle," he says. "The big wheel out front is clinical service, and the two little wheels on the back are research and education. The big wheel drives everything, but it can't move forward without the other two."

By virtue of its growing ability to foster automation, AI holds the promise of freeing up more time for all 3 wheels, to the benefit of the entire tricycle of radiology.

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Breast Arterial Calcification—At the Heart of Screening: A Canadian Perspective

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Introduction

Cardiovascular disease remains the primary cause of mortality in Canadian women, with deaths from adverse cardiac events rising in women over the past 5 decades.[1-3] Despite recent advances in cardiac care, the current methods used for cardiovascular risk stratification underestimate cardiovascular risk in women,[4,5] and there is an ever-increasing need for a system that considers sex-specific risk factors in addition to traditional cardiovascular risk factors.

Just as there are sex-specific cardiovascular risk factors for women that differ from traditional cardiovascular risk factors, men and women experience different signs and symptoms of acute coronary syndrome. Women with myocardial infarction are more likely to present with atypical symptoms such as gastrointestinal upset rather than typical retrosternal chest pain triggered by exercise and relieved with rest.[6,7] Despite this fact, the majority of Canadian women are unaware of their personal cardiovascular risk and factors that influence their risk for adverse cardiac events.[2,8] By reporting breast arterial calcification (BAC) found on mammography, radiologists can add value to patient care by identifying women at higher cardiovascular risk, allowing for earlier preventive measures.

Clinical Importance of Breast Arterial Calcification

Evidence of the association between the presence of BAC on mammography and increased cardiovascular risk, and the development of clinically significant heart disease, is growing.[9-14] Patients with BAC have been found to have an increased incidence of critical coronary artery stenosis and are more likely to develop ischemic heart disease or ischemic stroke compared with those without BAC on mammography, even when controlling for age.[15,16]

Despite some evidence to the contrary,[17,18] an ever-increasing volume of studies are finding a correlation between BAC and coronary artery disease. These newer studies, which are being performed prospectively on larger cohorts, are providing stronger evidence of the clinical significance of BAC.[19,20]

While many authors caution against using BAC as a diagnosis of cardiovascular disease or to justify invasive testing, supporters of BAC reporting, including The Canadian Society of Breast Imaging, note that the findings should prompt conversations between women and their health care providers about preventative care.[21]

Current Perceptions and Practice

Reporting of BAC among radiologists is inconsistent across North America. In Canada, although 50% of radiologists are aware of the relationship between BAC and cardiovascular risk, only 16% routinely report its presence on mammography.[22] One-third report the presence of BAC when it is found in young patients or if the calcium burden is high.[22] Of those who report BAC, only 4% follow-up or offer management recommendations, and even fewer (only 1%) directly inform the patient.[22] With only 4% of radiology departments having established protocols for reporting BAC, it is widely agreed that national guidelines are needed.[22]

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In the United States, up to 87% of radiologists report BAC on mammography; however, only 15-41% do so consistently,[23,24] and fewer than half agree that identification of BAC adds value to screening mammography.[24] Of the radiologists who routinely report BAC, only 0.7% consistently provide follow-up recommendations.[24]

Results of North American survey studies suggest that referring physicians would like to be made aware of the presence of BAC on mammography.[25,26] Furthermore, an overwhelming majority of patients surveyed in a 2020 study by Margolies et al indicated that they wanted to be made aware of the presence of BAC on mammography in order to guide informed decision-making.[27] Approximately 22% of the those patients were familiar with BAC prior to taking the survey.[27] In a 2023 study by Vincoff et al, 57% of patients who were notified about BAC on their mammogram had discussed the results with their physician within 3 months, and 81% said that direct notification of the presence of BAC was "very helpful" or "somewhat helpful."[28] In a 2025 prospective cohort, McKee et al reported that informing patients without known cardiovascular disease about BAC and coronary artery calcium on calcium score CT led to increased primary care follow-up and lifestyle changes.[29]

Practical Considerations

While there is limited evidence on when and how to meaningfully report BAC, the Canadian Society of Breast Imaging has published a grading system and reporting guide to support radiologists.[21] There are geographic barriers to BAC reporting in some provinces and territories. For example, the standard reporting templates utilized by some screening programs do not currently allow for free text; adding a free-dictation text box or equivalent could facilitate nationwide BAC reporting.[22]

Discussion on the reporting and clinical management of BAC on mammography is not complete without acknowledging the potential impact of widespread reporting on an already-stretched Canadian health care system. An increase in administrative burden and unnecessary referrals can be avoided with coordination and clear communication among radiologists, family physicians, cardiologists, and oncologists surrounding the reporting and management of BAC. The decision to report BAC on mammography should be made in partnership with regional referring physicians to mitigate capacity issues resulting from increased cardiology referrals.

For patients in whom BAC is identified on mammography, the primary recommendation is that the referring physician and/or family physician assess the patient's cardiovascular risk factors and optimize primary or secondary preventative methods. This may encompass lifestyle modifications such as increased physical activity, dietary adjustments, decreasing alcohol consumption, and smoking cessation, in addition to initiation or adjustment of lipid-lowering medications and altered treatment thresholds for hypertension.

Conclusion

Routine reporting of BAC on mammography is a powerful opportunity for radiologists to enhance patient care by identifying women at increased cardiovascular risk and enabling timely preventive interventions. With a significant overlap between postmenopausal women and those undergoing screening mammography, incorporating BAC reporting into standard practice can serve as a critical tool in early cardiovascular risk stratification. By facilitating the early initiation of optimal medical management, BAC reporting has the potential to significantly improve long-term health outcomes and drive greater awareness of cardiovascular disease prevention in women, ultimately transforming routine mammography into a dual-purpose screening tool for both breast and heart health.

