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Systematic Review of Breast Fat Necrosis After Breast Surgery (2022–2025)

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ABSTRACT

Modern supply chains for cloud infrastructure (spares, server racks, networking equipment, optics, and related components) operate as globally distributed systems spanning data centers, suppliers, carriers, and multiple legal entities. Yet most research on AI in supply chain management remains forecast- or optimization-centric and treats security, auditability, and financial correctness as secondary concerns. This manuscript reframes supply chains as globally distributed, financially governed, stateful cloud systems. In a Supply Chain 4.0 setting where devices and environments are instrumented with IoT, Bluetooth, and RFID telemetry, we propose a cloud-native reference architecture that unifies (i) event-sourced inventory and custody state, (ii) cryptographically verifiable asset transfer across regions and legal entities, (iii) policy-as-code enforcement for accounting, FinOps, and VAT/tax controls, and (iv) demand sensing that incorporates search and discovery signals in addition to historical demand. The architecture separates control plane and data plane responsibilities, uses trust domains aligned to physical and organizational boundaries, and provides end-to-end lineage from device-level observations to financial ledgers. We define four original contributions and present a design-science evaluation strategy with metrics that expose failure modes in traditional systems (latency to financial close, cost leakage, inventory accuracy under partial connectivity, and compliance risk). The results are positioned as a foundational infrastructure contribution to Industry 4.0 supply chain

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DEFINITION

Breast fat necrosis is a benign but frequent complication following breast surgery, particularly reduction mammaplasty.
It corresponds to necrosis of adipose tissue caused by local ischemia or surgical trauma.
Clinically, it presents as a firm, sometimes tender nodule that may mimic breast cancer.
The aim of this review is to summarize recent literature data (2022–2025) regarding breast fat necrosis, including risk factors, diagnostic modalities, and management strategies.

METHODS

A literature search was conducted in PubMed, Embase, and Scopus databases, covering the period from January 2022 to November 2025.
The following keywords were used: *fat necrosis*, *breast*, *reduction mammaplasty*, *breast fat necrosis*.
Clinical studies, case series, and systematic reviews addressing postsurgical breast fat necrosis were included.

RESULTS

In the literature, the incidence of breast fat necrosis ranges from 3% to 38% after autologous breast reconstruction, and from 2% to 18% following fat grafting, with the lowest rates reported after reduction mammaplasty [9].
Several studies have reported variable crude incidence rates of fat necrosis following radiotherapy for early-stage breast cancer. Wazer et al. reported a crude incidence of clinically evident fat necrosis of 27%. Garza et al., in a study of 238 breasts, reported a crude incidence of 17.6% [2].
Regarding breast lipofilling, reported fat necrosis rates range from 2% to 18%. In reduction mammaplasty, the amount of excised breast tissue is directly correlated with complication rates. The incidence of fat necrosis after breast reduction ranges between 1% and 9% [9].

Concerning fat grafting, no variables such as age, body mass index, malignancy stage, smoking status, radiation exposure, harvest site, or technical factors (fat/tumescent volume, syringe versus pump-assisted aspiration, cannula type or size) were found to predict the development of fat necrosis [2].

In a review addressing the etiology, pathophysiology, evaluation, and management of breast fat necrosis in surgical patients, individual patient factors such as smoking, obesity, and advanced age, as well as breast cancer–related treatments (radiotherapy, chemotherapy, and mastectomy), were specifically associated with increased rates of fat necrosis [8].

Age and smoking status were also significantly associated with complications in a study focusing on secondary reduction mammaplasty [3].

Following mastectomy, timing is a critical factor in patient evaluation, as local cancer recurrence tends to occur within the first 1 to 5 years after surgery [9].

In flap-based reconstructions, increased fat necrosis incidence has been associated with smoking, pedicle caliber, flap type, radiation therapy, and surgeon experience [2].

In the 2022 article propofound to be more appropriate than surgical excision. Surgical intervention was associated with higher postoperative complication rates (68.75% vs. 31.25%) [9].