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Breast Arterial Calcification: Why Radiologists Should Start Reporting This Silent Risk Factor for Heart Disease

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Breast arterial calcification (BAC) has long been visible to radiologists reading mammograms. It appears as characteristic linear, parallel "tram-track" calcifications outlining breast arteries[1] —easy to spot, easy to classify, and entirely incidental to the task at hand: ruling out breast cancer. Because BAC is not a marker of breast malignancy, however, radiologists have historically ignored it in reports, dismissing it as a benign finding.

Yet a growing body of evidence shows that BAC is anything but benign. Its presence on mammography is strongly correlated with cardiovascular risk, including heart attacks, stroke, and cardiovascular death. That makes BAC a powerful "free" biomarker—information available to every radiologist, every day, at no additional cost, dose, or imaging burden. The challenge: radiologists must decide whether to report it.

From where Nina Vincoff, MD, stands, they should.

"We have an incredible opportunity here to do two-for-one screening for two of the biggest threats to women's health and women's lives," says Dr Vincoff, who is a breast imager and the editor-in-chief of *Applied Radiology*. "There's really no argument that anybody can make to me for not doing it."

What Is BAC?

"Breast arterial calcification is an entity we've always seen on mammography," explains Dr Vincoff, who until recently was the Breast Imaging Division Chief at Northwell Health in New York. "It doesn't require special training, special equipment, or additional views. It simply appears as white linings along breast arteries."

Importantly, BAC is not the result of the same process as the intimal calcification familiar in coronary arteries. Instead, it represents medial calcification—arterial stiffening rather than luminal narrowing. "People make much of that distinction," noted Laurie Margolies, MD, Vice Chair for Breast Imaging at Mount Sinai Health System in New York City.

"But the bottom line is that both are associated with ischemia and infarction. Different pathways, same outcome."

The Overlooked Killer in Women's Health

For decades, women's heart disease has been underdiagnosed and undertreated. Historically, prevention campaigns focused on men, while women's symptoms were minimized or misinterpreted. "It wasn't that long ago," Dr Margolies recalled, "that American Heart Association pamphlets for women were all about cooking

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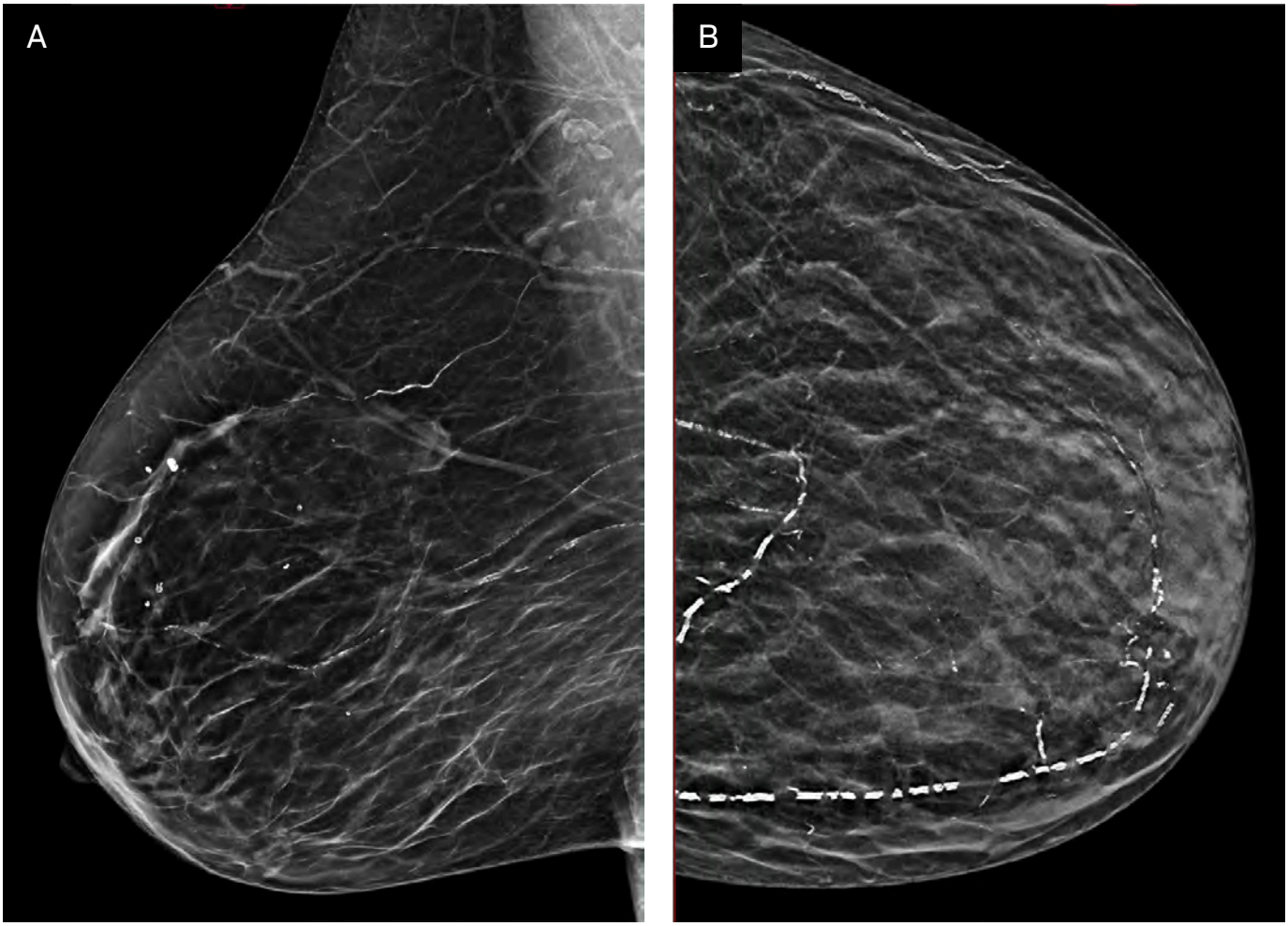
Figure 1. Right MLO (A) and left CC (B) views of a breast with Grade 3 breast arterial calcification. Images courtesy Canadian Society of Breast Imaging.



better meals for their husbands to prevent his heart attack."

The reality, she says, is that cardiovascular disease kills more women than breast cancer, yet patients overwhelmingly fear the latter. Annual mammograms are viewed as the gold standard of preventive care, while heart health often goes unexamined, agrees Dr Vincoff.

"Women come in thinking they've checked the preventive care box by getting their mammogram. But they often haven't had their cholesterol, blood pressure, or other risk factors evaluated," she observes. "They're so focused on breast cancer and not really thinking about heart disease at all."

Indeed, according to the Centers for Disease Control and Prevention, more than 60 million women (44%) in the United States are living with some form of heart disease, which it labels as the leading cause of death for women in the country and says can affect women at any age.[2]

This makes BAC reporting uniquely powerful. A woman who thinks she's only being screened for breast cancer may also be alerted to hidden cardiovascular risk—at the very moment she is most focused on her health.

Evidence Links BAC to Cardiovascular Risk

A robust body of literature confirms the association between BAC and adverse cardiovascular outcomes. Dr Margolies in fact co-authored a recently published study, "Breast Arterial Calcifications on Mammography: A Review of the Literature," examining epidemiologic studies that have consistently shown that BAC prevalence rises with age, diabetes, hypertension, and chronic kidney disease—classic cardiovascular risk factors.[3]

Longitudinal studies link BAC to major adverse cardiac events, including myocardial infarction, stroke, and cardiovascular death, independent of traditional risk markers. In addition, the prognostic value of BAC persists regardless of statin therapy, suggesting that it provides additive risk information.

"Longitudinal studies show that BAC correlates not only with death but with major adverse cardiac events," she says.

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"Cardiologists say, 'please send us these patients and we will prevent these things.'"

The Patient Perspective: "How Dare You Not Tell Me?"

If the science were not persuasive enough, patient preference is unequivocal. In one study led by Dr Margolies, 97% of women said they would want to know if BAC was present. "The reaction was consistent: 'How dare you know something about my body and not tell me?'" she recalls.

Dr Vincoff, meanwhile, conducted a pilot study of 500 consecutive patients. Of those with BAC, 57% spoke with their doctor about the finding within 3 months.[4] Several underwent further testing and, in some cases, life-saving interventions such as stent placement or bypass surgery.

"Women can handle scary news," she says. "They'd rather hear it and act on it than be shielded and miss the chance to prevent a heart attack."

Lessons from Breast Density Reporting

The trajectory of BAC reporting parallels that of breast density, says Dr Margolies. For decades, density was acknowledged but rarely communicated. Advocacy from patients—women who developed advanced cancers despite "normal" mammograms—changed the landscape. Federal law now mandates breast density notification.

"We don't want to repeat that history," Dr Margolies cautioned. "We shouldn't need patients to start foundations to force us to do the right thing. We already know BAC is important. We should act now."

One Click Is All It Takes

Radiologists may hesitate, worrying about reporting burden. In reality, the workflow impact is negligible. Drs Vincoff and Margolies point out that radiologists already evaluate all calcifications carefully, distinguishing suspicious morphologies from benign or vascular.

"That decision is already made internally," Dr Vincoff explained. "Reporting BAC is simply putting words to the thought process you've already had."

Structured reporting makes it even easier. At Northwell Health, Dr Vincoff's team adopted the Canadian Society of Breast Imaging grading scale (0-3) and built it into reporting templates. Radiologists select the grade with a single click. Patients receive plain-language explanations through patient-friendly reporting systems, allowing them to discuss results with their physicians.

"This is trivial to do," Dr Margolies emphasizes. "Literally one click."

Addressing Skepticism: "It's Not in My Lane"

Why, then, has reporting lagged? According to Drs Vincoff and Margolies, perceived irrelevance is one reason: some radiologists argue BAC is outside the lane of breast imaging. Another is pathophysiologic quibbling: critics highlight differences between medial and intimal calcification, even though the presence of both suggests a referral for cardiovascular evaluation is in order.

In addition, some argue over the absence of guidelines—unlike BI-RADS for breast findings, no US authority mandates BAC reporting. Finally, critics cite the potential for uncertainty: without standardized management pathways, radiologists fear burdening fellow clinicians with "what next?" questions.

But these objections are eroding. Cardiologists have published studies on BAC for decades, and radiologists must catch up, says Dr Vincoff. Canadian guidelines already encourage reporting, and US studies are rapidly expanding.

"Yes, we don't yet know the perfect management algorithm," Dr Vincoff acknowledged. "But the only way we'll learn is by reporting, collecting data, and studying outcomes. Waiting accomplishes nothing."