DISCUSSION

Fat necrosis accounts for approximately 3% of all breast lesions and represents an aseptic saponification process of adipose tissue. The process begins with local destruction of adipocytes, followed by liquefactive necrosis of lipid-containing material.

In the hyperacute phase, inflammatory reaction leads to transient capillary dilation, resulting in fluid extravasation into the interstitial space and surrounding edema.

Neovascularization develops between endothelial cells with loose intercellular junctions, allowing contrast agents such as iodine and gadolinium to leak into the interstitium, producing lesion enhancement on imaging.

A fibrous capsule forms around necrotic debris, leading to the formation of an oil cyst.

Subsequently, foreign-body reaction and chronic granulomatous inflammation result in dystrophic calcifications and irregular fibrosis. These different stages explain the wide range of imaging appearances of fat necrosis, which may sometimes mimic malignant breast [1] disease.

Regarding timing, necrotic material appears surrounded by fibrous tissue at low magnification. Fibrosis may lead to the formation of an irregular spiculated mass due to retraction of adjacent vascularized tissue within 2 to 4 weeks after breast surgery.

Calcifications may appear within 6 to 12 months. Extensive fibrosis may be associated with dystrophic calcifications, requiring further evaluation to exclude malignancy [8].

Breast fat necrosis remains a multifactorial condition. Accidental trauma represents the most frequent cause, accounting for 21% to 70% of all cases. Idiopathic breast fat necrosis is also described, particularly in large, pendulous breasts of middle-aged women [2]. Rarer causes include panniculitis associated with systemic lupus erythematosus, polyarteritis nodosa, and Weber– Christian disease[1].

Various surgical procedures—including lumpectomy, breast-conserving surgery, mastectomy, reduction mammaplasty, implant removal, and breast reconstruction—increase the risk of breast fat necrosis [2].

Nutritional status also plays a role; hypoalbuminemia significantly increases the risk of 30day postoperative complications following reduction mammaplasty [4].

Lesion location may help identify etiology. Chan et al. reported that in reduction mammaplasty, fat necrosis can occur anywhere depending on surgical technique, but is most commonly located in the inferior breast, where parenchymal resection and displacement are most frequent [1].

Specific distributions are also observed in other etiologies. Fat necrosis is typically superficial following blunt trauma. In flap reconstruction, lesions are usually located at the peripheral flap region due to compromised blood supply at the surgical anastomosis. In panniculitisrelated hyaline fat necrosis, bilateral involvement may occur. In autologous fat grafting, necrosis is often unevenly distributed due to bolus injection and random revascularization from adjacent tissues [1].

Clinical presentation is variable. Oil cysts are the most common and earliest manifestation and can be treated with simple needle aspiration. Macrophagic swellings with thick yellowish content and firm fat necrosis lesions are rarer and may require cannula-assisted lipofragmentation [6]. Patients may also be asymptomatic or present with a palpable mass, skin tethering, induration, and occasionally axillary lymphadenopathy [10].

Diagnosis and management depend on clinical presentation and lesion location. High-risk patients—those with prior oncologic surgery, patients over 40 years of age, and those with delayed presentation—require more extensive evaluation [8].

In the algorithmic management of postsurgical breast fat necrosis, Haran et al. [8] analyzed data from 192 patients who underwent breast surgery, including 50 unilateral DIEP reconstructions and 142 reduction mammaplasties. Fat necrosis was diagnosed in 36 breasts, of which 20 were managed conservatively. Conservative treatment with nonsteroidal anti-inflammatory drugs (NSAIDs) and local massage was favored. Conservative management is also recommended when lesions are located in unfavorable areas, such

as the retroareolar region, where surgical excision may compromise nipple–areola complex viability. When lesions fail to improve, staged micro-aliquot fat grafting may be offered to avoid further fat necrosis [9].
An analysis of the ACS-NSQIP multicenter database demonstrated that surgical management of breast fat necrosis is safe, effective, and results in clinical and aesthetic improvement [4].