Practical Considerations

For radiologists ready to adopt BAC reporting, Drs Vincoff and Margolies recommend the following straightforward framework:

- Use structured language: Incorporate a standardized BAC grading scale such as the one developed by the Canadian Society of Breast Imaging (0 = none; 1-3 = increasing severity).
- Report presence/absence in all screening mammograms: Err on the side of inclusion; any BAC warrants attention. A simple yes/no checkbox can work.
- Educate referrers: Share literature and institutional protocols with referring clinicians, especially OB/GYNs, who may be unaccustomed to cardiovascular findings on mammograms.
- Provide patient-friendly explanations: Whether via portals, reports, or handouts, ensure patients understand the finding and why follow-up matters.
- Encourage cardiovascular evaluation: Patients with BAC should undergo comprehensive cardiovascular risk assessment—lipids, blood pressure, diabetes screening, smoking history, and possibly cardiology referral.

The Future of BAC Reporting

The field is moving quickly. Institutions like Northwell and Mount Sinai now universally report BAC. National attention is growing, with research about BAC reporting being published not only in radiology journals but in high-profile cardiology venues like the *Journal of American Cardiology Advances*.[5]

Ongoing research will clarify prevalence, refine grading utility, and establish evidence-based management pathways. Early data from Northwell suggest that BAC is present in about 15% of screening mammograms, a prevalence far exceeding breast

cancer detection rates, says Dr Vincoff. She argues that the findings underscore BAC's potential as a major public health tool.

"[Reporting BAC] is so easy for us to do, and there's really no excuse for not doing it," she reiterates. "We can change women's lives just by empowering them with those kinds of pieces of information."

"We may end up finding more cardiovascular disease than breast cancer through BAC reporting," agrees Dr Margolies.

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Breast Granular Cell Tumor

Elmira Taghi-Zadeh, MD; Moumita Saha Roy Choudhury, MD; Mohanad Shaar, MD; Evita Singh, MD

Case Summary

A middle-aged adult with a complex medical history, including diabetes mellitus, osteoporosis, and previous bilateral salpingo-oophorectomy for stated malignancy, presented for overdue routine breast screening.

Imaging Findings

Screening full-field digital mammography with digital breast tomosynthesis (DBT) in craniocaudal (CC) and mediolateral oblique (MLO) projections demonstrated a 0.6-cm focal asymmetry in the upper inner left breast, posterior depth (Figure 1). An additional previously biopsied fibroadenoma in the left breast with biopsy marker was stable.

The patient was called back for diagnostic CC and MLO spot compression mammographic views with DBT, which confirmed the presence of a 0.6-cm focal asymmetry in the upper, inner left breast, posterior depth. (Figure 2)

Targeted diagnostic ultrasound of the left breast demonstrated a 0.5 × 0.4 × 0.3 cm hypoechoic mass with indistinct margins and minimal associated internal vascular flow at the 11 o'clock position, 15 cm from the nipple, corresponding to the mammographic finding (Figure 3), and assessed as BI-RADS 4 (suspicious). Ultrasound-guided core needle biopsy was performed with clip placement, confirming mammographic correlation.

Diagnosis

Granular cell tumor (GCT), negative for in situ or invasive carcinoma.

The gross pathology specimen after localized surgical excision demonstrated an ill-defined, firm, homogeneous, gray-white, and yellow mass measuring 1.5 × 1.2 × 1 cm. Microscopic examination revealed infiltrating sheets and cords of polygonal bland cells with relatively well-defined cell borders, abundant eosinophilic granular cytoplasm, and round/oval nuclei surrounded by collagenous stroma. Immunohistochemistry showed that the tumor cells were positive for SOX10, S-100, and CD68, while they were negative for AE1/AE3, CAM5.2, CD163, and MART-1, supporting the diagnosis of GCT.

Discussion

Granular cell tumors in the breast are rare, typically benign, and can often mimic malignant lesions both clinically and radiologically. They present a diagnostic challenge because they may exhibit features similar to breast carcinomas, such as irregular margins and heterogeneous echo patterns on ultrasound. Studies suggest that the incidence of these tumors in the breast is low, accounting for approximately 5%-8% of all GCTs.[1]

Granular cell tumors typically present as firm, usually non-tender masses and may be found incidentally on routine mammograms or during physical examinations. They can vary in size and are often mobile unless they are located deep and adherent to the chest wall or overlying fascia, where they may feel fixed.[1]

GCTs may grow slowly without significant change over time. Any rapid change in size or newly associated symptoms should prompt further investigation to rule out malignant transformation or other complicating factors. Importantly, GCTs can occasionally be associated with pain or discomfort if they impinge on nerves or have a deep location affecting muscle or connective tissue layers.[2,3] They do not usually present with systemic symptoms unless they are part of a rare malignant variant. However, patients with GCTs can present with skin changes such as thickening or dimpling over the tumor, which can further complicate the clinical picture, suggesting more aggressive underlying pathology.[1]

Mammographically, GCTs usually present as high-density masses with irregular or spiculated margins. These characteristics overlap significantly with those of invasive breast carcinomas,

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Figure 1. Screening full-field digital mammography with DBT of the left breast in the CC (A) and MLO (B) projections demonstrates a focal asymmetry in the left breast upper inner quadrant, posterior depth (arrows). An additional stable fibroadenoma in the upper outer left breast, middle depth (arrowhead)

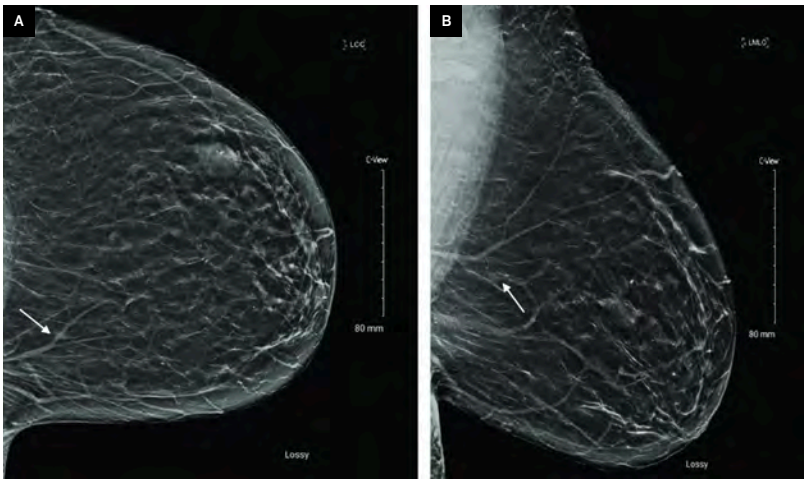
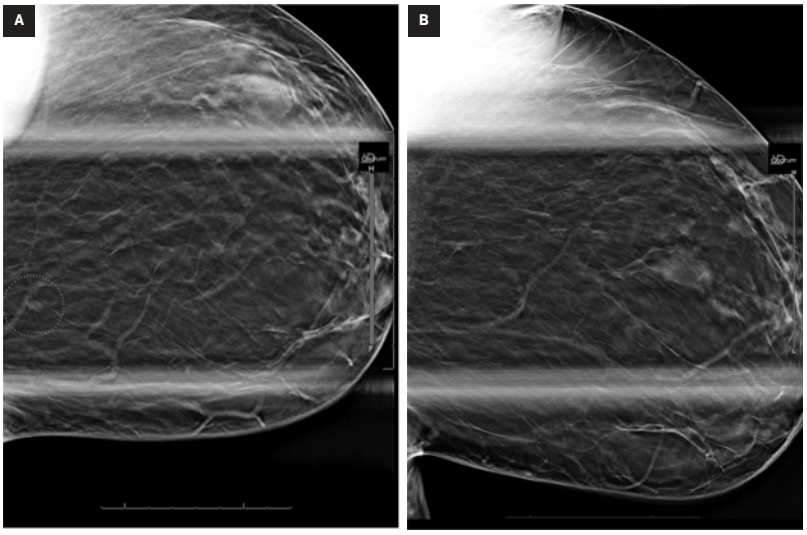


Figure 2. Diagnostic spot compression views with DBT in the CC (A) and MLO (B) projections confirm a focal asymmetry in the upper inner left breast, posterior depth (circles)



making it difficult to differentiate between the two based solely on mammographic findings.[1] Occasionally, GCTs may appear as circumscribed oval masses, mimicking benign conditions such as fibroadenomas.[1]

On ultrasound, GCTs are typically hypoechoic masses with indistinct or spiculated margins and may exhibit posterior acoustic shadowing as in malignancies, thus necessitating needle biopsy to achieve a definitive diagnosis.[3]

While not always utilized, MRI can provide additional detail, particularly in complex cases. GCTs on MRI generally appear as well-defined masses with low signal intensity on T1-weighted images and variable signal intensity on T2-weighted images. They may enhance uniformly or heterogeneously after contrast administration.[1]

These details emphasize the importance of a comprehensive diagnostic approach, including imaging and biopsy, to distinguish GCTs from more aggressive breast lesions.

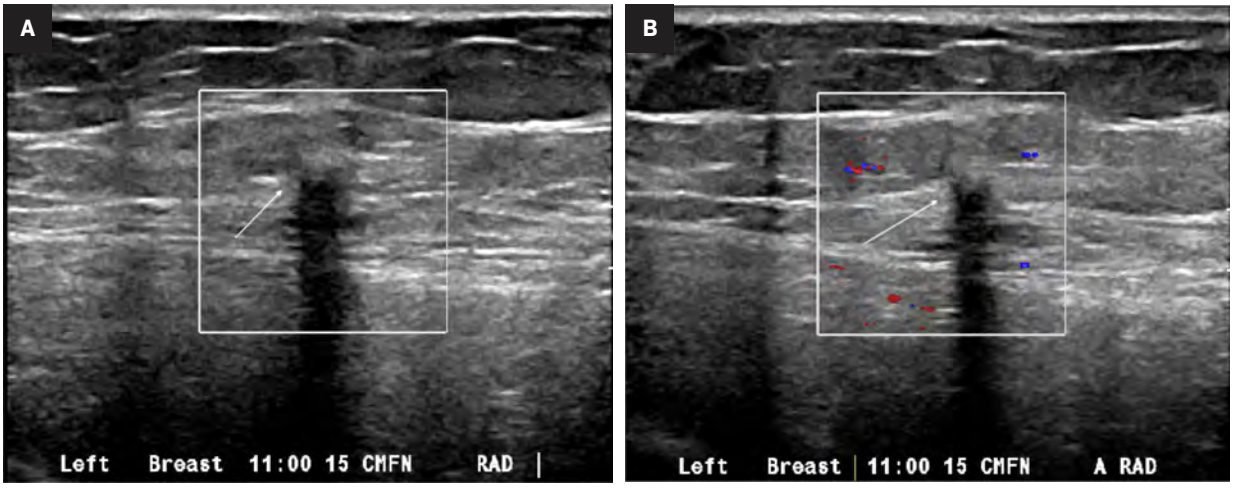
Granular cell tumors arise from Schwann cells and are histologically defined by polygonal cells with granular eosinophilic cytoplasm, arranged in clusters or sheets. The cytoplasmic granules, indicative of lysosomal origin, are PAS-positive and diastase-resistant. Immunohistochemically, GCTs are consistently positive for neural markers and negative for epithelial and melanocyte markers, helping to distinguish them from other neoplasms.