IMAGING

Imaging modalities for diagnosing breast fat necrosis include mammography, ultrasound, and magnetic resonance imaging (MRI). Contrast-enhanced mammography (CEM) is an emerging technique that aids diagnosis in equivocal cases and, along with MRI, serves as a roadmap for targeted biopsies [2].
On mammography, fat necrosis may present as a well-circumscribed radiolucent oil cyst (Figure 1). Depending on the degree of fibrosis, it may also appear as clusters of pleomorphic microcalcifications with abnormal opacities, complicating differentiation from malignancy [9].
On MRI, a typical oil cyst (Figure 2) follows fat signal intensity on all sequences, appearing hyperintense on T1- and T2-weighted images with signal suppression on fat-saturated sequences. A thin enhancing fibrous capsule may be present. Fat–fluid or fluid–fluid levels can also be observed [1].
On ultrasound, cystic lesions show internal echogenic bands (Figure 3), with orientation influenced by patient position. Noncystic lesions may demonstrate increased subcutaneous echogenicity, anechoic cysts with posterior enhancement, hypoechoic masses with posterior shadowing, solid masses, or normal appearance. Doppler ultrasound assists diagnosis by demonstrating absence of internal vascularity, helping exclude malignancy [9].
Spiculated dense masses on mammography and hypoechoic masses with angular margins on ultrasound in posttherapy breasts are suspicious and warrant tissue diagnosis. Polymorphic, amorphous, or fine microcalcifications also require histologic sampling, unlike dystrophic calcifications, which are typically benign [2].
Tissue diagnosis is indicated in clinically and radiologically equivocal cases. Minimally invasive sampling techniques include fine-needle aspiration cytology, core needle biopsy, and vacuum-assisted biopsy [9].

CONCLUSION

Breast fat necrosis presents with a wide range of appearances on mammography, ultrasound, MRI, CT, and PET/CT. Lesion location and imaging characteristics vary according to etiology and guide therapeutic management. Careful and critical analysis of imaging features correlated with clinical history is essential to differentiate fat necrosis from other breast pathologies, particularly malignancy.

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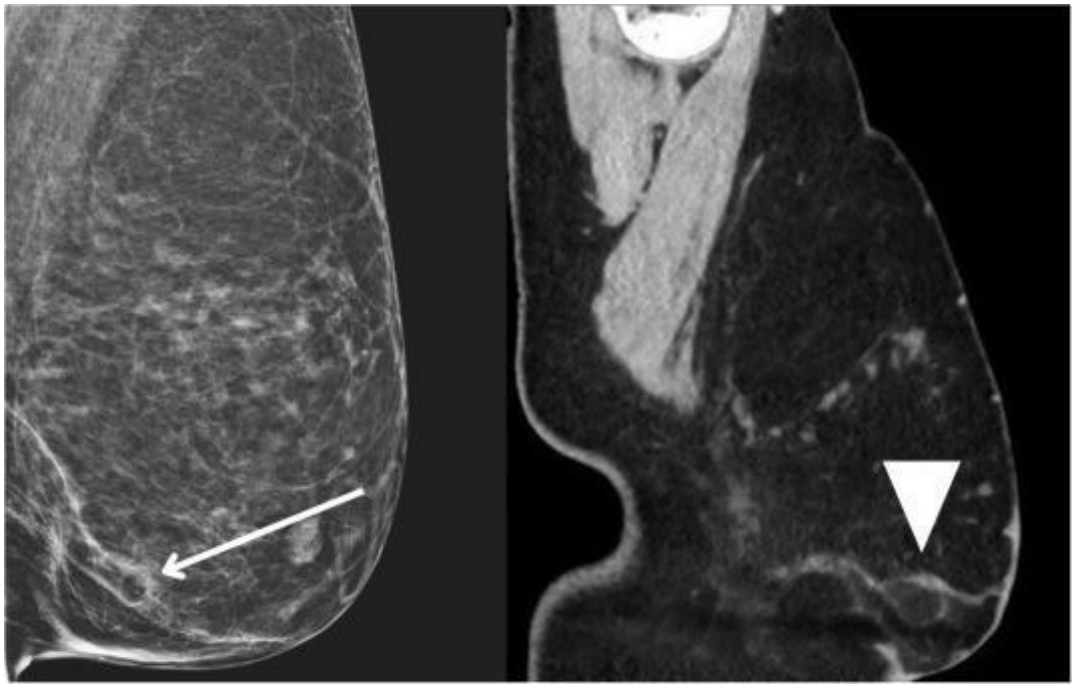