Most GCTs are benign, but the risk of recurrence or rare malignant transformation makes thorough surgical management essential.[1] The standard treatment is wide local excision with clear margins to prevent recurrence, which can range from 2%-8%.[2,3] Clear margins and meticulous surgical techniques are crucial for minimizing recurrence. In rare cases of malignant GCTs, management may require additional therapies similar to those used for breast cancers, highlighting the importance of precise pathological assessment and follow-up.[3]

Conclusion

Granular cell tumors of the breast, while rare, present a significant diagnostic challenge due to their ability to mimic more aggressive malignancies. This case emphasizes the importance of

Figure 3. Targeted gray scale (A) and color Doppler (B) ultrasound demonstrates an irregular hypoechoic mass with posterior acoustic shadowing at 11 o'clock, 15 cm from the nipple (arrows)



a thorough diagnostic workup, including advanced imaging and biopsy, to differentiate GCTs from other breast pathologies. Wide local excision with clear margins is crucial to prevent recurrence, and regular follow-up is necessary to monitor for any signs of recurrence. A multidisciplinary approach is essential for effective management and favorable patient outcomes. This case also highlights the importance of considering GCTs in the differential diagnosis of breast masses with suspicious imaging features, ensuring comprehensive care, and accurate diagnosis.

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Inflammatory Breast Cancer

Alison Stiller, BA; Daniela Cocco, MD; Christina Ferraro, MD

Case Summary

An adult with a past medical history of diabetes presented to the clinic for a 6-week postpartum visit with the chief complaint of a right breast rash. The rash first appeared during her pregnancy and was attributed to atopic dermatitis. She denied pain, fevers, or chills but reported occasional pruritus. The rash worsened despite the use of topical triamcinolone cream (Figure 1B). The initial physical exam demonstrated a localized erythematous rash on the right upper outer quadrant without palpable breast or axillary masses. On exam, the left breast was unremarkable. The patient reported no known family history of breast or ovarian cancer.

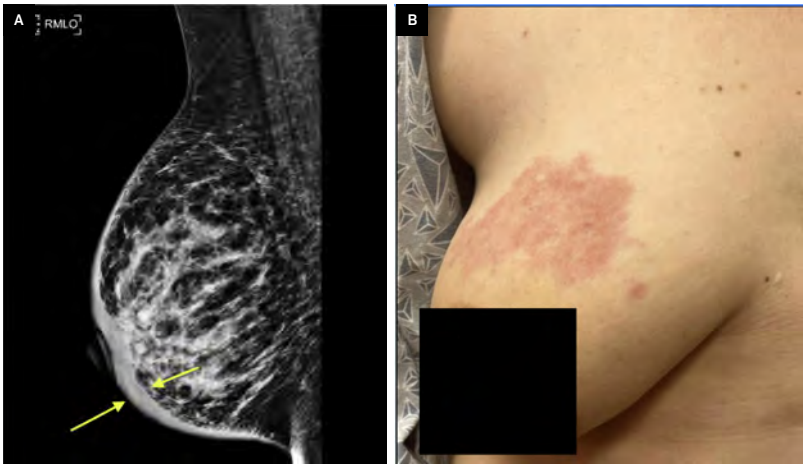
Imaging Findings

Mammography revealed diffuse dermal thickening of the entire right breast with underlying trabecular coarsening and thickening without definitive masses (Figure 1A).

Ultrasound of the right breast revealed marked edema beneath the dermis in nearly every quadrant and below the areola. Additionally, there was an infiltrating appearance of hypoechoic, irregular areas, most prominently seen at 2 o'clock and 6 o'clock positions (Figure 2A). Ultrasound of the axilla revealed a mildly prominent lymph node with an eccentrically thickened cortex (Figure 2B).

A punch biopsy was recommended secondary to the skin thickening, which depicted dermal involvement of invasive ductal carcinoma in the superficial and deep dermis, with possible vascular permeation. MRI showed multifocal, suspicious masses and areas of enhancement involving all four quadrants, and the nipple of the right breast was suspicious for multicentric right breast malignancy (Figure 3A, B). The most prominent mass measured 2.8 cm.

Figure 1. Mediolateral oblique view mammogram. Diffuse thickening of the dermis (yellow arrows) with trabecular coarsening and thickening in the right breast is seen (A). No masses are visible. Clinical photograph (B) shows a worsening right breast lesion after 1 month of topical triamcinolone.



Diagnosis

Invasive ductal carcinoma with lymphovascular permeation, consistent with inflammatory breast cancer.

Discussion

Inflammatory breast cancer (IBC) is a rare malignancy that imparts a worse prognosis than non-inflammatory, locally advanced breast cancer.[1] The incidence of IBC rises

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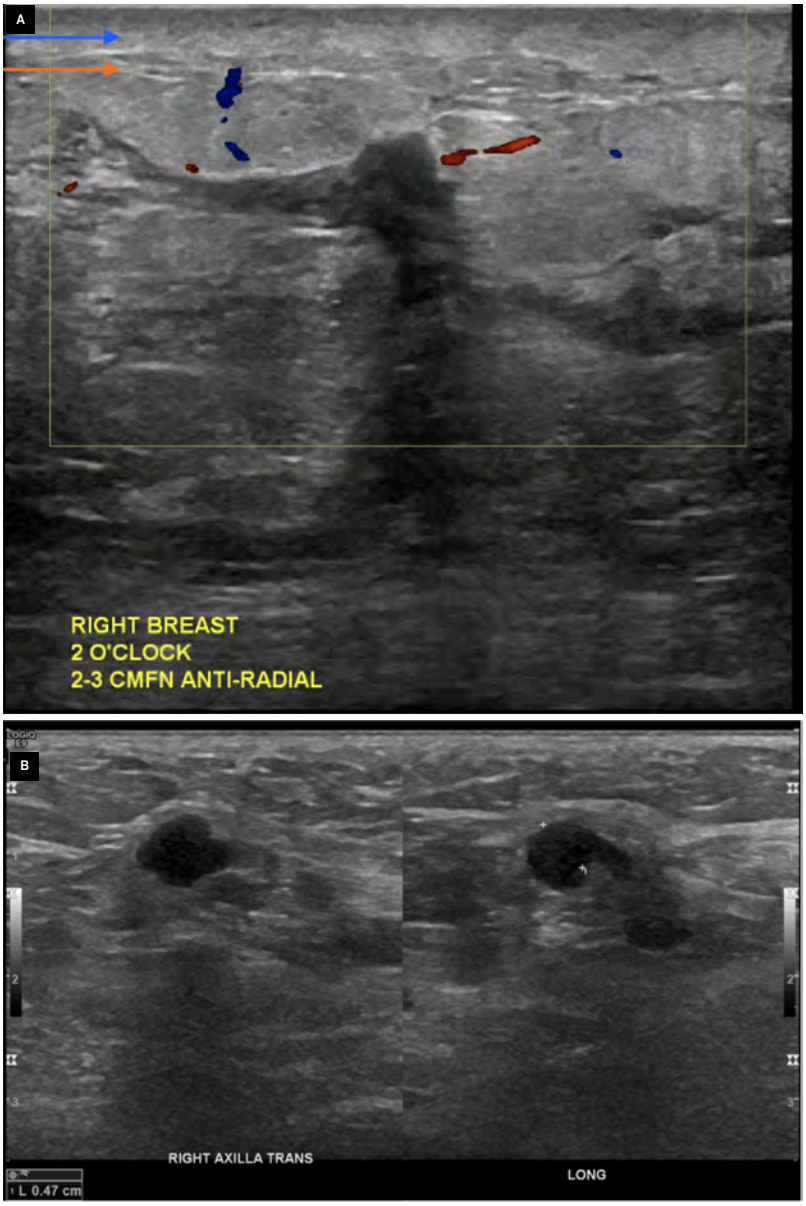
Figure 2. Ultrasound of the right breast imaging shows dermal thickening (blue arrow) with underlying edema (orange arrow), as well as ill-defined hypoechoic collections without discernible Doppler flow (yellow box) at the 2 o'clock position (A). Ultrasound of the right axilla (B) shows a lymph node with an eccentrically thickened cortex (white markers) measuring 0.47 cm and a diminutive fatty hilum.



with age and the plateaus after age 65. The mean age at diagnosis is estimated to be 55-59 years.[2] Inflammatory breast cancer accounts for approximately 2%-4% of all breast cancer diagnoses.[3]

A diagnosis of IBC must meet the following criteria: presence of invasive carcinoma on pathology, rapid onset of less than 6 months, and erythema occupying at least one-third of the breast with edema, peau d'orange, or warmth.[4] After confirmation of invasive breast cancer, a clinicopathologic diagnosis of IBC can be made based on the distinct clinical features.[5] Interestingly, the patient in this case presented with a localized, pruritic breast rash.

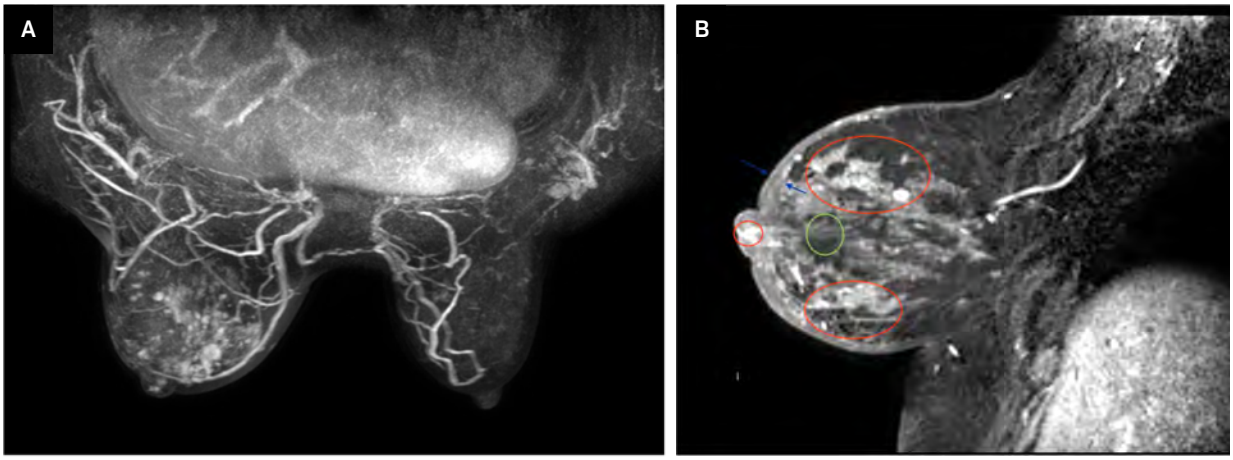
The differential diagnosis of IBC includes atopic dermatitis, infectious mastitis, and idiopathic granulomatous mastitis. Clinical and radiologic features of benign mastitis commonly overlap with breast malignancies such as IBC.[6] While infectious mastitis is more common in younger peripartum women,[4] providers must have a high clinical suspicion for IBC to ensure early recognition. There should be a low threshold for biopsy, especially when suspected atopic dermatitis or mastitis fails to respond to corticosteroids or antibiotics. Some patients with IBC (20%-40%) will have distant metastasis at initial presentation, so early recognition is imperative.[7]