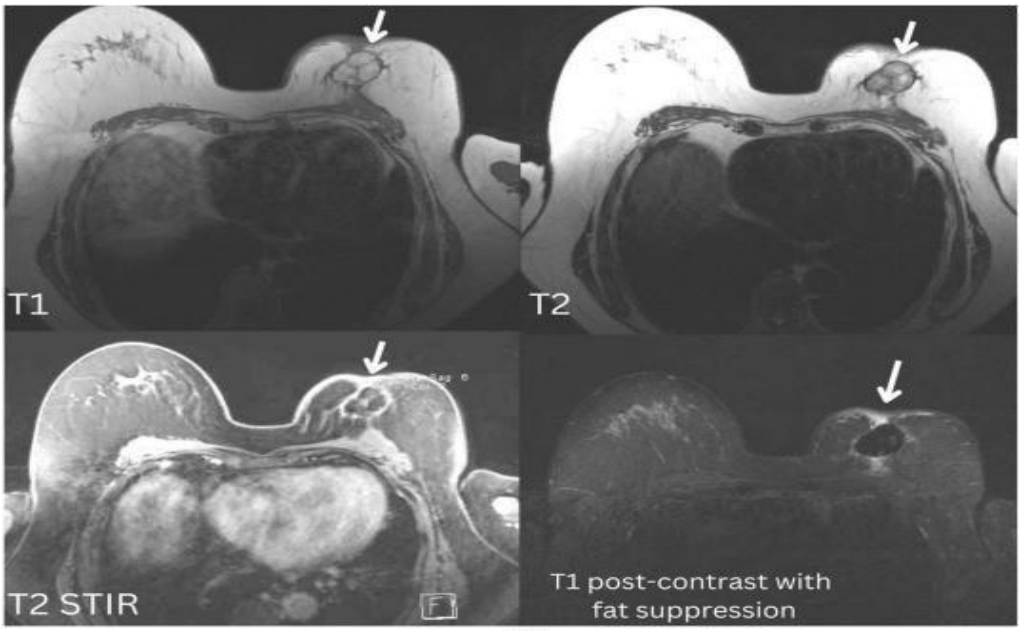

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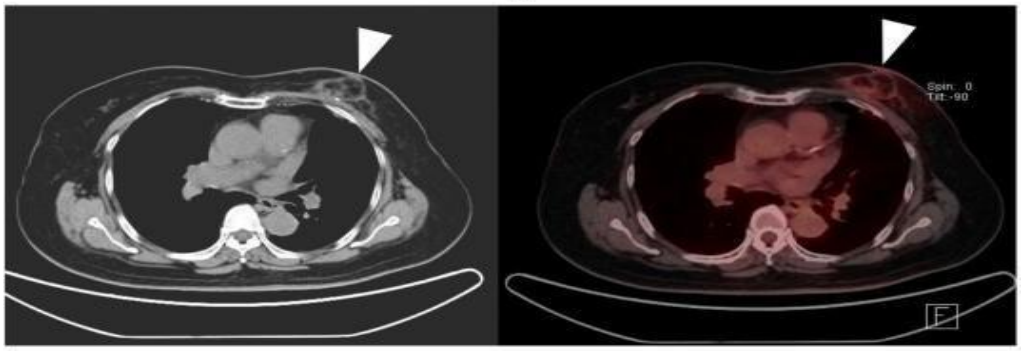