Dermal lymphatic involvement is the pathologic hallmark for IBC, as the clinical characteristics are caused by tumor emboli in the papillary and reticular dermis. Cancer cells block the lymphatics, causing subsequent edema and erythema.[7]

On mammography, IBC may appear with skin thickening, increased breast density, and trabeculation. Less commonly, multiple masses, pleomorphic calcifications, or architectural distortion may be seen.[7] On ultrasound, IBC is more likely to appear as a solid mass, whereas mastitis tends to appear as solid-cystic lesions or collections.[6]

Inflammatory breast cancer and benign mastitis may exhibit similar morphological features on MRI. These features include skin thickening, edema, and the presence of mass lesions or non-mass-like enhancement. However, enhancement features may allow for

Figure 3. Axial post-contrast maximum-intensity projection magnetic resonance image shows the left lactating breast without appreciable enhancement (A). The right breast has innumerable foci of enhancement and areas of mass enhancement, with a dominant mass at the 2 o'clock position. Sagittal post-contrast MRI of the right breast (B) shows dermal thickening (blue arrows) with abnormal non-mass enhancement in multiple quadrants and extending to the nipple (red circles). Centrally located, normal background parenchymal enhancement is seen (green circle).



differentiation between IBC and benign mastitis. In IBC, the initial enhancement is often greater, with more frequent, subsequent washout. Benign mastitis will likely have a more persistent or plateaued enhancement pattern.[6]

The overall prognosis of IBC is poor, with a 5-year overall survival rate between 29.9% and 42.5%.[3] However, multimodal treatment increases 5- and 10-year survival rates by 55.4% and 37.3%, respectively.[8] Treatment includes anthracycline-based neoadjuvant chemotherapy followed by modified radical mastectomy and postmastectomy radiation therapy to the chest wall and draining lymphatics.[8] Unfortunately, patients with lower incomes, lack of insurance, and multiple comorbidities are significantly less likely to receive multispecialty therapy, resulting in decreased survival rates.[8]

Conclusion

Inflammatory breast cancer is a rare and aggressive malignancy that, in the initial stages, may mimic benign conditions such as atopic dermatitis, infectious mastitis, or idiopathic granulomatous mastitis. Patients with IBC tend to be younger than those with other breast cancers; thus, there should be a low threshold for biopsy and imaging in younger women with persistent, suspicious skin changes. Metastatic disease is common at initial presentation, and the overall prognosis of IBC is poor. Early diagnosis is crucial for the highest chance of prolonged survival.

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Rituals

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It is well into baseball season, and baseball makes me think of many things, but among the most prevalent thoughts crawling around in my brain are the baseball rituals or superstitions.

Other sports certainly have them. Baseball thrives on them. Throwing balls back and forth between the outfielders, the first baseman throwing ground balls to the infielders, warm-up pitches culminating in a throw-down.

It hardly stops there. Batters waiting in the on-deck circle with their practice swings, watching and swinging in time to the pitcher's warm-ups, adjusting their batting gloves, readjusting their batting gloves, tapping the bat on their helmet a few times.

If you watch players, you realize that rituals are everywhere and almost a sacred thing: inside-out hats for rallies; greeting the scoring runner; high-fives or more intricate receptions for home run hitters. The list goes on and on.

Well, some of us also have our rituals. What are your workday warm-ups? A mantra? A special beverage (coffee, tea, or juice)? A special chair and a constant location in the reading room? Calisthenics? Music? Dictaphone in the hand and a few spins of the microphone around your head, before you commence?

Yes, I have some rituals. I *must* have the same workstation. Chair armrests down as low as they go; chair up high and desk at a high level for most people—just right for me; crack the knuckles; Dictaphone on the left; coffee left of the Dictaphone; mouse on my favorite mousepad on the right. Streaming jazz playing (I prefer a Miles Davis channel). Telephone pushed as far away as I dare; almost out of reach; cell phone charger cable on the right. Monitor height very high and angled down at me. Okay. Everything is turned on. I'm logged into the network and ready to work. Final warm-up time: My hands are overhead and I crack my knuckles, roll my head to loosen up the cervical musculature, say hello to the first case, and lean forward with a cup of coffee to my lips.

I've seen quite a few radiology warm-up routines. One of my early attending radiologists was a recruit from my first chair who came from Sweden. Heavy accent, brilliant eye, but horribly streaked glasses. He would push up to the roller scope (remember those days?), take off his horribly streaked glasses, and smear them up a little more with his white coat, humming some unknown tune to himself while rubbing them for 3 or 4 minutes. His glasses invariably went from bad to worse; it didn't matter to him. Somehow, even with those heinously foul lenses, he would see everything I had missed overnight.

One of my prior body-CT attendings would walk to the CT scanner room (before ever eyeing a case) and go inside and chat for 10 minutes or so with the techs. He'd tell them jokes, drink his coffee, and wrap up with the same statement every time: 'Okay, have to get out there and save some lives.'

Here's how old I am. During my training, one of my interventional attendings would go into the hallway, outside the procedure rooms, and smoke his pipe. The first bowl of the day (there were many more to come) was in the hall outside an angio suite *in a patient corridor. Jeez!*

I'm interested to hear what you might do for your rituals. Drop me a note; I'll collect the best and share them some month.

Keep on doing that good work. Mahalo.

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