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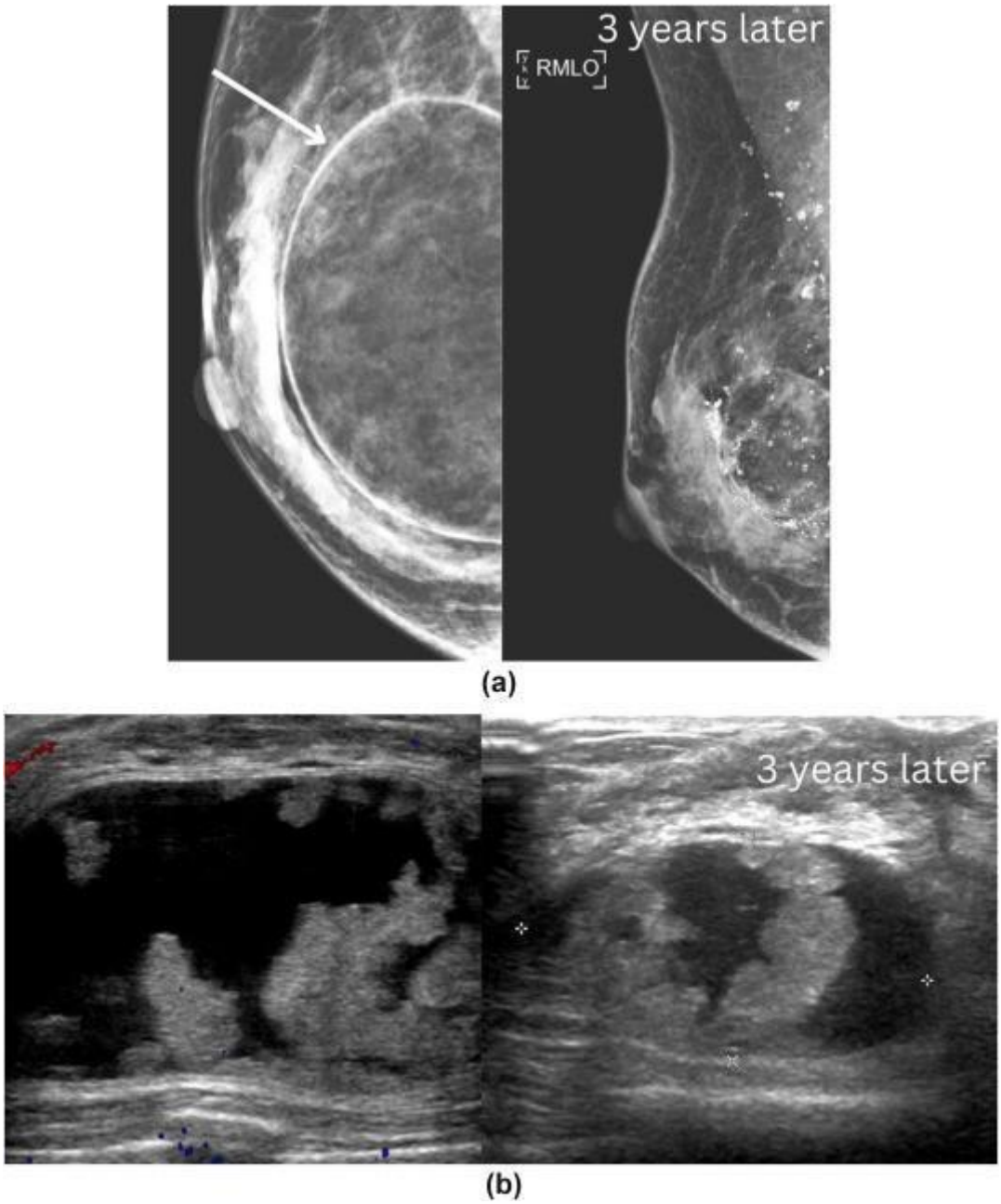

Picture 1: In mammography fat radiolucent

Picture 2: Oil cyt on MRI

Picture 3: Calcification on mammography and ultrasound